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Abstract

In the liberalized air transport where the demand for air tickets grows considerably, the authorities implement restrictive measures in some airports to congestion control. In the Brazilian context, due to tariff releases implemented in the early 2000s, the emergence of new airlines, the increased in competition that led to lower ticket prices and the economic improvement in this country, set off a large increase in demand for Brazilian air transport. This article aims to investigate the relationship between perimeter rules implemented in Congonhas Airport, central airport located in São Paulo - Brazil's largest city, and the dynamic impact on short, medium and long-haul flights over the 2000s. In particular, the endeavor is to verify how restrictive strategies imposed by airport management led to change in the network planning. The main conclusion is that the perimeter rules adopted led to a decrease in demand for flights in the short and long periods, especially on long-haul flights. In addition, the results showed that the aircraft size increased, especially in the long period, whereas there was no significant impact on the number of planned flights. Besides of that, we identified a reduction in the percentage of passengers in connection, mainly for long-haul flights, and a significant decrease in the proportion of short flights delays. In this sense, the contribution of this study is the empirical investigation of the impact of restrictive measures in airport planning through an econometric analysis.

Keywords: Airport capacity constraints, Airport congestion, Demand, Aircraft size, Flights frequency.

Introduction

The global air transport industry has grown significantly over the past few years. In the Brazilian context, the tariff releases implemented in the early 2000s, the emergence of new airlines, the increased in competition that led to lower ticket prices and the economic improvement in Brazil, set off a large increase in demand for Brazilian air transport. Nonetheless, most Brazilian airports had already showed evidence of operations near the limit of their capacities, such as São Paulo/Congonhas Airport (CGH). The imbalance between demand and capacity led to congestion problems, delays and cancellations of flights. This unfavorable context impacted on operation restrictions practices adopted by Congonhas' management airport.

According to some authors, the vast growth of air transport in the past and the perspective of its perpetuation in the long term led to the need to analyze the operational capabilities of major world airports. Gelhausen, Berster and Wilken (2013) affirm that there are many airports whose traffic's volume approaches their capacity limit only in certain peak hours, while other airports operate at high levels of capacity utilization over several hours of the day. Gelhausen, et al. (2013) aimed to investigate if the perimeter rules could be considered as a global air transport's problem in order to create barriers to demand growth in the future. The authors concluded that only 6% to 15% of global air transport operates near to its capabilities' limit. However, in the long term, considering the demand's growth, it is expected that this number will grow considerably.

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Takebayashi (2012) analyzed a multi-airport region considering airlines' behavior towards network features, passengers´ choice of route and the results of operational constraints. He inferred that the central airports - with capacity constraints - should operate only short-haul flights, while peripheral airports - with higher capacities - should take short and long duration flights.

In line with these researches, Forsyth (2007) studied the relationship between the demand's growth for air transport and the impact on airports, and how airport management must act, in the short and long term, to cope with the changes in the air transport industry. Thus, he noted that an increase in demand impacts on facilities that cannot be expanded in the short term. In this way, the slots' adoption is presented as a viable alternative in order to avoid congestion. In the long term, the infrastructure expansion's strategies are not always feasible due to environmental issues and government policies contrary to expansion. Other presented alternatives involve change in aircraft's profile, as well as, the increased use of secondary airports.

Madas and Zografos (2008) extended the results and analyzed the best slots allocations strategies in different settings airport and concluded that slots should be allocated according to the context of each airport. Jones, Viehoff and Marks (1993) investigated the problems of operational constraints at the Heathrow airport, as well as other European and North American airports. They showed some practices adopted for congestion control, such as different fares for passengers at peak and off-peak times as well as the management of slots through exchanges and negotiations between airlines or sales through auctions. Debbage (2002) analyzed the capacity constraints and its impact on United States (U.S.) and European Union (EU) tourism markets and concluded that the adoption of slots was feasible in that context.

Following this idea, the problem of this study corresponds to: What is the dynamic impact of the congestion control rules on airport regulation in view the case study from Congonhas Airport in the late 2000s, considering the setting of rise of the air transportation industry and high competition amongst companies on prices and frequency of flights?

The goal of this research is to achieve an empirical understanding of the impact of restrictive measures in airport planning through an econometric analysis. More specifically, the aim is to investigate the operational restrictions' effects imposed to Congonhas' airport in the latest 2000s on short, medium and long duration flights. It is intended to examine how these restrictions, applied over time by the Congonhas' airport management impacted the network planning, regarding the demand, the number of passengers per flight, aircraft size, number of passengers in connection and the proportion delayed and cancelled flights.

This paper was divided into four sections, followed by the conclusion and references. In the first section, the theoretical aspects of the problem are presented through a literature review and a conceptual model. The section 2 involves the development of empirical research model that detailed the sample, regression models and tests. The section 3 shows the obtained results and, then, section 4 presents the robustness' tests and research limitations.

1. Theoretical framework

Due to the growing demand for air transport, this sector has become a major challenge for the airport management congestion control at several airports worldwide. The authorities that face this scenario adopt different strategies to minimize the impact of demand growth in airports with limited infrastructure capacity. Thus, measures such as restriction of slots, different rates at peak and off-peak times and perimeter rules are implemented. It is known that these actions provide network planning changes and, for this reason, airlines restructure their business models to better serve their passengers.

Debbage (2002) analyzes the markets of the U.S. and EU as capacity constraints and reflections that the tourist industry. In this study they are highlighted major world airports that operate with perimeter rules, including London's Heathrow and Gatwick and New York´s JFK and La Guardia, with JKF-Heathrow considered the busiest route passenger gateway of US-based. This situation illustrates the binomial demand and capacity constraints settings of airport management and the impacts on airlines´ network planning.

