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What drives effective competition in the airline industry? An empirical model of city-pair market concentration

Marcus V. R. Oliveira

Alessandro V. M. Oliveira

Instituto Tecnológico de Aeronáutica
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What drives effective competition in the airline industry?
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Marcus V. R. Oliveira
Alessandro V. M. Oliveira✈

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Abstract

Market concentration is a widely recognized metric of effective competition, as it provides a quantification of the relative success of large, mid-sized and smaller firms in the battle for consumers. Concentration has been a public policy issue in the airline industry since deregulation due to the long-standing airport dominance by major carriers, which is a concern that is recurrently intensified by merger announcements. This paper develops an empirical model to examine the evolution of concentration in the airline markets and its possible drivers. We analyze the case of the Brazilian airline industry in which the two major carriers acquired a combined market share of more than 90% in the late 2000s and have experienced a sharp reversion since then. We test the effects of traffic density and route-airport dominance of flight frequencies on the Herfindahl-Hirschman index (HHI) of city-pair markets. Additionally, we investigate the effects of a potential intensification of airport-dominant airlines' vertical relationships after airport privatization. Our estimated scenarios reveal that a long-run decline in flight dominance produced a *ceteris paribus* 23% decrease in the estimated HHI. Additionally, market expansion induced an extra 4% decline in concentration. In contrast, ownership change at privatized airports raised concentration by 9%. Our results also suggest that fighting market concentration with the entry facilitation of new low-cost carriers at primary airports may be an effective policy.

Keywords: airlines; Herfindahl-Hirschman index; vertical relationship; airport privatization.
JEL Classification: D22; L11; L93.

✈ Corresponding author. Email address: alessandro@ita.br.

▪ Affiliations: Center for Airline Economics, Aeronautics Institute of Technology, Brazil (all authors).

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1. Introduction

It is well known that contemporary market deregulation has produced notable effects on the airline industry. After almost four decades since the Airline Deregulation Act in the United States, it is clear that the American airline market and many others internationally have experienced the benefits of the free economic environment, which has allowed for more intense cost competitiveness, price reduction and sustained market expansion. As a result, air travel has become one of the most popular items in the consumption basket of millions of families, while market concentration has apparently performed a minor role in the opposite direction. For example, in the late 1980s, the U.S. Government Accountability Office (GAO) reported that, due to an impressive sequence of twenty-six mergers, the five largest American carriers accounted for 74% market share, versus 69% in 1978[1]. Notwithstanding that apparent market dominance issue, the national average yield in the early 1990s was one-third lower than that which had prevailed immediately before deregulation[2]. Many years later, in 2014, the same institution stated that the situation had evolved to a dominance of 85% of the market, which this time was only held by the top four carriers[3]. In contrast, the US Department of Transportation in the same year reported a 14.7% decrease in prices in a comparison of the average inflation-adjusted airfare of 2014 to the prevailing rate in 1995[4]. These facts illustrate the challenges that are faced by researchers in the investigation of market concentration in the airline industry, as market structure does not appear to be an impediment to the long-run welfare gains that have thus far been brought about by liberalization.

The international experience of the airline industry has shown that the potential negative effects of market concentration have been more than compensated for by the impacts of the entry and expansion of low cost carriers (LCCs), which have been a major force that ultimately has shaped and driven competition in the air transportation markets. Much of this evidence has been extensively corroborated by the literature - Windle & Dresner (1999), Morrison (2001), and Brueckner, Lee & Singer (2013). However, despite the emergence of LCCs and, more recently, ultra-LCCs, market concentration continues to be an important characteristic that may undermine contestability in the airline markets. Hofer, Windle & Dresner (2008) use the term "price premium" to define the airfare

[1] "*Factors Affecting Concentration in the Airline Industry*", U.S. Government Accountability Office (GAO), T-RCED-88-65, Sep 22, 1988.

[2] Morrison & Winston (1995, p. 12)

[3] "*Report to Congressional Requesters - Airline Competition*", U.S. Government Accountability Office (GAO), GAO-14-515, Jun, 2014.

[4] US Department of Transportation - Air Fare Press Releases - 2nd-Quarter 2014 Air Fare Data (Table 1), available at www.rita.dot.gov.

impacts that have been attributed to both airport and route market dominance and/or concentration. The authors estimated a US $27.6 premium for major carriers, even in the presence of LCC competition. Additionally, the recent US Department of Justice's settlement approving the American Airlines - US Airways merger, which required them to divest more than a hundred takeoff and landing slots to facilitate competition from LCCs, illustrates the authorities' concerns that slot-controlled airports may constitute a venue for market concentration that may be of harm to consumers[5].

Although the empirical literature on the *consequences* of market concentration in the airline markets is vast, the literature on the *causes* of such concentration is scarce. Indeed, since the deregulation, airline studies have addressed the issue of the relationship of airfares and route and/or airport concentration - Borenstein (1989), Evans and Kessides (1993), and Bilotkach & Lakew (2014). In addition to price, other dimensions of airline service have also been linked to the market structure of the air transportation markets. For example, the literature has investigated and found a statistically significant association between airline delays and concentration at the airport and route levels - Mayer & Sinai (2003), Mazzeo (2003), Ater (2012), and Bendinelli, Bettini & Oliveira (2016). In contrast, the empirical literature that is related to the inspection of the main determinants of market concentration is confined to Leahy (1994), who examined concentration in the top 150 city-pairs markets in the US airline industry. Ciliberto & Williams (2010) suggest that research should focus on the role of barriers to entry on entry decisions due to their importance to long-run competition in the airline markets. We consider the flight frequency dominance of the major carriers at both the route and airport levels to be relevant entry barriers in the industry. To the best of our knowledge, no study has yet formally tested the effects of the flight frequencies of major carriers on the concentration level in the market. This paper aims to fill this gap by developing an empirical model to investigate some of the main determinants of market concentration in the airline markets. We also test the effects of city-pair traffic density and potential economies of density on concentration.

We consider the case of the Brazilian airline industry in the 2002-2013 period, which is an emerging market that has experienced very rapid demand growth and two relevant episodes of LCC entry. This industry was marked by an upsurge in market concentration in the first years of deregulation, with the formation of a quasi-duopoly that was composed of TAM and Gol airlines. These major carriers had a combined domestic market share of 93% in 2008, but they have

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[5] "*American Airlines-US Airways Merger Settlement Approved*" - Bloomberg, April 26, 2014.

experienced a sharp decline in their dominance since then[6]. In parallel, the Brazilian air transportation industry has recently been subject to a major change in the governance structure of airports. In the early 2010s, the Brazilian government embraced an airport privatization program that was aimed at promoting investments in capacity expansion, which enhanced efficiency and alleviated congestion. Fu, Homsombat, & Oum (2011) suggest that the growing trend of commercialization and privatization has induced airport managers to explore new business strategies, with one possibility being the formation of vertical relationships among airlines, for example, by means of long-term contracts that cover the control of key airport facilities, signatory airline status, airport revenue bonds and revenue sharing. We therefore raise the hypothesis that airline-airport vertical relationships may emerge and intensify with the change in airport ownership. Our econometric model tests this hypothesized relationship by estimating the effects of airport privatization on market concentration in Brazil. Our empirical framework accounts for the endogeneity of flight concentration and traffic density by employing an instrumental variables estimator. We also utilize a Heckit model to control for sample selectivity in the government's choice of airports to be privatized, and a difference-in-differences approach that aims to distinguish the concentration effects of privatization on routes with airports that are subject to ownership change ("privatized airports"), from comparable routes that may have had a similar evolution ("placebo-privatized airports"). To allow for a study of the causes of the persistent decline in the market concentration of the air travel markets since 2008 in Brazil, we complement our econometric model with a set of counterfactual analysis experiments.

The remainder of this paper is organized as follows: Section 2 presents the theoretical framework with a literature review of airline market concentration studies and the proposed conceptual model. Section 3 presents our research design with the description of the evolution of the airline industry in Brazil, the available data set, the empirical model development and our estimation strategy. Section 4 presents the estimation results, some robustness checks and the results of the counterfactual experiments, followed by our concluding remarks.

