Transport Policy 63 (2018) 165–175

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

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

Marcus V.R. Oliveira, Alessandro V.M. Oliveira *

Center for Airline Economics, Aeronautics Institute of Technology, Brazil

ARTICLE INFO

Keywords:
Airlines
Herfindahl-Hirschman index
Market concentration
Airport privatization

JEL classification:
D22
L11
L93

ABSTRACT

Market concentration is a widely recognized metric for assessing 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. 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 hypotheses regarding the association of market concentration with market size and service quality, as well as the impacts of vertical relationships after airport privatization. Our results suggest that the entry-attraction effect of market size more than compensates for the economies-of-density effect, while the vertical product differentiation created by the strategic investment in capacity is a key driver of concentration in the airline industry.

1. Introduction

It is well known that contemporary market deregulation has had 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 played 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% of the 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 and Dresner (1999), Morrison (2001), and Brueckner et al. (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 et al. (2008) use the term "price premium" to define the airfare impacts that have been

* Corresponding author.
E-mail address: alessandro@ita.br (A.V.M. Oliveira).

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

https://doi.org/10.1016/j.tranpol.2017.12.021
Received 28 October 2016; Received in revised form 26 May 2017; Accepted 19 December 2017

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 one 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 and Lakew (2014). In addition to price, other dimensions of airline service have 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 and Sinai (2003), Mazzeo (2003), Ater (2012), and Bendinelli et al. (2016). In contrast, the empirical literature related to the inspection of the main determinants of market concentration is confined to Leahy (1994) and Brueckner and Spiller (1994), who provided a cost-based justification based on the economies of traffic density for the increase in airport and industry-wide concentration in the US airline industry. Here, we raise hypotheses regarding the association of market concentration with market size and airline service quality to inspect the validity of the theoretical framework of the strategic behavior of incumbents of Spence (1977), Dixit (1979), Sutton (1991, 1998), and Cohen and Mazzeo (2004).

We consider the case of the Brazilian airline industry in the 2002–2013 period, during which time it was an emerging market that experienced 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 composed of TAM and Gol airlines. These major carriers had a combined domestic market share of 93% in 2008, but they have 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 et al. (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 dominant 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. These analyses have important policy implications, as the regulators and antitrust authorities around the world are typically interested in avoiding dominance, stimulating competition and enhancing the access to major hub airports. Our empirical framework accounts for the endogeneity of traffic density, flight concentration and entry 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").

The remainder of this paper is organized as follows: Section 2 presents a literature review on the issue of market concentration. We also raise three hypotheses. Section 3 presents our research design with a 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 and a series of robustness checks, followed by our concluding remarks.

2. Determinants of market concentration

In this section, we discuss the literature on the determinants of market concentration, with a focus on the case of the airline industry. We begin with an analysis of some of the most important models established in the Industrial Organization literature. We then move forward to the analysis of the empirical studies available in the airline literature. We raise three hypotheses regarding the determinants of market concentration in airline markets and relate these hypotheses to the existing theoretical framework available in the surveyed literature.

2.1. Market structure in the Industrial Organization literature

According to the neoclassical theory of the firm, market structure, such as the number of firms and their relative sizes, is mainly governed by efficiency considerations.[7] The degree of concentration in a market is a function of the magnitude of the economies of scale relative to the size of the market. If the minimum efficient scale is large relative to market size, then there will not be many cost-efficient market participating firms, and the industry concentration will be high. Market expansion allows the attraction of new viable effective players, which drives concentration downwards, *ceteris paribus*.

The Industrial Organization literature has been concerned with the economic impacts of market structure since its early stages. One of the most prominent frameworks was Structure-Conduct-Performance (SCP), which was mainly concerned with the one-way causation relationship between market structure (industry concentration, for example), the conduct of firms, and market performance (profitability, for example).[8] In essence, the SCP paradigm considers higher concentration in a market a source of higher prices and profits by the established firms, as it allows for less competition. However, as Schmalensee (1989), Bresnahan (1989) and Evans et al. (1993) discuss, the SCP tradition typically considers market structure as exogenous and therefore provides no insights into its key drivers apart from the basic market conditions derived from the neoclassical theory of the firm, such as the nature of the product, the available technology and market size. In an opposite direction of the SCP framework, Demsetz (1973) observed that market concentration might be caused by superior firm performance. The Demsetz critique therefore suggests an inverse concentration-competition relationship, in which the most efficient and profitable firms would be able to achieve higher participation in the market, and consequently, the concentration of firms in the industry would soar. The important consequence of such a reverse causality issue is the introduction of elements of endogeneity in the relationship between market structure and performance in the analysis.

In accordance with the Demsetz critique, the literature has investigated how the strategic behavior of established firms may limit competition and the potential for entry. It has done so first, with the entry deterrence models in which the possibility of a post-entry predatory price war produces a reputation for toughness of incumbents - Kreps and Wilson (1982), Milgrom and Roberts (1982); second, with the capacity commitment framework of Spence (1977) and Dixit (1979), in which excess capacity is used as an effective tool for deterring entry; and third, with the case of contracts as a barrier to entry - Aghion and Bolton

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

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

[7] See Panzar (1989) for a presentation of the neoclassical theory of the firm.

[8] See Schmalensee (1989).

(1987), who investigate whether optimal contracts between buyers and sellers could be an effective method for impeding newcomers' entry. The literature has also considered exclusive contracts as a means to raising rivals' costs and undermining their ability to compete - Salop and Scheffman (1983) and Krattenmaker and Salop (1986). Bresnahan and Levin (2012) state that, differently from the SCP paradigm, the traditional relationship between market size and market concentration may not be straightforward in the situation of strategic investments by incumbents.