1.1. Literature review

The growth in demand for global air transport in recent years and the major airports worldwide operations near the limit of their capabilities have arisen the interest of many researchers. In general, they seek to understand how this demand growth impacts or may impact in the long run in airport infrastructure.

Studies in this regard (GELHAUSEN; BERSTER; WILKEN, 2013) aim to understand what actions are needed in the short and long term, given the disparity between demand growth and capacity limited airport (FORSYTH, 2007). The studies also focus their analysis on multiple airports, in order to understand the best allocation of short and long haul flights in perimeter rules situations (TAKEBAYASHI, 2012) and investigate the best allocation of slots across the various types of airports (MADAS; ZOGRAFOS, 2008).

According Gelhausen et. al. (2013), it is expected that demand will continue to grow, but the current problem is the fact that many major world airports already operate with capacity constraints and this impacts on the airlines strategies. Based on several studies, the authors point out that some airlines, even before the strong growth in demand, could not increase the supply of services. Moreover, some airlines had to reschedule some flights to less congested airports nearby; ergo airports without considerable restrictions capacity demonstrated growth in demand for air transport. Hence, they showed possible strategies such as investment in new lanes, reorganization of traffic operations with better use of peak hours, diverte traffic to less congested airports, as well as the use of aircrafts with larger seating capacities, which may be adopted by those responsible for air traffic to support growing demand in the long run.

Also regarding the growth in demand and the airport infrastructure limitations, Forsyth (2007) presents actions that could be implemented in the short and long term. In the short term, he suggests, as an alternative to growing demand, the restriction for slots. According to him, the advantage of slots is their ability to improve demand management according to the available capacity, even though the slots are not always allocated efficiently as they should be. In the long run, Forsyth (2007) mentions the investment in additional capacity which is usually done by the government. In such cases, the author shows that it is necessary to identify the right investment, since the lack of investment can generate lower demand while high investments may be unnecessary. In addition, he presents the alternative to build new airports or expand secondary airports. He also reinforces the evidence of the new business models of low cost that, in order to achieve more market share, adopt strategies such as using airports with larger as well as cheaper capacities available. An additional aspect is the substitution of smaller aircraft by others with larger seating capacities to relieve the pressure on airports with heavy movements and operational constraints.

Takebayashi (2012) analyzed the management of the airport system and the short and long flights. According to this author, metropolitan areas are composed of two one smaller and more congested airport that is located close to major business centers and large airport that is located in a peripheral area. Takebayashi (2012) also considered aspects such as the airlines´ management of flights, as well as the profiles of passengers who seek for shorter travel times, lower travel costs, lower congestion, amongst other factors. Thus, it was possible to infer that the best approach is to operate only short-haul flights in an airport with capacity constraints located in the central region. Notwithstading, short and long-haul flights should be operated in the airport located in a peripheral area. Nonetheless, if the government does not act on setting guidelines for flights allocations, there will be a shift of the balance point. As a consequence, the central airport will operate with both types of flights and the peripheral with only short-haul flights, which will not be beneficial either for passengers or for airlines.

As a result of the congestion and delays at most airports in Europe and the United States, strong political pressure for an efficient demand management and the airport capacity's shortage, Madas and Zografos (2008) sought to evaluate the best strategies for slots allocation, considering the criteria and policy priorities in various airport settings. They also analyzed the applicability of these results in several airport configurations and their acceptance by regulatory agencies and other stakeholders involved. Lastly, they made recommendations for airport policy makers in in Europe. They showed that the political criteria and indicators are not the same for the different airport configurations. Hence, the allocation of slots must be adapted to the context of each airport.

Following this perspective, Jones, Viehoff and Marks (1993) studied the the growing demand and capacity constraints of the Heathrow airport. They documented the European airline deregulation history. Hence, the authors showed that there are clear opportunities to improve the efficiency of airport capacity in order to stimulate more intense competition amongst the airlines. Jones et al. (1993) also surveyed current practices slots allocation and concluded that the combination of price reform - posted near the equilibrium level of the market - with more extensive negotiations regarding the formal property rights in slots can effectively improve competition amongst airlines in a deregulated market.

Debbage (2002) analyzed the U.S. and European Union markets airport capacity constraints and their reflections in the tourist industry. The results showed that the lack of runway slots, airspace congestion and insufficient terminal capacity are impacting factors in international tourism, including airports such as Heathrow and JFK. According to her, many of the world's largest airports suffer from inadequate runway capacity and the measures for capacity expansion involve substantial financial costs and environmental opposition. Thus, some airports show evident capacity constraints, including New York's JFK and La Guardia - one of the main routes across the North Atlantic is the New York-London. Therefore, she performed a historical analysis of the slot allocation policy and showed that a reform in the management of slots is not only necessary, but essential in order to make them more elastic in consonance with origin-destination tourist.

Given the the literature presented, it is clear that the global demand for air transport has grown over the past few years and, because of this, many airports that already had limitations in their operational capacities have adopted restrictions as an alternative solution. One of them, as stated by Madas and Zografos (2008) and Forsyth (2007), is the capacity management offered by slots which limited the number of landings and takeoffs of aircraft at the airport as a form of demand control. This action allows the airlines to suit their business models according to the new constraints scenarios. In order to face the new scenarios, the authors highlighted alternatives such as improvements on existing runways, as well as the creation of new ones to support the growing demand for air transport, directing part of flights to less crowded airports and also the adoption of aircraft with higher seating capacity.

Regarding Congonhas airport, which was already operating near the limit of its capabilities given the demand growth in the 2000s, restrictive practices were implemented as a form to control the large volume for airline tickets, guarantee an efficient airport management and control the level of service provided to customers. Subsequently, the airlines changed their business models to follow the airport requirements, enhance the quality of services offered to its clients and not incur in large business losses. Thus, they adapted the planned flights to the new reality of limitations slots, sought new business models with changes in the profile of the aircraft and directed some flights to less congested airports, such as Cumbica in Guarulhos - peripheral airport in São Paulo region.