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[6] Source: Air Transportation Market Statistical Database - Monthly Traffic Report, 2008.

2. Theoretical framework

The notion that the airline industry is not marked by perfect contestability and that it is rather imperfectly contestable is not only a well-known fact, but it has been empirically tested and confirmed since Morrison and Winston (1987). Perfect contestability in this industry would imply the possibility of "hit-and-run" entry by a potential carrier that, for example, operates a route with seasonal flights without being retaliated against or deterred by any strategic behavior by the incumbent airlines. With respect to retaliation, cutting fares is by far the most investigated incumbent response - Windle & Dresner (1999), Morrison (2001), Huse & Oliveira (2012), Brueckner, and Lee & Singer (2013). Goolsbee & Syverson (2008), Bettini & Oliveira (2008), and Fageda (2014) study capacity responses to entry. With respect to strategic responses, it has been shown that incumbents may price react in anticipation of entry - Goolsbee & Syverson (2008), Huse & Oliveira (2012). Other strategic investments by incumbents may be effective in deterring entry without the need for actual retaliation. For example, some studies have suggested that the intensity and sequence of past retaliations may produce a reputation for predation to incumbents that can inhibit entry by newcomers that lack "deep pockets" - Edlin & Farrell (2002), Snider (2009). Strategic entry barriers may also be associated with the localized competitive advantage that stems from either route or airport share and the concentration of major incumbent airlines - Borenstein (1989), Evans & Kessides (1993), Lee & Prado (2005), Hofer, Windle & Dresner (2008), and Bilotkach & Lakew (2014). Other strategic investments that have been suggested in the literature are related to the biased flight information that is provided to consumers due to incentives from travel agent commission overrides and the control of computer reservation systems - Borenstein (1989), Evans & Kessides (1993), to frequent-flier programs - Borenstein (1989), Lederman (2007), and to the control of the airport bureaucracy and scarce facilities - Berry (1992), Evans & Kessides (1993), Dresner, Windle & Yao (2002), Ciliberto & Williams (2010).

It is fairly reasonable to conceive a direct and positive association between route dominance and airport dominance. In discussing the results of their empirical model of price determinants in the US airline industry of the late eighties, Evans & Kessides (1993) not only suggest that relationship, but they provide an interpretation of its consequences to market power: "*Given the strong positive correlation between airport and route market share, exclusion of the Airport Market Share*$_{ij}$ *variable should increase the coefficient on Market Share*$_{ij}$" (Evans & Kessides, 1993, p. 72). The authors conclude that the substantial increase in the coefficient of the route market share regressor with the drop in the airport market share regressor in their price equation indicates that the apparent pricing power of a dominant carrier on a route is essentially transmitted through the dominance of the whole airport. In that sense, carriers that are not provided by dominance over a given airport would therefore be unable to exert significant pricing power, even if they possessed high dominance on a given route out of that airport.

As far as we know, Leahy (1994) is the only paper in the literature that directly investigates some of the drivers of market concentration with an econometric model. The author examines the change between 1979 and 1988 in the Herfindahl-Hirshman Index (HHI) of a cross-section of the top 150 city-pairs markets in the US airline industry. The empirical results showed the relevance of changes in the average length of individual flights - measured by city-pair airport-to-airport statute miles - and in economies of density - measured by the number of city-pair passengers - as the key determinants of changes in concentration in the period. However, the author does not fully discuss and explain these findings. First, average flight length may be associated with lower concentration if we consider a gravity model of air transport demand: the higher the distance the lower the air travel demand, and therefore, the lower the market size, which in turn inhibits profitable entry. After deregulation, with the more intense use of hub-and-spoke networks by airlines, the average flight length may have increased as direct flights were replaced by indirect flights through a hub. The positive association between average flight length and market concentration that was found by the author may therefore be interpreted as an indirect result of the evolution of hub dominance in the period. Second, the route density of passenger traffic is a traditional metric that has been used to assess economies of density in cost studies since Caves, Christensen, and Tretheway (1984), who find no role for differences in scale in the explanation of higher costs for small airlines, but they do find a significant role for the differences in traffic density. In this sense, as stressed by Brueckner & Spiller (1994), economies of density should be able to explain higher market concentration in the airline markets. However, a higher traffic density also means a higher market size, in the same sense of the gravity-model interpretation of air travel demand that is discussed above - the higher the traffic density is, the higher the number of carriers with profitable operations. Additionally, there is an endogeneity issue in the relationship between concentration and traffic density: a higher density may provoke a higher concentration due to economies of density, but a higher concentration may allow for higher prices, which in turn hamper demands and traffic density.

Figure 1 depicts our conceptual model of the concentration in the airline markets, which is the basis for our empirical strategy in Section 3. Our key concept is "city-pair market concentration," which may be more precisely viewed as the Herfindahl-Hirschman Index calculated utilizing the competing airlines' market shares of passengers at the city-pair level. It is possible to observe in Figure 1 that in our conceptual framework, market concentration is determined by a set of factors that are related to demand and cost fundamentals as well as the strategic behavior of carriers and the issues that are associated with airline access to airports. The most basic concepts are "demand drivers" - such as income growth and overall economic conditions - and "air transport institutions" - for example, the overall regulatory framework, input prices and state of technology, which are determinant of most of the other concepts that have a more direct impact on "city-pair market concentration." The other relationships that are presented in Figure 1 are related to the hypotheses that are presented below.

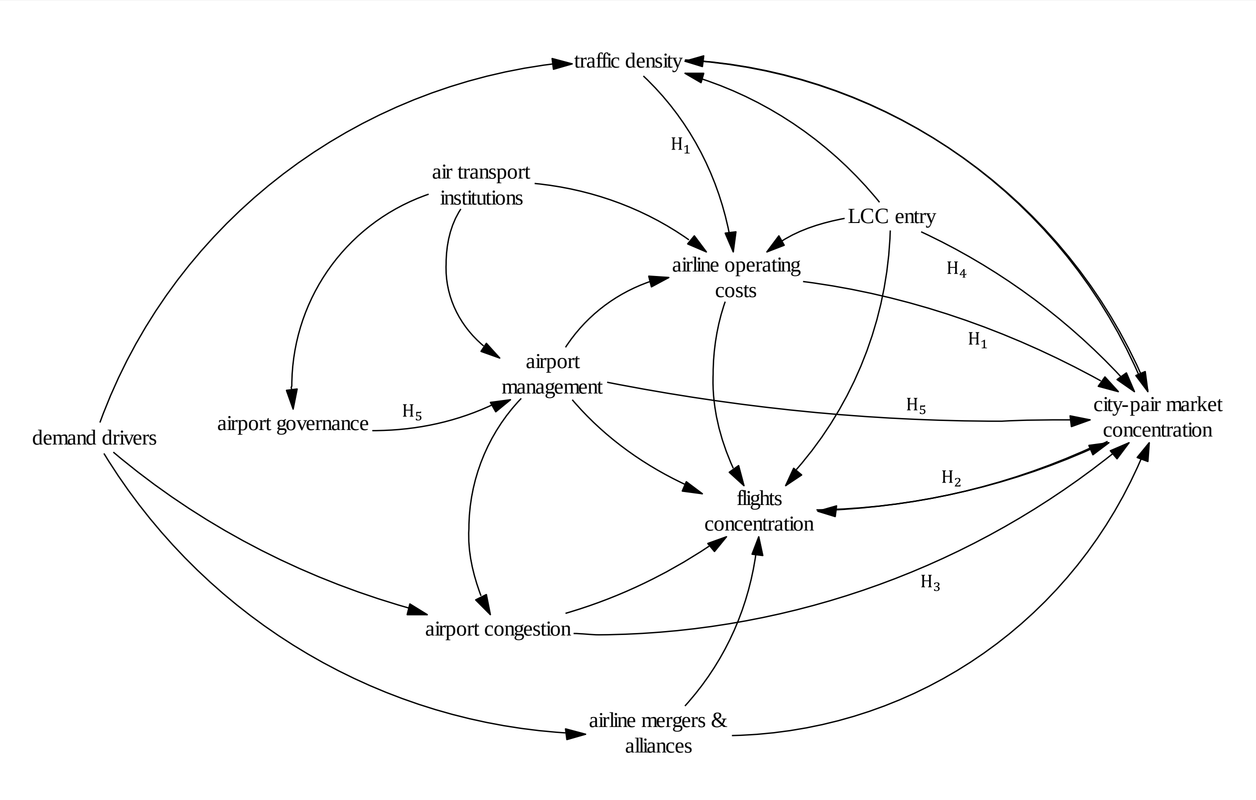

Figure 1 - Conceptual model of airline market concentration

The first hypothesis is the Brueckner-Spiller-Leahy hypothesis (Brueckner & Spiller, 1994, Leahy, 1994):

H_1. Market concentration increases with traffic density.