Another important strand of the literature that is consistent with the Demsetz critique is the endogenous sunk costs framework of Sutton (1991, 1998). In his framework, one could observe a negative relation between market size and market concentration only in markets characterized by exogenous sunk cost, that is, the "Type 1 industries". If we assume that firms intensively engage in endogenous sunk costs - the "Type 2 industries", in which firms invest in advertising and R&D activities, among others - then market concentration is actually increased by market expansion. The positive relation between market size and market concentration is driven by the fact that market expansion in this case stimulates the largest firms to intensify their investments in the endogenous sunk costs, which in turn makes smaller firms unviable and inhibits entry.

Cohen and Mazzeo (2004) study the relationship between market structure and product quality. They build upon Sutton's (1991) framework to model firms that use fixed costs to enhance the quality of their products to drive competitors out of the market, which ultimately increases market concentration. The authors assume endogenous quality choice, modeling firms that compare the costs of providing additional quality with consumers' willingness to pay for a higher quality product. Quality improvement could therefore make markets more concentrated if it makes entry more difficult or exit more likely.

2.2. Market concentration in airline studies and hypotheses

Several studies have investigated the effects of market concentration on prices in the airline industry - Borenstein (1989), Evans and Kessides (1993), Hofer et al. (2008), Oliveira and Huse (2009), among others. As far as we know, Leahy (1994) and Brueckner and Spiller (1994) are among the few papers in the literature that investigate both the consequences and the causes of market concentration. Leahy (1994) examines the change between 1979 and 1988 in the Herfindahl-Hirschman Index (HHI) of a cross-section of the top 150 city-pair 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 traffic density, measured by the number of city-pair passengers, as the key determinants of changes in concentration in the period. Brueckner and Spiller (1994) estimate a structural model of competition among US hub-and-spoke airlines to measure the strength of economies of traffic density on individual route segments. They find strong economies of density that justify market concentration in the industry.

As seen before, the neoclassical theory of the firm predicts that market concentration depends on the size of economies of scale relative to the size of the market. The classic study of Caves et al. (1984) has not found evidence supporting the existence of economies of scale in the US airline industry but has estimated statistically significant economies of 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 and 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 and 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 more passengers on the route is lower due to the higher traffic densities. We would therefore observe an economies-of-density effect in the positive association between market concentration and traffic density, as raised by Hypothesis $\mathbf{H_1}$ below, which we call the Brueckner-Spiller-Leahy hypothesis (Brueckner and Spiller, 1994; Leahy, 1994):

H1. Market concentration increases with market size due to economies of density.

It is important to note that the result dictated by $\mathbf{H_1}$ is not inconsistent with the framework of Sutton (1991, 1998). In fact, if the airline industry is marked by elements of the "Type 2 industries" of the author, then market expansion measured by traffic density growth may allow major airlines to intensively invest in endogenous sunk costs - for example, advertising, airport facilities, network development and frequent-flier programs. Therefore, a positive relation between market size and market concentration is also expected in markets with endogenous sunk costs.

Against $\mathbf{H_1}$, we have the possible entry attraction effect of market size growth. In fact, in the absence of significant entry barriers, an amplified market size may attract more competitors to the industry. If the competitive advantage that is allowed by economies of traffic density is not considerable, i.e., a situation of weak economies of density, then traffic growth may ultimately enhance the economic viability of operations of a higher number of carriers. This can also be the case if the airline industry is consistent with the "Type 1 industries" of Sutton (1991, 1998), in which only exogenous sunk costs prevail. In both cases, an inverse relationship between market size and market structure will likely arise, and thus, we expect a negative association between traffic density and market concentration.

Note that because the economies-of-density effect and the entry-attraction effect of market size have opposing impacts on market concentration, being negative and positive, respectively, the ultimate impact 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. Note that we stress the endogeneity issue in the relationship between concentration and traffic density, which is consistent with the Demsetz critique of the SCP paradigm: a higher density may provoke a higher (lower) concentration due to economies of density, but a higher (lower) concentration may allow for higher (lower) prices, which in turn decreases (increases) demand and traffic density. This endogenous relationship was not addressed by either Leahy (1994) or Brueckner and Spiller (1994).

Our second hypothesis is associated with the network management of airlines regarding scheduling, in particular the setup of flight frequencies:

H2. Market concentration increases with flight frequency concentration and airport congestion.

Consistent with Cohen and Mazzeo (2004), we investigate whether a positive relationship between market structure and product quality may emerge in airline markets if major carriers amplify their flights portfolio in such a way as to dominate the most-desired departure and landing hours. Flight frequency dominance in peak hours by passengers may enhance the perceived quality of larger carriers and give them a competitive advantage over smaller carriers due to vertical product differentiation - Brueckner (2010).[9] Additionally, the dominance of flights at the airport level may allow major carriers to better engage in the internalization of delays of their own flights (Brueckner, 2002; Mayer and Sinai, 2003; Bendinelli et al., 2016) and thus to enhance their perceived service quality. Finally, and consistent with the Spence's (1977) and Dixit's (1979) theories of strategic excess capacity, the

[9] Brueckner (2010) shows that transport providers compete on both price and 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 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.

additional flights may result in congested hours at the airports, which can also result in higher concentration due to blockaded entry in highly demanded peak-hour flights.[10] We therefore expect a positive relationship between the concentration of flight frequencies by a few dominant carriers - when examined at both the route and airport levels - with airport congestion and market concentration. Although $\mathbf{H_2}$ may be regarded as very intuitive and expected *ex-ante*, the *ceteris paribus* effects of both flight frequency concentration and airport congestion on market concentration, isolated from the effects of market size, have not been tested before in the literature. The consideration of hypothesis $\mathbf{H_2}$ therefore provides a way of examining and formally testing the isolated impacts of product quality and excess capacity on market structure caused by the strategic investment in capacity in the airline industry, i.e., the hypotheses of, respectively, Cohen and Mazzeo (2004) and Spence-Dixit (Spence, 1977; Dixit, 1979).