In line with extant researches about congested airports and close operations to capacity limits, it is possible to note that the general goal is to present alternatives to be adopted by both airports' managers and airlines in order to meet the growing volume of passengers. Although many of these researches show the runway´s size as the main infrastructure bottleneck, it is important to consider the infeasibility of reform and construction of new runways due to environmental and politics reasons. Thus, in general, no studies have been identified with the purpose to empirically analyze the long-term effects of operational constraints in airport management through an econometric study. The trend study about airport capacity constraints is related to the slot restrictions' practices, the direction of flights to less congested airports in multiple airport regions, as well as the adoption of aircraft with larger seating capacity, as a measure to control demand.

1.2. Conceptual model

The proximity to the demand generation areas turns downtown airports in major urban centers to be preferably chosen by companies to centralize their network routes. Due to considerable local demand and the feasibility of combinations with passenger connections, larger aircraft and long commutes, business strategies become profitable. However, with the growth in demand for air transport, the occurrence of congestion and decreasing quality of services offered to passengers forced airport regulators to adopt restrictions on these hubs.

Forsyth (2007) in his analysis of the growth in demand and the impact of perimeter rules, presented alternatives in the short and long run in order to better suit this growing demand. According to him, a possible solution to solve the problem would be the adoption of aircraft with higher seat capacity and the efficient use of slots. On the other hand, Takebayashi (2012) studied a region with multiple airports, taking into account aspects of airlines and the passengers profiles. Then, he proposed that hub airports facing serious runway capacity constraints should work exclusively with short flights, while peripheral airports could serve all flights.

Gelhausen, Berster e Wilken (2013) analyzed the relationship between the operational constraints and demand. They realized that the airports that were working on high capacity and could not increase the frequency of service led the airlines to redirect some of their flights to less busy airports, while airports, with lower operating restrictions, increased demand for flights.

Therefore, the first and second hypotheses of this study are:

H1: The high demand for daily passengers leads companies to structure their network planning as the increased frequency of flights and aircraft size;

H2: The increase in airline ticket prices reduces the demand for daily passengers and provides increased in the percentage of passengers connections;

Given the high demand scenario for air transportation and fierce competition among airlines, the presence of low costs and strategies such as codeshare can significantly impact the business model of companies.

In this sense, we have the following assumptions:

H3: The low costs operation in hubs airport with significant growth in demand reduces the frequency of flights offered by airlines, whereas the size of aircraft increases;

H4: Codeshare actions provide cuts in flights and in the percentage of passengers in connection.

Due to the growing demand for air transport, limited operational capabilities of many world airports and the use of perimeter rule as an alternative to control congestion and delays in aviation, many researchers are focused on understanding how airport operators and airlines can take actions to improve this context. In this regard, strategies for congestion control such as prices rates and slots management are adopted by regulators airports (JONES; VIEHOFF; MARKS, 1993), but the slots allocation should follow the different profiles of the airports to improve the demand management (MADAS; ZOGRAFOS, 2008) and to turn the demand more elastic as the management of the origin-destination tourist (DEBBAGE, 2002).

In this regard, two other hypotheses of this study are:

H5: The implementation of perimeter rules at hub airports reduces the demand for airline tickets on flights of short, medium and long term;

H6: The effects of operating restrictions on the decrease in percentage of delayed and cancelled flights are stronger for short and medium duration flights.

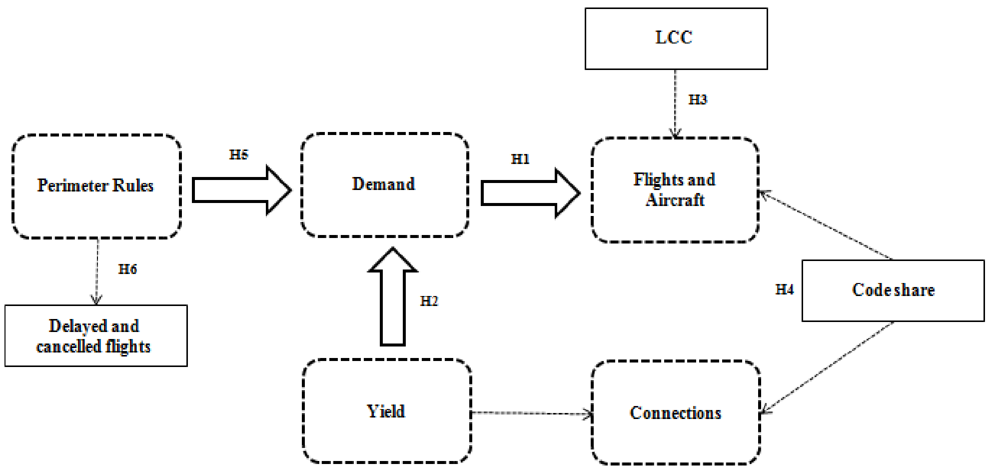

Figure 1: The relationship between perimeter rules and network planning

In view of the assumptions submitted, the designed conceptual model shows the long-term dynamic impact of operational constraints on network planning for airlines. With the increasing demand of daily passengers, it is expected that the number of planned flights, as well as the size of aircraft increases (H1), whereas high prices of airline tickets tends to decrease the demand for air transport (H2). Regarding competition strategies, the performance of low-cost companies can reduce the number of planned flights and increased aircraft size in order to achieve a greater efficiency demand (H3). Hence, in return, the codeshare training may reduce the number of planned flights and the percentage of passengers in connection. So the strategy is to cut down on operation costs (H4). In terms of operating restrictions strategies to congestion control, it is understood that perimeter rules reduce the number of daily passengers (H5) and the percentage of cancelled and delayed flights (H6).