Economies of traffic density occur in the airline industry when the marginal cost of carrying an extra passenger on a nonstop route falls as traffic on the route increases. Brueckner & Spiller (1994) explain that a higher density allows the airline to use larger aircraft, to operate at higher load factors, and to have a more intense utilization of aircraft and fixed ground facilities. Brueckner & Spiller, (1994) and Leahy (1994) suggest that economies of traffic density give dominant carriers important advantages in the competition for traffic on the route, as their marginal cost of serving+ passengers on the route is lower due to the higher traffic densities. Under the cost advantage of larger carriers, *ceteris paribus* it is more difficult for a newcomer to enter the route due to the more credible threat of price retaliation. We would therefore observe an economies-of-density effect in the positive association between market concentration and traffic density, as raised by Hypothesis **H1**. This fundamental relationship is presented in Figure 1 in the indirect link between "traffic density" and "city-pair market concentration" in the concept of "airline operating costs." Note that we also insert a direct link between the two concepts to suggest that an amplified market size may attract more competitors as it would also enhance the viability of the profitable operations of more carriers if the competitive advantage that is allowed by economies of traffic density was not considerable[7]. In this case, we expect a negative association between "traffic density" and "city-pair market concentration" due to a market size effect. Note that as the direct and the indirect effects of market size have opposing effects on market concentration, negative and positive, respectively, the net effect may be a result of the balance between these two partial effects and therefore may accommodate the cases of either a positive or a negative association. In the case of a positive association, we would then provide support to the Brueckner-Spiller-Leahy hypothesis.

Our second hypothesis is associated with the concentration of flight frequencies:

H2. Market concentration is determined by the flight frequency concentration both at the airport and at the route levels.

Based on the literature on the competitive advantage of dominant carriers at airports - Borenstein (1989), Evans & Kessides (1993), Hofer, Windle & Dresner (2008), Ciliberto & Williams (2010), and Bilotkach & Lakew (2014) - and due to a multiplicity of potential causes such as the control of scarce airport facilities and the effects of frequent flier programs, we raise Hypothesis **H2**. We therefore suspect that the *airport* concentration of flight frequencies is a key element that induces the market concentration in the airline industry. However, in **H2**, we also include the possibility that the *route* concentration of flights is capable of producing relevant effects. Brueckner (2010) shows that transport providers compete on price but also in service frequency and that passengers value higher flight frequency because a broader portfolio of flights allows for more options in the choice of departure times. This element of vertical product differentiation implies that when a few carriers

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[7] Note that we stress the endogeneity of such relationship with a bidirectional arrow that links the two concepts in Figure 1.

dominate most of a route's flights, the majority of passengers will fly with them, and thus flight frequency concentration on the route will result in a higher market concentration.

Our third hypothesis is the following:

H_3. Airport congestion constitutes an entry barrier that raises market concentration.

The literature has suggested that airport congestion is not only a welfare decreasing situation due to higher operating costs, delays and cancellations, but it also has the perverse allocative effect of creating effective entry barriers that ultimately enhance the pricing power of the dominant carriers. For example, Dresner, Windle & Yao (2002) find that slot controls, gate constraints, and high gate utilization during peak hours have a significant impact on yields, with the latter being the most significant entry deterrent. Ciliberto & Williams (2010) find that the control of gates is a crucial determinant of hub premium. We therefore raise Hypothesis **H_3**, which suggests that the entry disincentive that is caused by the congestion of a given airport eventually materializes in a higher concentration of the air travel markets in which that airport participates.

Our fourth hypothesis is the following:

H_4. The entry of low cost carriers (LCC) provokes an effective decline in market concentration.

The literature of price responses to LCC entry is extensive - Windle & Dresner (1995), Dresner, Lin & Windle (1996), Windle & Dresner (1999), Morrison (2001), Brueckner, and Lee & Singer (2013). We contribute to that literature by considering the impacts of LCC entry on market concentration. Faced with the entry of a LCC, incumbents may retaliate by expanding their flight frequency as a way not only to enhance their product quality but also to aim at strategically building extra capacity to signal the capability of playing vigorously and to blockade entry at the most popular departure times. By increasing flight frequency, incumbents may minimize the impact of entry on the concentration of flights and target the minimization of the loss in market shares and the resulting drop in market concentration. We therefore raise Hypothesis **H_4** to test and estimate the magnitude of decrease in concentration that is caused by LCC entry.

Our final hypothesis is the following:

H_5. Changes in airport governance structure provoke changes in market concentration that may be generated if the airport administration engages in vertical relationships with dominant airlines.

Gillen (2011) discusses that the study of the performance and price impacts of airports under alternative governance structures is a recent research issue. He identifies at least seven possible ownership and/or governance structures according to the degree and mode of the shift of airports out of full public ownership to any type of privatization, for example, the cases of "government owned, privately operated," and "partially private for-profit with government controlling interest" setups. Fu, Lijesen and Oum (2006) emphasize the increasing trend of airport privatization and the concerns that a lack of upstream competition in the airport markets may influence the downstream competitiveness of the air travel markets. Additionally, Barbot (2011) describes that airports and airlines have been increasingly engaging in vertical agreements, with contracts that may allow major carriers to exert dominance over airport operations and thus exert market power over the downstream market. Bettini & Oliveira (2016) provide evidence that airport privatization creates expectations of long-term contracting with the new administration and thus generates incentives to engage in vertical relationships. With Hypothesis $\mathbf{H_5}$, we therefore consider the possibility that a change in airport governance structure from full public ownership towards privatization may increase the market concentration in the impacted air travel markets due to the strengthening of vertical relationships between the privatized airport and the existing dominant carriers.

3. Research Design

3.1. Application

We develop an empirical model to investigate the determinants and evolution of market concentration by considering the experience of the Brazilian air transportation industry. Table 1 presents some statistics of the evolution of this market since 2002.

The Brazilian airline market has experienced fast progress in the demand for air transportation, as is indicated in Table 1. Indeed, domestic traffic evolved from 29.1 million passengers in 2003 to 90.3 million in 2013, which is a growth of 210% in the period. However, the notable market expansion that was facilitated by rapid demand growth was concomitant with an increase of 16.8% in the industry concentration. Table 1 shows that the Concentration Ratio index of the top-2 airlines (CR_2) reached 0.930 in 2008, and it experienced an overall increase of 16.8% in the whole period. The industry-wide Herfindahl-Hirschman index (HHI) showed a 13.6% increase, whereas the average city-pair HHI that was calculated for revenue passengers was 0.426 in 2013 versus 0.404 in 2003. The rise in market concentration was mainly due to the market share evolution of TAM and Gol airlines, which were the dominant players in the country after the bankruptcy of legacy carrier Varig airlines. TAM is a former regional airline that began in the mid-sixties as an air taxi carrier and eventually became the largest airline in Brazil in the mid-2000s. TAM currently belongs to LATAM, which is the largest airline group in Latin America. Gol was the first low-cost carrier of the region, with operations starting in January 2001. After reaching a peak in 2008, both the CR_2 and the HHI indexes fell considerably in the 2008-2013 period, due to the intensification of competition that was caused by the entry of newcomer Azul airlines, in December 2008. Azul is a fast-growing low-cost carrier that is based at São Paulo/Campinas (VCP) airport, which, since its entry, has increased from 0.66 million enplanements in 2009 to 3.61 million in 2012 in the São Paulo Multiple Airports Region[8]. The main difference between the business models of LCCs Gol and Azul is that the former obtained facilitated access at primary airports in Brazil since the start up, whereas the latter is notably marked by secondary airports operations: whereas 51.5% of Azul's 2013 traffic was generated on routes to and/or from a secondary airport such as São Paulo/Campinas and São Paulo/São José dos Campos, this figure drops to 1.5% if we consider Gol's 2013 operations.