An important issue in our econometric setting is airport privatization and its relation to market concentration in airline markets. Fu et al. (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. Our final hypothesis is therefore the following:

H3. Airport privatization produces an increase in market concentration due to the formation of vertical relationships between the new airport administration and the dominant airlines.

As discussed before, the classic studies of Salop and Scheffman (1983), Krattenmaker and Salop (1986) and Aghion and Bolton (1987) suggest that exclusive contracts may be a source of entry prevention and, ultimately, of market concentration. Bettini and Oliveira (2016) investigate the impacts of airport privatization and the possibility of airline expectation formation regarding possible long-term contracting with recently privatized airports, in the sense of Aghion and Bolton (1987). Such long-term contracting may be accomplished not necessarily by formal contracts, as in Barbot et al. (2013) and D'Alfonso and Nastasi (2014), but also by solid vertical airline-airport relationships that result in control over the airport bureaucracy and scarce facilities by major carriers - Berry (1992); Evans and Kessides (1993), Dresner et al. (2002), Ciliberto and Williams (2010). With Hypothesis $\mathbf{H_3}$, 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. Episodes of airport privatization may, in this case, constitute "quasi-natural experiments" in which the researcher is able to dissociate the effect of flight frequency dominance on market concentration ($\mathbf{H_2}$) from the vertical relationship effect ($\mathbf{H_3}$).

3. Research design

3.1. Application

We develop an empirical model to investigate the determinants of market concentration and to test the raised hypotheses, $\mathbf{H_1}$, $\mathbf{H_2}$ and $\mathbf{H_3}$. We consider the case of the Brazilian air transportation industry as an application. Table 1 presents some statistics on the evolution of this market since 2002.

The Brazilian airline market has experienced rapid 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 in 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.[11] 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 airport 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, a figure that drops to 1.5% if we consider Gol's 2013 operations.

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, 2011) and of the small, regional Pantanal airlines by TAM (2010). Additionally, after years of discussions, the government launched a privatization plan on May 31, 2011, to alleviate airport congestion, induce investments and expand the airport system. The first round of privatization included two airports 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 monthly and that are composed of routes that involve the 26 state capitols and the country's capitol. 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, which are publicly available from the airline regulator, the National Civil Aviation Agency (ANAC), comprise the Active Scheduled Flight Report (VRA) and the Air Transportation Market Statistical Database - Monthly Traffic Report.

[10] The literature has suggested that not only is airport congestion 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 et al. (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 and Williams (2010) find that the control of gates is a crucial determinant of hub premium.

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

Table 1
Airline market concentration evolution in Brazil.

Year	Domestic pax (million)	Industry & market concentration				
		CR2 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.

3.3. Econometric model

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

$$\begin{aligned}\text{lgcity}-\text{pair pax concentration}_{kt} = {} & \beta_1\text{daily pax}_{kt} + \beta_2\text{daily pax squared}_{kt}\\ & + \beta_3\text{prop flight congested hours}_{kt}\\ & + \beta_4\text{codeshare between majors}_{kt}\\ & + \beta_5\text{merger}_{kt}\\ & + \beta_6\text{LCC entry at primary airport}_{kt}\\ & + \beta_7\text{LCC entry at}|\text{secondary airport}_{kt}\\ & + \beta_8\text{lgcity}-\text{pair flights HHI}_{kt}\\ & + \beta_9\text{lgcity flights HHI}_{kt}\\ & + \beta_{10}\text{privatized airports}_{\text{kt}} + \gamma_k + \gamma_t + u_{kt},\end{aligned} \tag{1}$$

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

- lg*citypair pax concentration*$_{kt}$ is the logit transformation of the Herfindahl-Hirschman index (HHI) of passengers on the route. In our context, having a concentration index on the right-hand side of the equation involves some econometric complications, as it is a limited dependent variable (LDV) confined to the interval $\left(\frac{1}{N}, 1\right)$, where N is the number of airlines. With an LDV, a linear regression would generate predictions of HHI that could lie outside the interval between the theoretical lower and upper bounds of the index. According to Heiberger and Holland (2009), when the assumption that the dependent variable is continuous on the infinite interval $(-\infty, \infty)$ is not met in a regression model, one alternative is to use a suitable transformation to change its range - a link function, such as the logit transformation.[12] Spiller (1983), Greenfield (2014), and Bendinelli et al. (2016) also employ logit transformation models applied to the airline industry. The logit transformation maps the original bounded variable to the real line and therefore allows for employing the usual regression methods. Additionally, because it is derived from a probability model, it allows for a probabilistic approach to the HHI as an indicator of the propensity of any market participant acquiring market power, as modeled by Kanagala et al. (2004).[13] In our case, to extract the concentration measure, we consider the city-pair level market shares of revenue passengers of the participating carriers. Source: National Civil Aviation Agency, Air Transportation Market Statistical Database - Monthly Traffic Report, with own calculations.
- *daily pax*$_{kt}$ is the average number of daily revenue passengers on the route, which is our measure of city-pair traffic density and is used to test Hypothesis **H$_1$**. Source: National Civil Aviation Agency, Air Transportation Market Statistical Database - Monthly Traffic Report, with own calculations.
- *daily pax squared*$_{kt}$, the quadratic term of *daily pax*$_{kt}$, in which we allow for a concavity in the relation between market size and market concentration. We therefore inspect whether a point of inflection occurs after a given magnitude of traffic density.[14] For example, it may be that low-density markets have a negative relation between market concentration and route density, whereas a positive relation emerges in high-density markets. The justifications for such behavior may be that economies of density become stronger as market size increases, or that Sutton's Type 2 industries are more predominant in denser route markets, or both.[15]
- *prop flight congested hours*$_{kt}$ is the proportion of daily scheduled flights operated during congested hours on the route. Our definition of a "congested hour" is 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). We use this variable, among others below, to test Hypothesis **H$_2$**.[16]
- *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 operations between March 2003 and April 2005. Source: Secretariat for Economic Monitoring (SEAE) of the Ministry of Finance.
- *merger*$_{kt}$ is a dummy variable to account for the effects of the most significant merger episode in the sample period, Gol's acquisition of Varig (2007). This variable is assigned a value of 1 for every route in which the acquired airline had a presence at the time of the merger announcement, from that period to the end of the sample period. Source: National Civil Aviation Agency, Active Scheduled Flight Report (VRA Report), with own calculations.
- *LCC entry at 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 1 for routes in which Gol was present until mid-

[12] An alternative approach would be to treat the dependent variable as a censored continuous variable and employ a two-limit Tobit model. Baum (2008) suggests that a censored regression would not be an appropriate strategy when using proportion-dependent variables, as values outside their expected interval are not censored but are actually infeasible.