2. Empirical model development

2.1. Application

The Brazilian economic improvement in the late 2000s and the tariff liberalization initiated in the early 2000s made possible the growth in demand for Brazilian air transport, corresponding to 10% per year during this period. Significantly, this growth was reached in some important Brazilian airports such as Congonhas.

Since Congonhas had already presented problems with capacity constraints, recurring congestion, delays and flight cancellations were also perceived in that period. Another important event was the crash of TAM flight (flight 3054) occurred in July 2007. This scenario forced Congonhas airport´s management to adopt restrictions to control the air chaos and also enhance security.

The period 2007-2008, considered in this study as short run, presented certain restrictions such as a limitation on the number slots allowed daily, bans on flights with connections, restrictions on the dimensions of the runway for safety criteria, amongst other factors. These restrictions have been changing over the months, given the relationship between airport management and airlines. However, many of them perpetuated in subsequent years, as the long run period adopted in this study, corresponding to the 2008-2012 period.

2.2. Data

To understand the impact of congestion control rules on airport regulation, we opted for an econometric study, which uses mathematical and statistical models to analyze set of economic data in order to provide empirical support to economic theories. The database was provided by the Agência Nacional de Aviação Civil - Brasil (ANAC) and it includes restricted routes to takeoffs and landings at Congonhas airport (routes analysis (k) origin and destination) over the 2002-2012 period - indexed in months (t). The research employed a panel data approach with fixed and seasonal effects controls.

The empirical model used was composed of seven econometric equations including variable data generation and experimentation, as well as dummies that show the effects of operating restrictions on flights 300m, 600m, 900m and 900m distances over. The short-term study period corresponds to the years 2007-2008, the long-term period to the years 2009 until 2012 and the sample consisted on average of 8353 observations. Since the impact of the restrictions lead to changes in the network planning, it was noticed that some data generated variables were endogenous. So, structural and lagged instruments were adopted for more robust results. In addition, some tests were conducted to check the presence of a unit root, cointegration, multicollinearity, heteroscedasticity and autocorrelation.

2.3. Empirical model

Econometric analysis of this study seeks to empirically analyze the long-term effects of operational constraints in airport management. Thus, the empirical model is comprised of seven econometric equations that aim to present various scenarios to better understand the impacts of perimeter rule at Congonhas in the late 2000s:

$$\begin{aligned} ln\ that\ var_{kt} = {} & \beta_0 + \beta_1 \ln income_{kt} + \beta_2 \ln pax\ daily_{kt} + \beta_3 \ln flights_{kt} \\ & + \beta_4 \ln aircraft\ size\ _{kt} \\ & + \beta_5\ proportion\ connect\ pax_{kt} + \beta_6\ global\ financial\ crisis\ _{kt} \\ & + \beta_7 \ln yield_{kt} + \beta_8\ presence\ LCC_{kt} + \beta_9\ codeshare_{kt} \end{aligned}$$

$$+ \sum_{k=300\text{m},600\text{m},900\text{m},>900m} short\ run_{kt} + \sum_{k=300\text{m},600\text{m},900\text{m},>900m} long\ run_{kt}$$

$$+ \alpha_{sk} + \gamma_{rt} + \varepsilon_{kt}$$

where:

- k… <routes to and from Congonhas>;
- t… <time index for months>;
- r... <region index - southeast , south, northeast , north and central west>;
- α... <seasonality control for the k routes>;
- γ... <control of fixed effects for the regions over the months>.

In this equation, that var corresponds to the independent variables - ln paxdaily, ln pax per flight, ln flights, ln aircraftsize, proportion connect pax (max), proportion delayed flights and proportion cancelled flights. The variables ln incomekt, ln pax dailykt, ln flightskt, ln aircraft size and ln yieldkt are, respectively, the logit transformation of incomekt, pax dailykt, flightkt, aircraft size and yieldkt. This is a traditional procedure to fit a model when the dependent variables are bounded by 0 and 1. Their meaning is, respectively, income index adjusted for inequality, average daily paying passengers, number of planned flights, average size of aircraft and price per Km.

Other dependent variables such as proportion connect paxkt, global financial crisiskt, presence LCCkt and codesharekt are dummies and represent, respectively, pax percentage in connection, impact of global financial crisis in the period of study, presence of GOL Airlines in the first years of operation as low cost and codeshare between TAM Airlines and Varig full services. It is emphasized that this study analyzes the effects of operational constraints through two periods: short-run (that covers the period t = 2007 and 2008) and long-run (t = 2009, 2010, 2011 and 2012) for flights of 300m, 600m, 900m and over 900m distances, where t is the month subsequent to the beginning of perimeter rules in Congonhas Airport.

We also include controls for seasonality (α_{sk}) because the demand for air tickets in Brazil is known to be highly seasonal in the period from December to February and July and this model controls the fixed-effects of the regions (γ_{rt}). Finally, ε_{kt} is the error term.

Through the dependent and independent variables relationships it is possible to understand the behavior of the demand and the airlines operations, competition strategies and the impact of operational constraints in the short and long term analysis. So, they were tested in seven different scenarios.

Table 1 shows the variables and their definitions for better understanding of econometric equations.

Table 1 - Definition of variables

Variable	Definition
ln pax daily	Average daily paying passengers
ln pax per flight	Average daily paying passengers per flight
ln flights	Number of planned flights
ln aircraft size	Average size of aircraft
proportion connect pax (max)	Pax percentage in connection
proportion delayed flights	Percentage of delayted flights
proportion cancelled flights	Percentage of cancelled flights
ln income	Income index adjusted for inequality
global financial crisis	Dummy of global financial crisis
ln yield	Price per Km
presence LCC	Dummy of young Gol low cost
codeshare FSC	Dummy of code-share Varig and TAM full services
short-run effects	Dummy of perimeter rule of short period
long-run effects	Dummy of perimeter rule of long period

Table 2 shows the statistical description of each variable used in this econometric study. Given the descriptions of the variables (Table 1) and the statistical information of each of them (Table 2), it is possible to understand how they relate to the hypotheses of this study.