Table 1 - Airline market concentration evolution in Brazil

year	domestic pax (million)	industry & market concentration				
		CR_2 industry pax	HHI industry pax	HHI city-pair pax	HHI city-pair flights	HHI city flights
2003	29.1	0.644	0.268	0.404	0.417	0.251
2008	50.1	0.930	0.414	0.505	0.472	0.343
2013	90.3	0.752	0.304	0.426	0.431	0.266
% change						
2003-2008	*72.2%*	*44.4%*	*54.7%*	*25.0%*	*13.1%*	*36.7%*
2008-2013	*80.1%*	*-19.1%*	*-26.6%*	*-15.6%*	*-8.7%*	*-22.4%*
2013-2003	*210.0%*	*16.8%*	*13.6%*	*5.5%*	*3.3%*	*6.0%*

Source: National Civil Aviation Agency, with own calculations, 2002-2013.

Since deregulation, apart from the entry of the LCCs Gol and Azul Airlines, other important events have occurred in the Brazilian market, such as the codeshare agreement of Varig and TAM in the 2003-2005 period and the acquisitions of Varig and Webjet airlines by Gol (2007 and 2011) and of small, regional Pantanal airlines by TAM (2010). Additionally, to alleviate airport congestion, induce investments and expand the airport system, after years of discussions the government launched a privatization plan on May 31, 2011. The first round of privatization included two airports

[8] National Civil Aviation Agency, Air Transportation Market Statistical Database - Monthly Traffic Report, 2009-2012, with own calculations.

that were located in the São Paulo area - São Paulo/Guarulhos (GRU) and São Paulo/Viracopos (VCP). The former is Latin America's largest international gateway, and the latter is the only relevant and effective secondary airport in the country. The third privatized airport in the first round of privatization was Brasília - BSB, which is the most centrally located domestic hub.

3.2. Data

Our dataset consists of a panel of domestic routes in Brazil that are available at the monthly periodicity and that are composed of routes that involve the 26 state capitals and the country's capital. The sample period is January 2002 to December 2013. In our analysis, a route is defined as a direct domestic directional city-pair with scheduled flights. In our city-pair setting, there are three extended metropolitan regions with multiple airports in the cities of São Paulo, Rio de Janeiro and Belo Horizonte The airports in these regions were aggregated to form extended city-pair markets: Guarulhos International Airport (GRU) and Campinas/Viracopos Airport (VCP) are considered to belong to São Paulo, and Confins International (CFN) is considered to belong to the Belo Horizonte area. The data are publicly available from the airline regulator, the National Civil Aviation Agency (ANAC), namely, the Air Transportation Market Statistical Database - Monthly Traffic Report -, and the Active Scheduled Flight Report (VRA).

3.3. Econometric model

Equation (1) presents our model of market concentration in the Brazilian airline industry:

$$\begin{aligned}
\ln[\text{city-pair pax HHI}_{kt}/(1-\text{city-pair pax HHI}_{kt})] = \\
\beta_1\text{daily pax}_{kt} + \beta_2\text{daily pax squared}_{kt} \\
+\beta_3\text{fuel unit cost}_{kt} + \beta_4\text{prop flight congested hours}_{kt} \\
+\beta_5\text{codeshare between majors}_{kt} + \beta_6\text{mergers}_{kt} \\
+\beta_7\text{LCC entry-primary airport}_{kt} \\
+\beta_8\text{LCC entry-secondary airport}_{kt} \\
+\beta_9\text{city-pair flights HHI}_{kt} + \beta_{10}\text{city flights HHI}_{kt} \\
+\beta_{11}\text{privatized airports}_{kt} + \gamma_k + \gamma_t + u_{kt}, \qquad (1)
\end{aligned}$$

where k denotes the directional city-pair and t denotes the time period. Equation (1) has the following variables:

- $city\text{-}pair\ pax\ HHI_{kt}$ is the Herfindahl-Hirschman index (HHI) of concentration of revenue passengers on the route. To extract this measure, we consider the city-pair level market shares of passengers of the participating carriers. Source: National Civil Aviation Agency, Air Transportation Market Statistical Database - Monthly Traffic Report, with own calculations. We used the logistic transformed version of the variable as the HHI if it is formed by bounded outcome scores that are restricted to a finite interval [0,1][9];

- $daily\ pax_{kt}$ is the average number of daily revenue passengers on the route, which is our measure of city-pair traffic density. Source: National Civil Aviation Agency, Air Transportation Market Statistical Database - Monthly Traffic Report, with own calculations. To allow for nonlinearities in the relationship between traffic density and market concentration, we also insert a quadratic term of $daily\ pax_{kt}$;

- $fuel\ unit\ cost_{kt}$ is a proxy for the fuel costs that are incurred by carriers on a route-level basis. It is the mean unit cost of jet fuel per available seat-kilometer of all airplanes with flight assignments on the route. Source: unpublished monthly report of costs, expenses and operations disaggregated by aircraft type and airline provided by the National Civil Aviation Agency. We also utilized the Active Scheduled Flight Report (VRA) of the same agency, to extract carrier-specific information of aircraft type assignment of scheduled flights for each domestic airport-pair of the sample;

- $prop\ flight\ congested\ hours_{kt}$ is the proportion of daily scheduled flights operated during congested hours on the route. Our definition of "congested hours" utilizes any full clock hour in which the number of flights (arrivals plus departures) operated in the airport was higher than the official declared capacity. Sources: National Civil Aviation Agency, Active Scheduled Flight Report (VRA Report) and an airport capacity study that was commissioned by the Brazilian government (2010)[10];

- $codeshare\ between\ majors_{kt}$ is a dummy variable to account for the city-pairs and periods in which the codeshare agreement between the major carriers TAM and Varig had

[9] We discarded the few city-pairs that were a monopoly in the air travel market between two capital states in Brazil.

[10] "*Study of the Air Transport Sector in Brazil*" (text in Portuguese) - Brazilian Development Bank, Jan, 25, 2010, available at www.bndes.gov.br.

operations, between March 2003 and April 2005. Source: Secretariat for Economic Monitoring (SEAE) of the Ministry of Finance;

- $mergers_{kt}$ is a dummy variable to account for some airline mergers that have occurred in the industry since the mid-2000s: Gol's acquisition of Varig (2007) and Webjet (2011), and Azul's acquisition of Trip (2012). This variable is assigned with a value of 1 for every route in which the acquired airline had presence on the occasion of the merger announcement, from that period to the end of the sample period. Source: electronic archives of the most important national newspapers;

- $LCC\ entry\text{-}primary\ airport_{kt}$ is a dummy variable to account for the presence of low-cost carrier Gol airlines in the startup years. As discussed, the business model of this LCC is marked by operations at primary airports. Gol airlines entered the market in January 2001, which is therefore prior to the beginning of the sample period. This variable is assigned with 1 for routes in which Gol was present until mid-2005, when Gol surpassed Varig as the second major carrier in the Brazilian market. Source: National Civil Aviation Agency, Active Scheduled Flight Report - VRA, with own calculations;

- $LCC\ entry\text{-}secondary\ airport_{kt}$ is a dummy variable to account for the presence of low-cost carrier Azul airlines, which is a carrier that is marked by operations at secondary airports. Azul airlines entered the market in December 2008. Source: National Civil Aviation Agency, Active Scheduled Flight Report - VRA, with own calculations;

- $city\text{-}pair\ flights\ HHI_{kt}$ is the Herfindahl-Hirschman index of direct flight frequencies calculated at the route level. Source: National Civil Aviation Agency, Active Scheduled Flight Report - VRA, with own calculations;

- $city\ flights\ HHI_{kt}$ is the geometric mean of the origin and destination of the Herfindahl-Hirschman indexes of direct flight frequencies calculated at the city level. Source: National Civil Aviation Agency, Active Scheduled Flight Report - VRA, with own calculations;

- $privatized\ airports_{kt}$ is a dummy variable to account for the presence of a privatized airport either at the origin or destination city. In our setup of the beginning of the privatization period, we consider the public announcement by the government of the shortlist of airports and the preparation for the privatization auction (May, 2011). Source: electronic archives of the most important national newspapers;

- γ_k are the city-pair fixed effects; γ_t are time fixed effects (two-way procedure); the β's are unknown parameters; u_{kt} is the associated error term.