[13] One drawback of the logit transformation of the HHI is that we cannot use observations where a monopoly is present. In our sample, only a few city-pairs between two state capitals were dominated by an airline monopoly. These observations were discarded.

[14] We experimented with other non-linear specifications of the *daily pax* variable - using ln *daily pax* alone and combined with $(\text{lndaily}\square\text{pax})^2$ - and chose the quadratic function based on the mean absolute percentage forecast error (MAPE) calculated when 25% of the sample was discarded to allow for out-of-sample forecasts.

[15] We are unable to disentangle the effects of these theoretical considerations, however.

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

Table 2
Descriptive statistics - variables of the empirical model.

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

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 at 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.
- lg*citypair flights concentration*$_{kt}$ is the logit transformation of the Herfindahl-Hirschman index of direct flight frequencies calculated at the route level. To be consistent with the setup of the dependent variable, we applied the logit transformation (lg) to this variable. This variable is used to test Hypothesis H_2. Source: National Civil Aviation Agency, Active Scheduled Flight Report - VRA, with own calculations.
- lg*city flights concentration*$_{kt}$ is the logit transformation of the geometric mean of the origin and destination of the Herfindahl-Hirschman indexes of direct flight frequencies calculated at the city level. As with the above HHI variables, we also employed the logit transformation (lg) to this variable. It is also used to test Hypothesis H_2. 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). This variable is used to test Hypothesis H_3. 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; and u_{kt} is the associated error term. The two-way fixed effects estimation procedure, particularly the time effects, are useful to account for the unobserved time-evolving effects that are common to all routes in the sample. It therefore aims at controlling for potentially confounding factors, such as the nationwide impacts of governmental policy - taxation, overall aspects of airport and air traffic control regulation, etc. - and airline strategic behavior across the country, which may affect both dependent and independent variables.

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

3.4. Estimation strategy

3.4.1. Endogeneity and instrumental variables

We acknowledge the reverse causality issues of our empirical framework, as traffic density and flight frequency may increase as a result of increased market concentration. We therefore treat *daily pax*, *daily pax squared*, lg*city-pair flights concentration* and lg*city flights concentration* as endogenous variables. In one setting, we also consider *LCC entry at primary airport*$_{kt}$ and *LCC entry at secondary airport*$_{kt}$ as endogenous to address the fact that market concentration may hinder or, in some cases, attract LCC entry, as in Boguslaski et al. (2004).[17] We therefore employ an instrumental variables estimator to account for these endogenous regressors in our empirical framework. 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. We therefore utilize the following values: *gdp*$_{kt}$, the gross domestic product (GDP) of the origin and destination cities of route k at time t; *population*$_{kt}$, the populations (in millions) of the origin and destination cities of route k at time t; and *unemployment*$_{kt}$, the unemployment rate of the origin and destination states of the cities of route k at 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. Because *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).[18] The employed Hausman instrumentation is similar to that of Piga and Bachis (2006), Mumbower et al. (2014) and Bendinelli et al. (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 and twelve lags. We utilized a proxy for the fuel costs incurred by carriers on a route-level basis[19] to construct the Hausman instrument set, as the price formation of jet fuel has a strong national-level component. We also utilized the concentration of flights during

[17] The authors find a positive association between the entry of Southwest Airlines in the US market and market concentration. They explain their results by suggesting that the higher concentration may indicate less competition and higher operating margins, which is viewed by the LCC as a signal for larger potential gains from entry. We thank an anonymous reviewer for suggesting that entry may be endogenous.

[18] Lag of twelve months.

[19] This instrumental variable is calculated as 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 on aircraft type assignment of scheduled flights for each domestic airport-pair of the sample.

congested hours with twelve lags in our Hausman approach. 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 overidentifying conditions and Kleibergen-Paap rk LM under identification 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 Identification CD and Weak Identification KP). We present the results of all of the above tests at 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.

3.4.2. Estimation

The method employed to estimate Equation (1) is the two-step feasible efficient generalized method of moments estimator (2SGMM), with standard errors that are efficient and robust 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.[20]

4. Results

Tables 3 and 4 present the estimation results of our empirical model. In Table 3, Column (1), we have the results of the specification without the privatization dummies. Columns (2) through (9) of that table present the results of a set of robustness checks. The estimated results of Table 2 allow an analysis of the statistical tests of our first two hypotheses. The first hypothesis, $\mathbf{H_1}$, states that market concentration increases with market size due to economies of density. The estimated coefficients of *daily pax* and *daily pax squared* were both statistically significant and indicated a negative relation between concentration and *daily pax* for most of the sample 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 138 out of 17,354 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. For all 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. Therefore, the evidence obtained from our empirical model that market concentration and traffic density have a *ceteris paribus* negative association suggests that the market size effect surpassed the effect of the economies of density in the Brazilian case study. As an alternative interpretation, we have evidence that the airline industry in the country resembles the “Type 1 industry” of Sutton (1991, 1998), but we acknowledge that the most important route in the country may provide evidence in favor of the endogenous sunk costs theory.