The first hypothesis (H1) of this study aims to understand the impact of changes in demand in the airlines operations related to planned flights and aircrafts size. The second, third and fourth hypotheses (H2, H3 and H4) test the competition factors and structure of network planning of airlines. In this sense, the second hypothesis (H2) analyzes the influence of an increase in the prices of airline tickets on the level of demand and on the percentage of connecting passengers. Yet, the third hypothesis (H3) investigates the impact of low cost operations at hubs about planned flights and aircraft design. At last, the fourth hypothesis (H4), check the actions of codeshare between full services TAM and Varig in flights and passengers connections. Finally, the fifth (H5) and sixth (H6) hypotheses analyze, respectively, the impact of operating restrictions in demand and in the proportion of delayed and cancelled flights.

Table 2 - Descriptive statistics of continuous variables

Variable	Mean	Std. Dev.	Min	Max
Demand and supply drivers				
Demand and operations				
ln income (mean)	7.045.494	.2818692	6.253.434	778.123
ln pax daily	5.628.003	1.244.464	3.401.197	8.676.742
ln flights	5.530.929	1.338.779	0	983.328
ln aircraft size	4.817.104	.3808139	3.401.197	5.349.486
proportion connect pax (max)	.1961715	.0548478	.0011557	.5688199
global financial crisis	.0297255	.1698392	0	1
Competition				
ln yield	-.331848	.5088926	-2.019.267	1.073.315
presence LCC	.7562028	.4293975	0	1
codeshare FSC	.2944984	.6473132	0	2
Airport restriction dummies				
Short-run effects				
up to 300 miles	.0665228	.2492087	0	1
301 to 600 miles	.0679612	.2516943	0	1
601 to 900 miles	.0262496	.1598861	0	1
more than 900 miles	.0152223	.1224435	0	1
Long-run effects				
up to 300 miles	.1162651	.3205618	0	1
301 to 600 miles	.1499461	.3570399	0	1
601 to 900 miles	.0473451	.2123886	0	1
more than 900 miles	.0335611	.1801072	0	1

2.4. Estimation strategy

2.4.1. Stationarity and cointegration

To start with the analysis of the empirical modelling, the unit root test was conducted on all continuous variables of the database in the seven models through Augmented Dickey-Fuller test (ADF). The test was performed with a deterministic trend and with a number of lagged first differences suggested by the most commonly used criteria3. In all seven econometric models, it was found that gminc variable exceeded the critical value of 5 % significance, but the unit root was not rejected which means that the variable is nonstationary. However, it is known that this variable may be cointegrated if there is/are one or more linear combinations among them is/are stationary. Then, if this variable is cointegrated, there is a stable long run or equilibrium linear relationship among them. Johansen's maximum likelihood method is a formal test for cointegration that was performed in all seven econometric models. This test was implemented with a linear deterministic trend, an intercept included in the cointegrating equation, and the selected lag order of 2, suggested by the

3 Namely, Ng–Perron sequential t (STNP), minimum Schwarz information criterion (SIC) and Ng–Perron modified Akaike information criterion (MAIC).

majority of a range of selection criteria4. At the 5% level significance, we rejected, for all six econometric models, the null hypothesis of no cointegration and fail to reject the null hypothesis of at most one cointegrating equation for subset of variables of these six models.

2.4.2. Multicolinearity, heteroskedasticity, autocorrelation

The variance inflation factor (VIF) was calculated to measure how much of the variances of estimated regression coefficientes was inflated by multicolinearity. The results of VIF in all of the seven econometric models were less than 10 and this is indicative that multicolinearity can't inflate the estimation of standard errors of some of these estimates. It was noticed that in seven econometric models, only two variables had VIF greater than 10: gminc in the first two models while pdew in other econometric equations.

In addition to the multicolinearity test, a series of formal methods were employed in order to detect the existence of heteroscedasticity and autocorrelation in the given regression models of this study. The tests of Pagan-Hall, White/Koenker and Breusch-Pagan/Godfrey/Cook-Weisberg heteroskedasticity were implemented using alternative specifications of levels, squares, cross products of regressors and also fitted values of the regress and that suggested the rejection of the null of homoskedastic disturbances for all variables in the six econometric models. The Cumby-Huizinga test (once accounting for heteroskedasticity and endogeneity5) was used for several order specifications to check the autocorrelation. These tests suggested the presence of autocorrelation of order 22, for the first two econometric equations and 12, 15, 5, 9 and 7 for the order respectively. At last, the procedure of Newey-West was applied for the sake of adjusting the standard error estimates.

2.4.3. Endogeneity and instrumental variables

In our estimating framework we have that yield, aircraft size, flights, proportion connect pax (max) and pax daily are potentially correlated with unobserved error (ε_t) in the seven equations of conceptual model. Hence, we have E(yield, ε_t) $\neq 0$, E(aircraft size, ε_t) $\neq 0$, and E(flights, ε_t) $\neq 0$, E(proportion connect pax (max), ε_t) $\neq 0$ and E(pax daily, ε_t) $\neq 0$ and, therefore, OLS estimation of the coefficients of seven equations would be biased. Even though we have this scenario, the goal of this paper is to understand the impact of operating restrictions implemented in Congonhas - represented by dummies in this conceptual model of operating restrictions in two study periods (short and long) in airport management.

In this econometric study, several variables were adopted to get the overview of the dynamic impact of operational constraints on network planning. In that case to obtain a consistent partial effect of variables, we must employ an instrumental variables estimator[6]. In this regard, the cost of structural instruments and lagged variables were used to achieve more robust results.