Henceforth, we omit indexes k and t. Table 2 presents descriptive statistics of the main variables of our empirical model.

Table 2 - Descriptive statistics - variables of the empirical model

Variable		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Pearson's Correlation												
city-pair pax HHI	(1)	1.000										
daily pax	(2)	-0.323	1.000									
fuel unit cost	(3)	0.115	-0.023	1.000								
prop flight congested hours	(4)	-0.152	0.207	-0.009	1.000							
codeshare between majors	(5)	-0.005	-0.031	0.119	-0.028	1.000						
mergers	(6)	-0.085	0.364	-0.140	0.061	-0.221	1.000					
LCC entry - primary airport	(7)	-0.215	-0.055	0.077	0.089	0.608	-0.307	1.000				
LCC entry - secondary airport	(8)	-0.222	0.308	-0.229	0.127	-0.194	0.533	-0.269	1.000			
city-pair flights HHI	(9)	0.588	-0.354	-0.046	-0.154	-0.027	-0.117	-0.123	-0.174	1.000		
city flights HHI	(10)	0.103	0.144	-0.036	-0.060	-0.181	0.125	-0.138	-0.091	-0.083	1.000	
privatized airports	(11)	-0.132	0.265	-0.127	0.184	-0.134	0.222	-0.186	0.341	-0.086	-0.060	1.000
Univariate statistics												
Mean		0.447	0.908	0.099	0.118	0.099	0.307	0.176	0.254	0.440	0.278	0.140
Standard Deviation		0.113	1.271	0.047	0.191	0.299	0.461	0.380	0.435	0.117	0.074	0.347
Minimum		0.205	0.030	0.021	0.000	0.000	0.000	0.000	0.000	0.202	0.002	0.000
Maximum		0.999	12.736	1.035	1.000	1.000	1.000	1.000	1.000	0.969	0.516	1.000

3.5. Estimation strategy

3.5.1. Endogeneity and instrumental variables

We treat $daily\ pax$, $daily\ pax\ squared$, $city\text{-}pair\ flights\ HHI$ and $city\ flights\ HHI$ as endogenous variables. We therefore employ an instrumental variables estimator. Our identification strategy employed a combination of structural and Hausman-type instruments (Hausman, 1996). Our structural instruments consist of demand shifters that have an impact on both $daily\ pax$ and the flight frequency concentration measures, as our conceptual model of Figure 1 suggests. We therefore utilize the following values: gdp_{kt}, the gross domestic products (GDP) of origin and the destination cities of route k and time t; $population_{kt}$, the populations of the origin and destination cities of route k and time t (in millions); $unemployment_{kt}$, the unemployment rate of the origin and destination states of the cities of route k and time t. The data source is the Brazilian Institute of Geography and Statistics (IBGE). The first two metrics have yearly periodicity and therefore required interpolation to produce monthly series. We utilize the following versions of each instrumental variable: minimum, maximum, geometric mean, and the product ("gravity") between the values of the endpoint cities of each market. As $daily\ pax\ squared$ must also be instrumented, we utilize some squared and natural log versions of the instrumental variables set. To instrument the flight concentration measures, we employ the Hausman instruments as well as a lagged version of the route concentration of the slots at the São Paulo/Congonhas Airport (CGH)[11]. The employed Hausman instrumentation is similar to that of Piga & Bachis (2006), Mumbower, Garrow & Higgins (2014) and Bendinelli, Bettini & Oliveira (2016). With Hausman-type instruments, we employ variables that are constructed with values from other routes to instrument the flight frequency concentration levels of a given route, both of which are set forth in current values and with one lag. We utilized the $fuel\ unit\ cost_{kt}$ variable that is defined above to construct the Hausman instrument set, as the price formation of jet fuel has a strong national level component. The identifying assumption of the Hausman-type instruments permits the exploitation of the panel structure of the data by assuming that both flight concentration levels and fuel unit costs are correlated across markets, but the latter is uncorrelated with the former's unobserved shocks.

To inspect the quality of our instrumentation approach, we employed statistical tests of the validity and relevance of the instrumental variables. We utilized Hansen J tests to check the validity of the full set of over-identifying conditions and Kleibergen-Paap rk LM underidentification tests (KP) to check the relevance of the instruments. We also inspected the issue of weak identification using the Cragg-Donald Wald F statistic and the Kleibergen-Paap rk Wald F statistic (Weak CD and Weak KP). We present the results of all of the above tests in the bottom of the tables in Section 3. With this statistical approach, we obtained evidence that supports the orthogonality and relevance of the proposed set of instrumental variables.

3.5.2. Estimation

The method that was employed to estimate Equation (1) is the two-step feasible efficient generalized method of moments estimator (2SGMM) with standard errors that are robust and efficient to autocorrelation and arbitrary heteroscedasticity. We implemented Cumby-Huizinga autocorrelation tests and Pagan-Hall, White/Koenker and Breusch-Pagan/Godfrey/Cook-Weisberg heteroscedasticity tests in the residuals of Equation (1). These tests indicated the presence of autocorrelation and heteroscedasticity. We employed the Newey-West procedure to adjust the standard error estimates[12].

[11] Lagged of twelve months.

[12] We utilized the Bartlett kernel function with a bandwidth of round$(T^{1/4})$, where $T = 144$.

4. Results

Table 3, Column (1) presents the estimation results of our baseline empirical model. Columns (2) through (9) present the results of a set of robustness checks of the results of the baseline model.

As is shown in Table 3, Column (1), the estimated results allow an analysis of the statistical tests of our five raised hypotheses. First, Hypothesis $\mathbf{H_1}$ states that market concentration increases with economies of traffic density. With regard to traffic density, we have the estimated coefficients of $daily\, pax$ and $daily\, pax\, squared$, which were both statistically significant. Although there is an indication of a quadratic function with upward concavity, the vast majority of the estimated full marginal effects of $daily\, pax$ for the entire sample was negative within the relevant interval for this variable. Indeed, in the extraction of the point estimates of the full marginal effects of $daily\, pax$ for every observation in the sample, we noted that only 13 observations out of 17,480 total observations were actually associated with positive estimated marginal effects. These exceptions were related to the densest city-pair in Brazil, the São Paulo-Rio de Janeiro route, but only for the 2012-2013 period. For all of the other cases, the estimates revealed a negative association with market concentration and therefore provide evidence against the Brueckner-Spiller-Leahy hypothesis ($\mathbf{H_1}$) in our sample. Remember that in our conceptual model we allowed for both direct and indirect effects of traffic density on market concentration. The evidence that is obtained from our empirical model that market concentration and traffic density have a *ceteris paribus* negative association therefore suggests that the market size effect surpassed the effect of the economies of density effect in the Brazilian case study.