The second hypothesis, $\mathbf{H_2}$, posited that market concentration is amplified by flight frequency concentration and airport congestion. This hypothesis was motivated by the suggestion of a positive relationship between market structure and product quality of Cohen and Mazzeo (2004) and by the theories of strategic excess capacity of Spence (1977) and Dixit (1979). Our empirical results provide evidence for both strands of the Industrial Organization literature, as we estimate that the coefficients of lg*citypair flights concentration*, lg*city flights concentration* and *prop flight congested hours* were positive and statistically significant. The results in Column (1) confirm $\mathbf{H_2}$ and, thereby, the relevance of the dominance of airline capacity at both the route and airport levels as a key driver of market concentration in the air travel markets. This result is also consistent with the literature on the competitive advantage of dominant carriers at airports - Borenstein (1989), Evans and Kessides (1993), Hofer et al. (2008), Ciliberto and Williams (2010), and Bilotkach and Lakew (2014). It is also consistent with Brueckner's (2010) model of vertical product differentiation, which also implies that flight frequency concentration on the route raises market concentration.

The remaining estimation results of Table 3, Column (1), allow for further analysis of the evolution of the city-pair market concentration in the sample period. With respect to the effect of the entry of low-cost carriers (LCC) on market concentration, we had mixed results with the variables *LCC entry at primary airport* and *LCC entry at secondary airport*. Whereas the entry of an 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 an LCC that mainly operates at secondary airports - Azul airlines since the late 2000s - was not significant. These results imply that LCC entry may not provoke declines in market concentration unless it is materialized at primary airports. 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. The merger episode of Gol's acquisition of Varig in the second half of the 2000s also had a statistically significant impact. These results confirm the common sense view that concentration is driven by consolidations and alliances engaged by effective players in the market.

4.1. Robustness checks

We implemented a series of experiments to assess the robustness of the results of Table 3, Column (1). We present the results of these experiments in Columns (2) through (7). First, in Column (2), we utilize an alternative, non-HHI-based, measure of flight concentration: a Two-Firm Concentration Ratio measure (CR_2).[21] Second, in Column (3), we include the variables *LCC entry at primary airport*$_{kt}$ and *LCC entry at secondary airport*$_{kt}$ among the endogenous regressors list to address the fact that entry and market concentration may be simultaneously determined or at least that the motivation for entry may be correlated with the unobserved determinants of market concentration.[22] Thirdly, in Columns (4), (5) and (6) of Table 3, we drop some the key regressors of the model of Column (1) to analyze the resulting changes in the estimates of the remaining regressors. We therefore experiment with the discarding of the variables *daily pax squared* in Column (4), lg*city flights concentration* in Column (5), and lg*citypair flights concentration* in Column (6). As a fourth and final experiment, we insert two additional regressors to account for the possible effects of hub dominance and airport regulation in the period: the variables *hub airport* and *slot regulation introduction*. The first is a dummy variable assigned with value one if any of the endpoint cities operated more than fifty percent of passenger flight connections and if the network carrier TAM is present in the market. The second is the concentration (HHI) of flight frequencies at congested hours for routes from/to São Paulo/Congonhas Airport (CGH) after the introduction of a new slots regulation in July 2006.[23] With this experiment, we test whether the presence of a major hub carrier in a given route market and whether the major airport

[20] We utilized the Bartlett kernel function with a bandwidth of round$(T^{1/4})$, where $T = 144$, as recommended by Baum et al. (2007).

[21] We thank an anonymous reviewer for suggesting that experiment.

[22] See the discussion of the utilized instrumental variables in 3.5.

[23] This variable is therefore constituted by the interaction of flights HHI at congested hours of CGH routes with a dummy variable of São Paulo being one of the endpoint cities. The source of both additional regressors in this experiment is the National Civil Aviation Agency, Active Scheduled Flight Report - VRA, with own calculations. We thank an anonymous reviewer for suggesting the insertion of variables.

Table 3
Estimation results and robustness checks - dependent variable: lg city-pair pax concentration.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
daily pax (*endogenous*)	−0.2672***	−0.2365***	−0.2707***	−0.1219**	−0.2665***	−0.7268***	−0.1279***
daily pax squared (*endogenous*)	0.0193***	0.0100***	0.0202***		0.0169***	0.0413***	0.0101***
prop flight congested hours	0.1493***	−0.0315	0.1775***	0.0882**	0.1051***	0.0777*	0.1720***
codeshare between majors	0.1601***	0.1607***	0.1623***	0.1671***	0.1869***	0.1851***	0.1654***
merger	0.2020***	0.3354***	0.1764***	0.2599***	0.2203***	0.6075***	0.1186***
LCC entry - primary airport (*endogenous* in (3))	−0.1411***	−0.0906**	−0.3236***	−0.1181***	−0.1646***	−0.2491***	−0.1083***
LCC entry - secondary airport (*endogenous* in (3))	−0.0236	−0.1185***	−0.0485	−0.0604*	−0.0164	−0.1597***	0.0004
city-pair flights concentration (*endogenous*)	0.7143***	0.0204**	0.8267***	0.6098***	0.6737***		0.8778***
city flights concentration (*endogenous*)	0.5331***	0.3978***	0.6472***	0.6609***		1.3452***	0.6138***
hub airport							0.1010**
slot regulation introduction							0.0215
flights concentration measure	*HHI*	*CR2*	*HHI*	*HHI*	*HHI*	*HHI*	*HHI*
fixed effects	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*
Adjusted R-squared	0.5442	0.5421	0.5442	0.5428	0.5319	0.4510	0.5448
RMSE statistic	0.3532	0.2960	0.3532	0.3538	0.3580	0.3877	0.3530
F statistic	62.800	45.056	62.800	62.626	59.983	43.643	62.571
Minimum F statistic 1st stage	17.326	71.091	21.887	44.482	68.876	26.532	24.382
KP statistic	32.6764	70.7972	78.0074	42.2214	161.6381	42.6830	74.2820
Hansen J statistic	2.2581	11.4689	5.7038	0.3644	1.7033	1.9197	4.2923
Weak identification CD statistic	11.9147	10.9625	16.5393	18.2536	47.6224	16.1012	21.4823
Weak identification KP statistic	3.7661	5.1852	5.8640	7.2492	24.6528	8.7677	7.5568
Number of observations	17,354	12,446	17,354	17,493	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 and autocorrelation; R-squared and RMSE produced by a least-squares dummy variable model (LSDV) with identical specification; p-value representations: ***p < .01, **p < .05, *p < .10.