An important analysis presented by the estimator GMM2S (two-step Generalized Method of Moments) regarding to the strength of the instruments used in the equations through the results shown in Cragg - Donalds tests wald F statistic and Kleibergen wald - Paap F statistic. The higher the results, the better the strength of the instrument. All the equations of the econometric models in this study presented values above 10 which indicate good performance of the instruments used.

4 The criteria used were: Final Prediction Error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC).

5 On the issue of endogeneity, see the discussion below.

[6] For comparison purposes, we present the results of OLS estimation in the Appendix.

2.4.4. Estimator

We used in this econometric model the OLS (Ordinary least Square) estimator, and also the GMM2S (two-step Generalized Method of Moments) and LIML (Limited-Information Maximum Likelihood).

The OLS aims to minimize the differences between the observed responses and the responses predicted by the linear approximation fitted by estimation of the parameters. The OLS-HAC is a robust estimator to control both heteroskedasticity and autocorrelation. Nonetheless, it is necessary specify the period in time that the autocorrelation is significant.

GMM2S and LIML are used whether any independent variable is linked to the error term (ε_i). LIML is a model used when we have weak instruments. In this situation, a normal distribution for the errors or homoskedasticity is cogitated providing biased errors in the presence of heteroskedasticity (it is not the right tool to use). As to GMM2S, it is an estimator with statistics robust to arbitrary heteroskedasticity and autocorrelation. Results are available in the Appendix (OLS and LIML).

3. Results

To solve out the endogeneity problem , robust estimators were used to analyze the results. One of the estimators was the GMM2S which was on the Table 3. This table presents data from two points of view: demand drivers and supply, with breaking in demand and operations and competition, and the impacts of dummies on operational constraints at the Congonhas downtown airport in short and long run effects.

3.1 Demand and Operations

Concerning specifically the demand and operations in the seven econometric models, it is clear that the increase of passengers incomes result in the pax daily and passengers per flight numbers to increase.

Regarding the number of passengers, it is clear that the increase in demand leads to growth in the planned flights number and the aircraft average. Consequently, if there is a considerable demand for local passengers (OD), a wide range of connections is not necessary. Therefore, there was a decrease in the passengers connections percentage. It was significant the delayed flights proportion in comparison to the increased complexity of operations. Yet, there was a reduction in the cancelled flights proportion due to the fact that growth in demand for airline tickets engages companies to look more carefully into the risk management before adopting existing flight cancellations strategies.

It can be seen in the planned flights, that any growth in the frequency of flights generates a demand increase, notably when the passenger is time-sensitive. In this situation, he highly values the frequency of flights.

Table 3 - Estimation results GMM2S7

	(1) ln pax daily	(2) ln pax per flight	(3) ln flights	(4) ln aircraft size	(5) proportion connect pax (max)	(6) proportion delayed flights	(7) proportion cancelled flights
Demand and supply drivers							
Demand and operations							
ln income (mean)	0.8455***	1.4387***					
	[0.173]	[0.113]					
ln pax daily			0.1781**	0.0556***	-0.0558***	0.0141**	-0.0197*
			[0.088]	[0.017]	[0.010]	[0.006]	[0.012]
ln flights	0.0878**	-0.0202**		0.0008	-0.0014	-0.0003	-0.0024
	[0.038]	[0.009]		[0.014]	[0.002]	[0.003]	[0.004]
ln aircraft size	0.3777***	0.9770***	0.0176		0.0042	-0.0671***	-0.0531**
	[0.087]	[0.045]	[0.194]		[0.004]	[0.018]	[0.022]
proportion connect pax (max)	0.9928***	0.4046**	0.2584	-0.2866***		0.1067*	0.4831***
	[0.286]	[0.172]	[0.384]	[0.107]		[0.056]	[0.076]
global financial crisis	-0.1324***	-0.1534***	-0.0014	0.0486***	0.0053	0.0313***	-0.0853***
	[0.037]	[0.023]	[0.067]	[0.017]	[0.005]	[0.012]	[0.015]
Competition							
ln yield	-0.2379***	-0.0541*	-0.1722**	0.0223	0.0367**	-0.0373***	0.0076
	[0.045]	[0.031]	[0.086]	[0.024]	[0.016]	[0.008]	[0.013]
presence LCC	0.3705***	0.0949***	-0.2919***	0.1514***	0.0200***	-0.0139**	-0.0346***
	[0.037]	[0.026]	[0.093]	[0.024]	[0.005]	[0.006]	[0.011]
codeshare FSC	0.0366*	-0.0180	-0.1636***	-0.0157*	-0.0073***	0.0133***	0.0209***
	[0.020]	[0.013]	[0.029]	[0.009]	[0.001]	[0.003]	[0.005]
Airport restriction dummies							
Short-run effects							
up to 300 miles	-0.0246	-0.1016***	-0.1120**	-0.0175	-0.0879***	0.0072	0.0903***
	[0.056]	[0.033]	[0.055]	[0.026]	[0.006]	[0.014]	[0.016]
301 to 600 miles	-0.1850***	-0.1797***	-0.0366	0.1061***	-0.0812***	0.0293***	0.0800***
	[0.045]	[0.029]	[0.076]	[0.026]	[0.006]	[0.011]	[0.015]
601 to 900 miles	-0.7254***	-0.0399	0.2359	0.0676*	-0.1056***	0.0188	0.1694***
	[0.087]	[0.077]	[0.145]	[0.035]	[0.016]	[0.024]	[0.049]
more than 900 miles	-0.4631***	-0.0947***	-0.2208	0.1051***	-0.0690***	0.0599***	0.1790***
	[0.080]	[0.036]	[0.198]	[0.031]	[0.012]	[0.021]	[0.036]
Long-run effects							
up to 300 miles	-0.1559**	-0.2991***	0.0141	-0.0079	0.0059	-0.0568***	-0.0258*
	[0.064]	[0.046]	[0.059]	[0.027]	[0.007]	[0.008]	[0.013]
301 to 600 miles	-0.2575***	-0.3778***	0.0675	0.1387***	0.0107	-0.0310***	-0.0378***
	[0.066]	[0.044]	[0.090]	[0.027]	[0.008]	[0.007]	[0.012]
601 to 900 miles	-0.9827***	-0.1927***	0.4237**	0.1287***	-0.0260	0.0018	-0.0209
	[0.097]	[0.075]	[0.177]	[0.043]	[0.016]	[0.014]	[0.026]
more than 900 miles	-1.3369***	-0.2725***	0.4908***	0.1887***	-0.0407**	0.0031	0.0068
	[0.109]	[0.049]	[0.188]	[0.037]	[0.020]	[0.011]	[0.019]
N. Observations	8052	8003	8052	8052	8343	8052	7822
R-squared	0.9273	0.8149	0.6976	0.7739	0.4891	0.3399	0.2079
RMSE	0.3334	0.2243	0.7383	0.1786	0.0395	0.0891	0.1338
F Statistic	491.786	60.715	242.237	334.364	35.524	13.783	8.895
Kleibergen-Paap rk LM statistic	37.9692	243.8552	343.2734	290.5124	78.5390	404.1509	304.5698
Kleibergen-Paap rk KM p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Hansen J statistic	4.6431	1.6621	2.9714	1.6486	2.1602	1.0471	0.0225
Hansen J p-value	0.3259	0.4356	0.3960	0.4385	0.3396	0.5924	0.8808
Cragg-Donalds wald F statistic	134.6680	1475.06	1285.93	1513.52	30.7148	1281.38	962.5803
Kleibergen-Paap wald F statistic	7.1915	432.1012	557.8983	670.9288	14.2638	599.4318	320.1075