With respect to the estimated coefficients of $city\text{-}pair\, flights\, HHI$ and $city\, flights\, HHI$, we obtain that both were positive and statistically significant. Hypothesis $\mathbf{H_2}$ posited that market concentration is determined by both route and airport flight frequency concentration. The results in Column (1) confirm $\mathbf{H_2}$ and thereby the relevance of both levels as key drivers of market concentration in the air travel markets. This result is in accordance with the literature on the competitive advantage of dominant carriers at airports - from Borenstein (1989), Evans & Kessides (1993), Hofer, Windle & Dresner (2008), Ciliberto & Williams (2010), and Bilotkach & Lakew (2014), and it is also consistent with Brueckner's (2010) model of vertical product differentiation, which, as discussed above, implies that flight frequency concentration on the route raises market concentration.

Table 3 - Estimation results[13] - dependent variable: $\ln[\text{city-pair pax HHI}/(1 - \text{city-pair pax HHI})]$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
daily pax	-0.1756***		-0.2043***		-0.2153***	-0.1845***	-0.2222***	-0.2264***	-0.1925***
daily pax squared	0.0151***		0.0159***		0.0182***	0.0161***	0.0190***	0.0191***	0.0164***
fuel unit cost	0.3628	0.3678	0.3436	0.1561	0.2219	0.3679	0.2544	0.1838	0.2281
prop flight congested hours	0.1332***	0.1184***			0.1210***	0.1348***	0.1155***	0.1220***	0.1256***
codeshare between majors	0.1180***	0.1281***	0.1104***	0.1423***	0.1192***	0.1096***	0.1273***	0.1193***	0.1196***
mergers	-0.0239	-0.0326	-0.0216	-0.0080	-0.0102	-0.0241	-0.0034	-0.0065	-0.0111
LCC entry - primary airport	-0.1390***	-0.1098***	-0.1432***	-0.1133***	-0.1435***	-0.1468***	-0.1398***	-0.1423***	-0.1376***
LCC entry - secondary airport	0.0551	0.0360	0.0484	-0.0077	0.0385	0.0488*	0.0302	0.0342	0.0456*
city-pair flights HHI	3.8829***	3.9640***	3.7452***	3.4725***	3.6683***	3.8863***	3.5787***	3.5854***	3.7743***
city flights HHI	4.0432***	3.8047***	4.2923***	3.1732***	3.6009***	3.9825***	3.5492***	3.4729***	3.3491***
privatized airports	0.1355***	0.1109**	0.1522***	0.0776	0.1217***	0.1845***	0.0266	0.1813***	0.1266***
inverse Mills ratio					-0.0049***	-0.0053***	-0.0062***	-0.0052***	-0.0050***
privatized & placebo privatized airports						-0.1019***	0.1800***	-0.0833***	-0.1457***
placebo assignment rule	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*investment*	*sequence*	*growth*	*mega-event*
fixed effects	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*
Adjusted R-Squared	0.3810	0.3889	0.3807	0.4556	0.4158	0.3815	0.4292	0.4280	0.4185
RMSE Statistic	0.4119	0.4093	0.4120	0.3863	0.4001	0.4117	0.3955	0.3960	0.3992
F Statistic	25.243	25.825	25.248	29.661	26.720	25.270	27.005	27.424	26.741
KP Statistic	44.890	34.810	43.889	41.799	43.934	41.822	47.134	39.622	44.342
KP P-Value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
J Statistic	3.9379	4.1362	3.4611	6.9797	4.5590	2.6121	4.5886	5.5312	5.3737
J P-Value	0.7869	0.6582	0.8393	0.3227	0.7136	0.9184	0.7100	0.5954	0.6145
Weak CD Statistic	11.079	9.7736	11.062	11.704	10.919	10.396	11.119	10.225	10.699
Weak KP Statistic	4.2409	4.3968	4.1431	5.3280	4.1236	3.9049	4.4124	3.6968	4.1700
Nr Observations	17,354	17,354	17,354	17,354	17,354	17,354	17,354	17,354	17,354

*Notes: Results produced by the two-step feasible efficient generalized method of moments estimator (2SGMM); statistics robust to heteroscedasticity. Results of Column (5)-(9) produced by a Heckit model with first-stage result produced by a probit model of privatized airports (see details in Appendix 2); standard errors of the estimated coefficients (in brackets) were bootstrapped to account for the two-stage nature of the Heckit method. P-value representations: ***p<0.01, ** p<0.05, * p<0.10.*

Additionally, the estimated coefficients of the variables $prop\,flight\,congested\,hours$ and $privatized\ airports$ were positive and statistically significant, thus confirming Hypotheses $\mathbf{H_3}$ and $\mathbf{H_5}$ and suggesting that airport congestion and airport privatization may induce increases in market concentration through the creation of entry barriers that stem either from the control of scarce facilities, which confirms the findings of Dresner, Windle & Yao (2002) and Ciliberto & Williams, (2010), or from the strengthening of airport-dominant airlines' vertical relationships, which is consistent with Barbot (2011) and Bettini & Oliveira (2016). With respect to Hypothesis $\mathbf{H_4}$ on the effect of the entry of low-cost carriers (LCC) on market concentration, we had mixed results, as is shown in Table 3, Column (1), with the variables $LCC\,entry\text{-}primary\,airport$ and $LCC\ entry\text{-}secondary\ airport$. Whereas the entry of a LCC that is marked by operations at primary airports - Gol airlines in the early 2000s - had a statistically significant downward effect on market concentration, the results with regard to the entry of a LCC that mainly operates at secondary airports - Azul airlines since the late 2000s - was not significant. These results serve as a refutation of $\mathbf{H_4}$ as a general statement, which implies that LCC entry may not provoke declines in market concentration, unless it is materialized at primary airports.

The remaining variables of Equation (1), which can be seen in the results of Column (1), allow for the further analysis of the evolution of city-pair market concentration in the sample period. The variable representative of the codeshare between the major carriers Varig and TAM from 2003 to 2005 had a positive and statistically significant effect on concentration. However, the merger episodes between majors and smaller carriers in the second half of the 2000s did not have a statistically significant impact[14]. These results suggest that concentration is apparently driven by market structure dynamics that are only provoked when at least two effective players are involved.

4.1. Robustness checks

We implemented a series of experiments that were aimed at assessing the robustness of the results of Column (1). We present the results of such experiments in Columns (2) through (5) of Table 3. First, we drop some the key regressors of our baseline model to analyze the resulting changes in the estimates of the remaining regressors. We experiment with the discarding of the variables $daily\ pax$ and $daily\ pax\ squared$, Column (2), discarding the variable $prop\ flight\ congested\ hours$, Column (3), and simultaneously discarding all three of the variables, Column (4). All of the specifications

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[14] Note that on the occasion of Varig's acquisition by Gol, that legacy carrier had only 5.5% market share, in stark contrast with the 50.2% that Varig had two years earlier. Source: National Civil Aviation Agency (ANAC), Air Transportation Demand and Supply Monthly Report, with own calculations.

confirmed the validity of the main results, with the exception of the variable $privatized\ airports$ in the third experiment. As the coefficients of this variable obtain that its size is decreased by almost half and becomes statistically not significant in the underspecified model of Column (4), we conclude that privatization is related to these key market concentration drivers and may suffer from omitted variable bias in this model. As the analysis of the effects of privatization on market concentration is a central issue in our study, we develop further robustness checks with a special focus on the behavior of the results of the variable $privatized\ airports$.

An additional robustness check that we perform is to acknowledge the fact that the decision to privatize an airport is neither random nor exogenous to demand. To account for sample selectivity in the choice of airports to be privatized by the government, we utilized a Heckit correction procedure. With the Heckit framework, a selection decision equation is firstly estimated using a random-effects probit model and, in a second stage, the observed factors that determine such selection are included in the estimating equation in the form of an inverse Mills ratio variable. For details about the estimation and the results of the Heckit model, see Appendix 1. The estimation results of the second-stage of the Heckit model are presented in Column (5) of Table 3. The results show that the inserted variable $inverse\ Mills\ ratio$ is statistically significant, which indicates that sample selection is a relevant issue in our estimation. However, note that the results from the control of sample selectivity do not alter the main results that are obtained in Column (1) of Table (5).