Table 4
Estimation results and further evidence - estimation results - dependent variable: lg city-pair pax concentration.

	(1)	(2)	(3)	(4)	(5)	(6)
daily pax (*endogenous*)	−0.2435***	−0.2074***	−0.1763***	−0.2128***	−0.2212***	−0.1851***
daily pax squared (*endogenous*)	0.0159***	0.0142***	0.0125***	0.0146***	0.0150***	0.0126***
prop flight congested hours	0.1677***	0.1615***	0.1782***	0.1596***	0.1616***	0.1588***
codeshare between majors	0.1525***	0.1465***	0.1360***	0.1498***	0.1466***	0.1470***
merger	0.1291***	0.1179***	0.0923***	0.1281***	0.1320***	0.1117***
LCC entry - primary airport	−0.1270***	−0.1051***	−0.1057***	−0.1016***	−0.1056***	−0.1052***
LCC entry - secondary airport	0.0490	0.0476**	0.0588**	0.0442*	0.0415*	0.0484*
city-pair flights concentration (*endogenous*)	0.9074***	0.9445***	1.0006***	0.9384***	0.9185***	0.9462***
city flights concentration (*endogenous*)	0.6018***	0.5326***	0.6133***	0.5528***	0.4936***	0.4652***
hub airport	0.1074**	0.1035***	0.1258***	0.0845**	0.0825**	0.0941**
slot regulation introduction	0.0178	0.0192	0.0250	0.0208	0.0160	0.0102
privatized airports	0.1229***	0.1097***	0.1831***	0.0412	0.1843***	0.1069***
privatized & placebo privatized airports			−0.1092***	0.1435***	−0.1073***	−0.1541***
inverse Mills ratio		−0.0044***	−0.0048***	−0.0054***	−0.0049***	−0.0046***
flights concentration measure	*HHI*	*HHI*	*HHI*	*HHI*	*HHI*	*HHI*
fixed effects	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*	*two-way*
placebo assignment rule	*n/a*	*n/a*	*investment*	*sequence*	*growth*	*mega-event*
Adjusted R-squared	0.5449	0.5454	0.5458	0.5466	0.5464	0.5455
RMSE statistic	0.3529	0.3528	0.3526	0.3523	0.3524	0.3527
F statistic	62.427	62.355	62.271	62.483	62.433	62.196
Minimum F statistic 1st stage	19.757	27.823	27.206	27.730	25.403	29.441
KP statistic	57.8724	136.0590	127.0479	137.5246	120.1424	144.0848
Hansen J statistic	9.5210	6.9221	5.1248	5.7755	7.8346	9.3570
Weak identification CD statistic	14.8622	13.0510	12.1794	13.0920	11.8647	13.7049
Weak identification KP statistic	4.7966	12.6343	11.8191	12.7529	11.0939	13.3547
Number of observations	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); R-squared and RMSE produced by a least-squares dummy variable model (LSDV) with identical specification; Column (1) - statistics robust to heteroscedasticity and autocorrelation; p-value representations: ***p < .01, **p < .05, *p < .1. Columns (2)–(6) - statistics robust to heteroscedasticity; standard errors of the estimated coefficients were bootstrapped using a stratified bootstrapping procedure to account for the two-step nature of the Heckit method; see the Appendix for the first step estimates and further details.

regulatory change implied by the introduction of the new slots regulation would affect market concentration and change the results of Column (1), Table 3. The results of all four robustness checks clearly indicate that the estimates of Column (1) are not affected by the proposed specification changes of Columns (2)–(7).

4.2. Estimated effects of airport privatization

Table 4 presents the estimation results considering the effects of airport privatization on market concentration, i.e., including the *privatized airports* variable of Equation (1). Column (1) of Table 4 presents the results of the baseline model. The estimated coefficient *privatized airports* is positive and statistically significant, thus confirming Hypothesis H_3, which states that airport privatization may induce increases in market concentration through the formation of vertical relationships between the new airport administration and the dominant airlines, as suggested in Dresner et al. (2002), Ciliberto & Williams, (2010), Barbot (2011) and Bettini and Oliveira (2016).

As with Table 3, in Table 4, we present the results of a sequence of robustness checks to challenge the results of the baseline model in Column (1). The first experiment is to acknowledge 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. The results are displayed in Column (2). With the Heckit framework, a selection decision equation is first estimated using a random-effects probit model, and in a second step, 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 the Appendix. The estimation results of the second-step of the Heckit model are presented in Column (5) of Table 4. 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. Additionally, note that the results from the control of sample selectivity do not alter the main results that are obtained in Column (1) of Table 4.

The second challenge of the main empirical results we develop is to implement 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 - Columns (3) to (6). 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 a value of 1 if any of their endpoint airports are found to be similar to 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 we refer to as the “investment” rule. Based on that rule, we obtained a set of airports that are not privatized but are subject to the investments of the 2010–2014 restructuring program that was accomplished by the government.[24] Other routes that were not classified into the actually privatized or the placebo privatized groups 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 (3) of Table 4. Because 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 (3) 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* positive effect of market concentration that was above the effect of the control group. Actually, because 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 (3) of Table 4, we utilized the following alternative rules: a “sequence” rule (Column 4), which utilizes airports that are eventually privatized or assigned to be privatized after the end of the sample period[25]; a “growth” rule (Column 5), with airports with similar growth perspectives[26]; and a “mega-event” rule (Column 6), with airports of the cities that hosted the 2014 World Cup matches.[27] The results of all implemented specifications were robust to the utilization of the alternative placebo assignment rules and thus generated evidence that confirmed the validity of Hypothesis $\mathbf{H_3}$ in our application.