7 Results produced by the two-step feasible efficient generalized method of moments estimator (GMM2S); statistics robust and efficient to arbitrary heteroskedasticity and autocorrelation; figures are representative of the estimated elasticities calculated at the sample mean; P-value representations: ***p<0.01, ** p<0.05, * p<0.10; results generated by alternative estimators presented in the Appendix.

About aircraft size, in the same way as the number of planned flights, it is a capacity factor to reduce demand generation bottlenecks. Thus, it is expected that larger aircraft raise the number of passengers per flight. It was also observed that the aircraft management with increased seating capacity reduces the percentage of delays and cancelled flight due to the fact that it requires good service levels to a greater passenger demand, which is made possible through more precise operations management. It is known that the factors that promote changes in the proportion connecting passengers are correlated with the local passengers drivers. Then, if the proportion passengers in connection increase, the number of local passengers also increases.

Finally, due to the global financial crisis, there was a reduction on the number of daily passengers and the passengers per flight but there is no significant impact on the planned flights frequency. Then, an alternative is aircraft with the highest number of seats. This context leads to an increased percentage of delayed flights, but reduces the number of cancelled flights, because flight cancellations cost too much for airlines, especially, in a financial recession context.

3.2 Competition

This section highlights the variables that are directly related to competition factors amongst airlines. Regarding the air tickets prices, it is clear that more expensive airline tickets reduce the number of local passengers and passengers per flight as well as the flight frequency. However, due to airlines fierce competition, they charge lower prices in connections. This scenario also provides proportion delayed flights reduction, since airlines seek to rise airfares and high revenues. Therefore, the companies are pressured to operate with lower delayed flights incidence and to offer better quality services to passengers.

Regarding the LCC presence, the case GOL airline performance in its first years of operation in Brazil, it is known that where this airline has flight operations, there was a 37% increase on the daily passengers, ceteris paribus, and an increase of 9% the passengers per flight. In regard to flights, there is a tendency to decrease, due to the others airlines network planning´s reaction. This fierce competition context in order to seek greater flight efficiency and the aircraft size shows up more as an alternative to accommodate the increased demand. There is an increase in connecting passenger percentage and a decrease in both delayed and cancelled flight percentages. Hence, this is seen as a business strategy aimed to increase operational efficiency while seeking to offer higher quality services for passengers.

The codeshare presence of Varig and TAM full service companies presented as main effects cuts in flight frequencies, decrease in connecting passengers percentage and increase in delayed and cancelled flights percentages.

3.3 Airport restriction dummies

Given the operational constraints implemented in the downtown Congonhas airport, there was a sharp drop in demand for daily passengers on short and long period. This made Congonhas, considered in previous periods as Brazil's main airport, be surpassed by Guarulhos and Brasilia airports. It is emphasized that the operational constraints impacted, mainly, the long-term routes.

Analyzing flights number, in the short period was not observed considerable changes, although, in the long run period there was an increase in flight frequencies, especially in the medium and long term flights (over 600 miles), was noticed. The aircraft size revealed growth in the short term, but the results were more significant over the 2009-2012 period.

The percentage of passengers in connection decreased in the short run period of analysis but, in the long run period there was a rebound in order to achieve the foregoing levels restrictive practices. Note that, from 2008 to 2012, the number of passengers on connecting flights was reduced in more than 900 miles. Regarding the delayed and cancelled flights percentages, almost all flight tracks increased in the short term. In the long run period, it was noticed a return to previous levels of restrictions for flights over 600 miles. However, there was a reduction on the percentage of delayed flights flying up to 600 miles.

4. Robustness checks and limitations

The data generated by GMM2S estimator presented results close to what was expectated, compared with LIML estimator shown in Table 5 in the Appendix. From the results of the LIML, some important variables for understanding the general context of the study, such as pax daily, flight and aircraft size glob fin crisis were not considered statistically significant, as in GMM2S estimator. The other variables, in all seven equations, demonstrated similar behavior in both estimators, changing, in general, the values of the estimated betas.