4.2. Further evidence

To provide further evidence of the robustness of our main results, in particular with respect to the concentration effects of privatization (Hypothesis $\mathbf{H_4}$), we implemented a difference-in-differences (DiD) methodology as in Kwoka and Shumilkina (2010), Bilotkach (2011) and Bettini and Oliveira (2016). In our context, the idea of the DiD framework is to check whether privatization actually produced a *ceteris paribus* effect on market concentration that is not explained by other possible factors that affected similar airports. To implement the methodology, we allow for a slight modification of the specification of Equation (1) by inserting an additional variable, which is a $privatized\ \&\ placebo\ privatized\ airports$ dummy. The objective of this variable is to distinguish the estimated effect of the variable $privatized\ airports$ from the effects of a group of $placebo\ privatized\ airports$, i.e., a group of routes that are assigned with a value of 1 if any of their endpoint airports is found to be similar to the airports that have been exposed to privatization according to certain criteria. As a first placebo assignment rule, we searched for matches of actually privatized airports based on similar public investment patterns, which is referred to as the "investment" rule. Based on that rule, we obtained a set of airports that are not privatized but also subject to the investments of the 2010-2014 restructuring program that was accomplished by the government[15]. Other routes that were also not classified into the actually privatized or the placebo privatized group of routes constitute the base case of the dummies.

The result of the DiD specification using the "investment" rule for placebo assignment is presented in Column (6) of Table 3. As it contains both the Heckit and the DiD controls - in contrast to our baseline model of Column (1) in which these controls are not included - we consider the specification of Column (6) to be our preferred model. Note that in this specification, the estimated coefficient of the $privatized\ airports$ variable retains its statistical significance, which indicates that the routes that are associated with privatized airports had a *ceteris paribus* and positive effect of market concentration that was above the effect of the control group. Actually, as the estimated coefficient of the $privatized\ \&\ placebo\ privatized\ airports$ dummy was negative, we obtain that the control group experienced a decline in market concentration.

It is important to note, however, that in the case of mistakes that are associated with the selection of the control group in the DiD framework, we may have caused biased estimates. To avoid invalid conclusions, we therefore experimented with other possible criteria for the construction of the $privatized\ \&\ placebo\ privatized\ airports$ dummy. Apart from the "investment" rule for the placebo assignment that is presented in Column (6) of Table 3, we utilized the following alternative rules: a "sequence" rule (Column 7), which utilizes airports that are eventually privatized or assigned to be privatized after the end of the sample period[16]; a "growth" rule (Column 8), airports with similar growth perspectives[17]; and a "mega-event" rule (Column 9), airports of the cities that hosted the 2014 World Cup matches[18]. With the exception of Column (7), all of the other results were robust to the utilization of the alternative placebo assignment rules and thus generated evidence that confirmed the validity of Hypothesis **H_4**.

[15] Matching airports: Rio de Janeiro's Tom Jobim and Santos Dumont airports, and the airports of Vitória, Porto Alegre, Florianópolis, Curitiba and Goiânia cities.

[16] Matching airports: Belo Horizonte's Confins Airport, Rio de Janeiro's Tom Jobim airport, Natal's São Gonçalo do Amarante airport, and the airports of Porto Alegre, Salvador, Florianópolis and Fortaleza cities.

[17] For each privatized airport, we included three matched airports. We included only airports of state capitols with more than 1.5 million pax/year in 2011 that were in the top-20 list of highest long-run average growth in passenger traffic (2001-2011). Source: Infraero, with own calculations. Matching airports: Belo Horizonte's Confins Airport and the airports of Vitória, Uberlândia, Cuiabá, João Pessoa, Teresina, São Luiz, Foz do Iguaçu and Campo Grande cities.

[18] Matching airports: Belo Horizonte's Pampulha and Confins airports, Rio de Janeiro's Santos Dumont and Tom Jobim airports, São Paulo's Congonhas airport, and the airports of Curitiba, Cuiabá, Fortaleza, Manaus, Natal, Recife and Salvador.

4.3. Counterfactuals

To permit an assessment of the relative importance of the key determinants of market concentration in our case study, we conduct a study of the counterfactual analysis. The idea of the counterfactual analysis is to assess the relative impacts of changes in some of the most important drivers of Equation (1). In these exercises, we focus on the statistically significant regressors of market concentration in our preferred specification, as shown in Column (6) of Table 3. We consider 2008 to be a baseline scenario (S0), as that is the year that is associated with the highest concentration ratio of the two major carriers. We then compare the predicted average market concentration in 2008 with the one that would occur if changes in the regressors were introduced, e.g., the counterfactual scenarios. In most cases, the setup of the assumptions to construct the counterfactual scenarios was inspired by the *status quo* of five years later, in 2013, when the market concentration in the Brazilian airline industry was notably lower. We consider the five-year gap to be a sufficient time span for a long-run analysis of the market concentration dynamics over time. We therefore utilize the estimates of our preferred specification to calculate the estimated (predicted) market concentration of 2008 and to compare the predicted HHI in the baseline scenario (S0) with the predicted HHI that would prevail under eleven alternative counterfactual scenarios. We refer to the counterfactual scenarios as (S1)-(S11), which were constructed using a broad set of assumptions regarding traffic density, congestion, flight frequency concentration, and privatization. The results of the counterfactual analysis are displayed in Table 4.

The scenarios (S1)-(S7) that are displayed in Table 4 are associated with the isolated effects of the market concentration determinants. It is possible to infer that the decline in market concentration in the 2008-2013 period was mainly caused by flight frequency deconcentration, at both the route and the airport levels. Indeed, the estimated counterfactual change in market concentration that was caused by the variables $city\text{-}pair\ flights\ HHI$ and $city\ flights\ HHI$ was -7.84% and -15.15%, respectively. Among the factors that contributed to a rise in market concentration, privatization had the highest isolated impact, with variable $privatized\ airports$ generating the effect of a 9.14% increase.

Apart from the estimated counterfactual isolated effects of the key determinants of market concentration, Table 4 also presents the results for the assumptions that are based on the combined effects of such determinants. These experiments are presented in Scenarios (S8)-(S11) of Table 4. Scenario (S8) shows a 22.76% decline in the market concentration that is associated with a long-run joint decline in flight frequency concentration at the route and airport levels. Scenario (S9) shows that this effect is intensified to -26.13% if we include the effect of the growth in traffic density that occurred in the period, but it drops to a net effect of -17.34% in city-pair markets in which an endpoint airport was privatized, which thus suggests an unintended consequence of privatization, i.e., higher market concentration in (S10) in contrast to (S9)[19]. Note that the market concentration-inducing effect on routes that are subject to airport privatization is not sufficient to countervail the benefits that stem from the observed market expansion and flight frequency deconcentration that occurred in the period.

Table 4 - Estimation results - Counterfactual analysis[20]

Scenarios	Assumptions	Estimated HHI	Counterfactual vs Baseline		
			Diff.	% Diff.	
Baseline					
(S0)	*all variables fixed at baseline year (2008) values*	0.5075			
Counterfactual					
(S1)	*daily pax: 2013 values (+49.1%), ceteris paribus*	0.4894	-0.0181	*-3.57%*	***
(S2)	*prop flight congested hours: 2013 values (+308.4%), ceteris paribus*	0.5111	0.0036	*0.71%*	***
(S3)	*city-pair flights HHI: 2013 values (-8.7%), ceteris paribus*	0.4677	-0.0398	*-7.84%*	***
(S4)	*city flights HHI: 2013 values (-22.4%), ceteris paribus*	0.4306	-0.0769	*-15.15%*	***
(S5)	*privatized airports = 1, ceteris paribus*	0.5539	0.0464	*9.14%*	***
(S6)	*LCC entry - primary airports = 1, ceteris paribus*	0.4707	-0.0368	*-7.25%*	***
(S7)	*codeshare between majors = 1, ceteris paribus*	0.5343	0.0268	*5.28%*	***
(S8)	*city-pair flights HHI: 2013 values (-8.7%), city flights HHI: 2013 values (-22.4%), ceteris paribus*	0.3920	-0.1155	*-22.76%*	***
(S9)	*daily pax: 2013 values (+49.1%), city-pair flights HHI: 2013 values (-8.7%), city flights HHI: 2013 values (-22.4%), ceteris paribus*	0.3749	-0.1326	*-26.13%*	***
(S10)	*daily pax: 2013 values (+49.1%), city-pair flights HHI: 2013 values (-8.7%), city flights HHI: 2013 values (-22.4%), privatized airports = 1, ceteris paribus*	0.4195	-0.0880	*-17.34%*	***
(S11)	*city-pair flights HHI: 2013 values (-8.7%), city flights HHI: 2013 values (-22.4%), privatized airports = 1, LCC entry - primary airports = 1, ceteris paribus*	0.3840	-0.1235	*-24.33%*	***