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 market size, e.g., the Brueckner-Spiller-Leahy hypothesis, as in Leahy (1994) and Brueckner and Spiller (1994), and 2., the association of market concentration and strategic service quality/capacity as in Cohen and Mazzeo (2004), Spence (1977) and Dixit (1979). Consistently with the Demsetz critique of the Structure-Conduct-Performance paradigm, 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 vertical airline-airport relationships that emerged after airport privatization.

Our empirical results provide evidence that, as traffic density increases, the entry-attraction effect of market size more than compensates for the economies-of-density effect, which produces a negative relationship between market size and market concentration. The results are also consistent with the interpretation that airline markets in the sample may behave like the “Type 1 industries” of Sutton (1991, 1998), in which only exogenous sunk costs prevail. In contrast, we find that the vertical product differentiation created by the strategic investment in capacity by dominant carriers is a key driver of concentration in the airline industry. Finally, we have strong evidence supporting the hypothesis that airport privatization produces an intensification of the vertical relationships between the airport and the dominant airlines that results in higher concentration in the market. These results are relevant from the theoretical perspective of understanding market organization in the airline industry. They also support the notion that a regulatory setup in which dominant carriers are forced to divest slots at key airports to LCCs as part of a merger process is likely to produce higher long-run competition in the associated airline markets.

Acknowledgements

The authors wish to thank the São Paulo Research Foundation (FAPESP) - grants n. 2013/14914-4 and 2015-19444-1; the National Council for Scientific and Technological Development (CNPq) - grant n. 301654/2013-1; and CAPES Institutional Postgraduate degree funding. They also wish to thank Humberto Bettini, Cláudio Jorge P. Alves, Carlos Müller, Rogéria Arantes, Jessica Frazão, two anonymous reviewers, the editor, and the participants of the 10th Symposium on Transport Economics, 2015. All of the mistakes are ours.

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

[25] 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 the cities of Porto Alegre, Salvador, Florianópolis and Fortaleza.

[26] 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 the cities of Vitória, Uberlândia, Cuiabá, João Pessoa, Teresina, São Luiz, Foz do Iguaçu and Campo Grande.

[27] 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.

Appendix. First-step of the Heckit procedure

Our specification of the first-step probit model uses *privatizedairports* as the regress and 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 step of the Heckit correction model, we utilized a stratified bootstrap procedure[28] 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-step regression of the Heckit model.

Table 5 – Estimation results – dependent variable: selected for privatization.

	(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

Notes: Results produced by a random-effects probit regression; p-value representations: ***p < .01, **p < .05, *p < .10.