We performed a final counterfactual experiment regarding the combined effect of the key drivers in our empirical model, as is shown in Scenario (S11). In this experiment, we check whether the

[19] It is important to note, however, that elsewhere in the literature (Bettini & Oliveira, 2016), airport privatization has been reported to induce above-average increases in demand - and traffic density - on routes out of privatized airports. As our empirical model controls for the endogeneity between traffic density and market concentration, we believe that the results of our counterfactual experiments that consider privatization - such as (S11) - may be interpreted as a *ceteris paribus* effect.

[20] Results produced utilizing the estimates presented in Table 3, Column (6); p-value representations: ***p<0.01, ** p<0.05, * p<0.10.

unintended effect of privatization on market concentration in which Hypothesis **H4** is associated with vertical relationships between airports and dominant carriers could be eroded by the attraction of new entry. The idea of Scenario (S11) is therefore to simulate whether the insertion of additional competition in primary airports could produce an effect that would offset the concentration-inducing effect of privatization. We assign the variable $LCC\ entry\text{-}primary\ airport$ with a value of 1 in the setup of that experiment. The results of Scenario (S11), which are presented in Table 4, suggest that the perverse effects of privatization could almost fully be countervailed by facilitating the entry of new LCCs at primary airports, which would generate a statistically significant difference between the baseline and the counterfactual HHIs of -24.33%, versus -26.13% in Scenario (S9).

We are aware that the results of the counterfactual analysis that is displayed in Table 4 may be driven by the choice of the baseline year, namely 2008, and the year from which the counterfactual variations in the regressors were extracted, namely 2013, versus 2008. We therefore challenge the robustness of the counterfactual results by altering both of the years to 2007 and 2012, respectively. The results of this robustness check are presented in Appendix 2, with the final conclusions remaining basically the same.

5. Conclusion

This paper presents an econometric model of city-pair market concentration in the airline industry by considering the Brazilian market in the period 2002-2013. Our contribution is in the formal hypothesis testing of 1) the association of market concentration and traffic density, e.g., the Brueckner-Spiller-Leahy hypothesis, and 2) the association of market concentration and route-airport concentration of flight frequencies. We account for the inherent endogeneity that emerges in the relationship of these variables. Additionally, we provide the first study to empirically examine the market concentration effects of a potential intensification of airport-dominant airlines' vertical relationships due to airport privatization.

Our econometric approach is complemented by a counterfactual analysis to investigate the causes of the persistent decline in market concentration since 2008, when the dominance of the two major airlines in the country reached its peak. Our estimated counterfactual scenarios reveal that the observed long-run decline in flight dominance produced a *ceteris paribus* 23% decrease in the estimated HHI. Additionally, the market expansion produced an extra 4% decline in concentration. In contrast, ownership change at the privatized airports produced a rise of 9% in concentration. The results of a combined counterfactual scenario suggest that such unintended effects of privatization could almost be fully countervailed by facilitating the entry of new LCCs at primary airports. These results are not only relevant from the perspective of the public monitoring of market dominance at airports, but they also suggest that a regulatory setup in which dominant carriers are forced to divest slots at key airports to LCCs as part of a merger process may produce the beneficial results of achieving a lower concentration and a higher long-run competition in the air travel markets.

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Appendix 1 - First-stage of the Heckit procedure

Our specification of the first-stage probit model uses $privatized\ airports$ as the regressand and the following regressors: $ln\ gravity\ gdp\ per\ capita$, $ln\ gravity\ population$, $prop\ flights\ in\ congested\ hours$, and $city\ flights\ HHI$, as defined in 3.3. We also include as a regressor in the probit model the variable $yield$, which is a proxy for the market average price per kilometer on the route; this series has monthly periodicity, is inflation-adjusted to produce constant monetary figures, and is utilized in log values; source: National Civil Aviation Agency, Yield Report. After running the random-effects probit model in the first stage of the Heckit correction model, we utilized a bootstrap procedure in our GMM estimation of Equation (1) to account for the presence of the estimated inverse Mills ratio among the regressors and therefore to correct the standard errors of the second-stage regression of the Heckit model[21]

Table 5 - Estimation results - dependent variable: selected for privatization[22]

	(1) privatized
ln gravity gdp per capita	8.8028***
ln gravity population	5.7597***
prop flights in congested hours	4.7762***
flights city HHI	-7.9448***
ln yield	-1.0181***
Pseudo R-squared	0.6320
ρ Statistic	0.9919
ρ Nullity Test P-Value	0.0001
Wald χ^2 Statistic	1297.9
Wald χ^2 P-Value	0.0001
Nr Observations	17,493

[21] Note that with the bootstrap procedure, it is not possible (or necessary) to control for autocorrelation in the second-step regression.

[22] Results produced by a random-effects probit regression; p-value representations: ***p<0.01, ** p<0.05, * p<0.10.

Appendix 2 - Counterfactual analysis - Robustness check

Table 6 - Estimation results - counterfactual analysis (alternative years)[23]

Scenarios	Assumptions	Estimated HHI	Counterfactual vs Baseline		
			Diff.	% Diff.	
Baseline					
(S0)	*all variables fixed at baseline year (2007) values*	0.5014			
Counterfactual					
(S1)	*daily pax: 2012 values (+42.8%), ceteris paribus*	0.4861	-0.0153	*-3.05%*	***
(S2)	*prop flight congested hours: 2012 values (+112.0%), ceteris paribus*	0.5048	0.0034	*0.68%*	***
(S3)	*city-pair flights HHI: 2012 values (-3.9%), ceteris paribus*	0.4842	-0.0172	*-3.43%*	***
(S4)	*city flights HHI: 2012 values (-17.4%), ceteris paribus*	0.4450	-0.0564	*-11.25%*	***
(S5)	*privatized airports = 1, ceteris paribus*	0.5478	0.0464	*9.25%*	***
(S6)	*LCC entry - primary airports = 1, ceteris paribus*	0.4646	-0.0368	*-7.34%*	***
(S7)	*codeshare between majors = 1, ceteris paribus*	0.5283	0.0269	*5.36%*	***
(S8)	*city-pair flights HHI: 2012 values (-3.9%), city flights HHI: 2012 values (-17.4%), ceteris paribus*	0.4281	-0.0733	*-14.62%*	***
(S9)	*daily pax: 2012 values (+42.8%), city-pair flights HHI: 2012 values (-3.9%), city flights HHI: 2012 values (-17.4%), ceteris paribus*	0.4131	-0.0883	*-17.61%*	***
(S10)	*daily pax: 2012 values (+42.8%), city-pair flights HHI: 2012 values (-3.9%), city flights HHI: 2012 values (-17.4%), privatized airports = 1, ceteris paribus*	0.4589	-0.0425	*-8.48%*	***
(S11)	*city-pair flights HHI: 2012 values (-3.9%), city flights HHI: 2012 values (-17.4%), privatized airports = 1, LCC entry - primary airports = 1, ceteris paribus*	0.4226	-0.0788	*-15.72%*	***

[23] Results produced utilizing the estimates presented in Table 3, Column (6); p-value representations: ***p<0.01, ** p<0.05, * p<0.10.