References

Aghion, P., Bolton, P., 1987. Contracts as a barrier to entry. Am. Econ. Rev. 388–401.
Ater, I., 2012. Internalization of congestion at US hub airports. J. Urban Econ. 72 (2), 196–209.
Barbot, C., 2011. Vertical contracts between airports and airlines is there a trade-off between welfare and competitiveness? J. Transport Econ. Pol. 45 (2), 277–302.
Barbot, C., D'Alfonso, T., Malighetti, P., Redondi, R., 2013. Vertical collusion between airports and airlines: an empirical test for the European case. Transport. Res. E Logist. Transport. Rev. 57, 3–15.
Baum, C.F., 2008. Stata tip 63: modeling proportions. Stata Journal 8 (2), 299.
Baum, C.F., Schaffer, M.E., Stillman, S., 2007. Enhanced routines for instrumental variables/GMM estimation and testing. Stata Journal 7 (4), 465–506.
Bendinelli, W.E., Bettini, H.F., Oliveira, A.V., 2016. Airline delays, congestion internalization and non-price spillover effects of low cost carrier entry. Transport. Res. Pol. Pract. 85, 39–52.
Berry, S.T., 1992. Estimation of a Model of Entry in the Airline Industry. Econometrica: Journal of the Econometric Society,, pp. 889–917.
Bettini, H., Oliveira, A.V., 2016. Two-sided platforms in airport privatization. Transport. Res. E Logist. Transport. Rev. 93, 262–278.
Bilotkach, V., 2011. Multimarket contact and intensity of competition: evidence from an airline merger. Rev. Ind. Organ. 38 (1), 95–115.
Bilotkach, V., Lakew, P.A., 2014. On sources of market power in the airline industry: panel data evidence from the US airports. Transport. Res. Pol. Pract. 59, 288–305.
Boguslaski, C., Ito, H., Lee, D., 2004. Entry patterns in the southwest airlines route system. Rev. Ind. Organ. 25 (3), 317–350.
Borenstein, S., 1989. Hubs and high fares: dominance and market power in the US airline industry. RAND J. Econ. 344–365.
Bresnahan, T.F., 1989. Empirical studies of industries with market power. Handb. Ind. Organ. 2, 1011–1057.
Bresnahan, T.F., Levin, J.D., 2012. Vertical Integration and Market Structure (No. w17889). National Bureau of Economic Research.
Brueckner, J.K., 2002. Airport congestion when carriers have market power. Am. Econ. Rev. 92 (5), 1357–1375.
Brueckner, J.K., 2010. Schedule competition revisited. J. Transport Econ. Pol. 44 (3), 261–285.
Brueckner, J.K., Spiller, P.T., 1994. Economies of traffic density in the deregulated airline industry. J. Law Econ. 379–415.
Brueckner, J.K., Lee, D., Singer, E.S., 2013. Airline competition and domestic US airfares: a comprehensive reappraisal. Economics of Transportation 2 (1), 1–17.
Caves, D.W., Christensen, L.R., Tretheway, M.W., 1984. Economies of density versus economies of scale: why trunk and local service airline costs differ. RAND J. Econ. 471–489.
Ciliberto, F., Williams, J.W., 2010. Limited access to airport facilities and market power in the airline industry. J. Law Econ. 53 (3), 467–495.
Cohen, A.M., Mazzeo, M.J., 2004. Competition, Product Differentiation and Quality Provision: an Empirical Equilibrium Analysis of Bank Branching Decisions. Finance and Economics Discussion Series, Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.
Demsetz, H., 1973. Industry structure, market rivalry, and public policy. J. Law Econ. 16 (1), 1–9.
Dixit, A., 1979. A model of duopoly suggesting a theory of entry barriers. J. Reprints Antitrust L. & Econ. 10, 399.
Dresner, M., Windle, R., Yao, Y., 2002. The impact of hub dominance and airport access on entry in the US airline industry. In: Traffic and Transportation Studies: Proceedings of the ICTTS, pp. 1430–1437.
D'alfonso, T., Nastasi, A., 2014. Airport–Airline interaction: some food for thought. Transport Rev. 34 (6), 730–748.
Evans, W.N., Kessides, I.N., 1993. Localized market power in the US airline industry. Rev. Econ. Stat. 66–75.
Evans, W.N., Froeb, L.M., Werden, G.J., 1993. Endogeneity in the concentration–price relationship: causes, consequences, and cures. J. Ind. Econ. 431–438.
Fu, X., Homsombat, W., Oum, T.H., 2011. Airport-airline vertical relationships, their effects and regulatory policy implications. J. Air Transport. Manag. 17 (6), 347–353.
Fu, X., Lijesen, M., Oum, T.H., 2006. An analysis of airport pricing and regulation in the presence of competition between full service airlines and low cost carriers. J. Transport Econ. Pol. 40 (3), 425–447.
Greenfield, D., 2014. Competition and service quality: new evidence from the airline industry. Economics of Transportation 3 (1), 80–89.
Hausman, J.A., 1996. Valuation of new goods under perfect and imperfect competition. In: Gordon, Robert J., Bresnahan, Timothy F. (Eds.), The Economics of New Goods. University of Chicago Press, Chicago, pp. 207–248.
Heiberger, R.M., Holland, B., 2009. Statistical Analysis and Data Display, 2nd ed. Springer, New York.
Hofer, C., Windle, R.J., Dresner, M.E., 2008. Price premiums and low cost carrier competition. Transport. Res. E Logist. Transport. Rev. 44 (5), 864–882.
Kanagala, A., Sahni, M., Sharma, S., Gou, B., Yu, J., 2004, October. A probabilistic approach of Hirschman-Herfindahl Index (HHI) to determine possibility of market power acquisition. In: Power Systems Conference and Exposition, 2004. IEEE PES, pp. 1277–1282 (IEEE).
Krattenmaker, T.G., Salop, S.C., 1986. Anticompetitive exclusion: raising rivals' costs to achieve power over price. Yale Law J. 96 (2), 209–293.
Kreps, D.M., Wilson, R., 1982. Reputation and imperfect information. J. Econ. Theor. 27 (2), 253–279.
Kwoka, J., Shumilkina, E., 2010. The price effect of eliminating potential competition: evidence from an airline merger. J. Ind. Econ. 58 (4), 767–793.
Leahy, A.S., 1994. Concentration in the US airline industry. International Journal of Transport Economics/Rivista Internazionale di Economia dei Trasporti 21 (2), 209–215.
Mayer, C., Sinai, T., 2003. Network effects, congestion externalities, and air traffic delays: or why not all delays are evil. Am. Econ. Rev. 93 (4), 1194–1215.

[28] We utilized the indicator of the sample routes as the strata variable.

Mazzeo, M.J., 2003. Competition and service quality in the US airline industry. Rev. Ind. Organ. 22 (4), 275–296.
Milgrom, P., Roberts, J., 1982. Predation, reputation, and entry deterrence. J. Econ. Theor. 27 (2), 280–312.
Morrison, S.A., 2001. Actual, adjacent, and potential competition estimating the full effect of Southwest Airlines. J. Transport Econ. Pol. 35 (2), 239–256.
Morrison, S., Winston, C., 1995. The Evolution of the Airline Industry. The Brookings Institution Press, Washington, D.C.
Mumbower, S., Garrow, L.A., Higgins, M.J., 2014. Estimating flight-level price elasticities using online airline data: a first step toward integrating pricing, demand, and revenue optimization. Transport. Res. Pol. Pract. 66, 196–212.
Oliveira, A.V., Huse, C., 2009. Localized competitive advantage and price reactions to entry: Full-service vs. low-cost airlines in recently liberalized emerging markets. Transport. Res. E Logist. Transport. Rev. 45 (2), 307–320.
Panzar, J.C., 1989. Technological determinants of firm and industry structure. Handb. Ind. Organ. 1, 3–59.
Piga, C., Bachis, E., 2006. Hub premium, airport dominance and market power in the European airline industry. Riv. Politic. Econ. 11–54. Sept-Oct.
Salop, S.C., Scheffman, D.T., 1983. Raising rivals' costs. Am. Econ. Rev. 73 (2), 267–271.
Schmalensee, R., 1989. Inter-industry studies of structure and performance. Handb. Ind. Organ. 2, 951–1009.
Spence, A.M., 1977. Entry, capacity, investment and oligopolistic pricing. Bell J. Econ. 534–544.
Spiller, P.T., 1983. The differential impact of airline regulation on individual firms and markets: an empirical analysis. J. Law Econ. 26 (3), 655–689.
Sutton, J., 1991. Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration. MIT press.
Sutton, J., 1998. Technology and Market Structure. MIT Press, Cambridge, MA.
Windle, R.J., Dresner, M.E., 1999. Competitive responses to low cost carrier entry. Transport. Res. E Logist. Transport. Rev. 35 (1), 59–75.