It was noticed that the operational constraints impacting negatively on demand for flights, especially for long distances. Moreover, it was possible to notice how the dynamic impacts the network planning, such as the aircraft size, proportion of passengers in connection, proportion of delayed and cancelled flights, among other factors.

Conclusion

In recent years the binomial growth in demand for air transport and capacity constraints of many world airports has become an important study topic and has been analyzed from different perspectives. This is justified due to the problems of congestion and reflections in the percentage of delays or cancelled flight. Thus, decreasing supply slots, changing mesh and targeting flights to secondary airports are strategies adopted to manage demand and improve the quality of passenger service level. The analysis of this study contemplated routes to and from Congonhas over the years 2002 to 2012. The paper also show that the control rules applied at that airport led to short and long term effects on airport regulation.

The results showed that the implemented operational constraints have led to a sharp drop in demand in the short term and this scenario was perpetuated in the long-term study. This made Congonhas downtown airport - the Brazilian lead airport in volume of passengers - drop to the third position and be supplanted by the airports of Guarulhos and Brasilia. Regarding the proportion of passengers per flight, it was noticed a reduction in short and long recovery period, except for flights of longer distances. Similarly, there was a considerable drop in the number of connecting passengers in the short term and an upsurge in the long period. The percentage of delayed and cancelled flights in the short term presented an increase in almost all route tracks. On the other hand, in the long run, there was a decrease in percentage of delayed and cancelled flights, mainly for flights of 300 to 600 miles. Congonhas airport demonstrates a historically significant efficiency on short flight distances and it was possible to notice an improvement in the quality of services offered to customers. The results showed no reduction in the frequency of planned flights but due to a decrease on the demand, the flights became more unproductive and unprofitable and that was one of the relevant factors for the resumption of connections in the long period.

Considering the literature review previously presented, it was found that strategies such as limited slots are feasible in contexts of perimeter rules and strong demand growth, as outlined by Forsyth (2007), Jones, Viehoff and Marks (1993), Debbage (2002) and Madas and Zografos (2008). Furthermore, given the fact Congonhas is a central airport located in a multiple airport region, we see the restrictions especially for long-haul flights in the period of highest incidence of operational constraints. This fact was exposed as an alternative solution for Takebayashi (2012) in his analysis of short and long haul flights in multiple airport regions. Gelhausen, Berster and Wilken (2013), in this aspect, presented several alternatives to avoid congestion and problems with markdowns and cancellations of flights, such as the adoption of larger aircrafts. In consonance with the authors, this study pointed the adoption of larger aircafts as a viable alternative in Congonhas during analyzed period.

This study investigated the impact of restrictive measures in airport planning through an econometric approach. With regard to public policy perspectives is relevant to understand how the restrictions imposed by airport management influence the long-term airlines' business model. To corporative policies, this study shows how airlines operate on the network planning, fleet, aircraft design, flight frequency, route, etc. given the backdrop of operational constraints. It is noteworthy that many studies support the relationship between demand and operational restrictions, but the analysis through econometric data about the dynamic effects on the long-term of congestion control rules on airport regulation has been comparatively little explored. Therefore, this binomial strategy of regulatory airports and airlines through econometric analysis enables better planning and adjustment of the capacity according to airport infrastructure.

Based on the data and in the literature review presented and discussed, it is clear that changes in demand and practical operational constraints have a directt impact on the airlines' network planning. However, due to the fact of Congonhas downtown airport has infrastructure constraints, given its location and economic and environmental factors, it was not possible to prove the binomial frequency and size of aircraft. Another limitation is related to the size sample adopted in this paper. Since only one airport (origin or destination Congonhas) was analyzed; there are no comparative studies of these dynamic impacts on other national or international airports.

It is recommended for future studies a broader analysis regarding the impact of operational constraints on airport regulation in order to see how these restrictions have impacted on other factors such as the prices charged by airlines and the weights of the aircraft. In addition, it is suggested that a comparative analysis of airports with operating restrictions in national and international context in order to make sure correspondence on the results.

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Appendix

Table 4 - Estimation results (OLS)8

	(1) ln pax daily	(2) ln pax per flight	(3) ln flights	(4) ln aircraft size	(5) proportion connect pax (max)	(6) proportion delayed flights	(7) proportion cancelled flights
ln income (mean)	1.0725***	1.5103***					
	[0.069]	[0.045]					
ln yield	-0.1542***	-0.0250**	-0.1393***	0.0103	-0.0038**	-0.0258***	0.0038
	[0.018]	[0.012]	[0.039]	[0.009]	[0.002]	[0.005]	[0.007]
ln pax daily			0.1216***	0.0330***	0.0035***	0.0129***	-0.0353***
			[0.024]	[0.006]	[0.001]	[0.003]	[0.004]
ln flights	0.0227***	-0.0156***		0.0139***	0.0006	-0.0020	-0.0081***
	[0.005]	[0.003]		[0.003]	[0.000]	[0.001]	[0.002]
ln aircraft size	0.1264***	0.9378***	0.2410***		-0.0062***	-0.0591***	-0.0355***
	[0.021]	[0.014]	[0.046]		[0.002]	[0.006]	[0.009]
proportion connect pax (max)	0.9317***	0.5822***	0.3256	-0.2025***		0.0821**	0.2314***
	[0.124]	[0.082]	[0.263]	[0.063]		[0.032]	[0.049]
codeshare FSC	0.0057	-0.0119**	-0.1803***	-0.0141***	-0.0024***	0.0123***	0.0186***
	[0.007]	[0.005]	[0.015]	[0.004]	[0.001]	[0.002]	[0.003]
presence LCC	0.3938***	0.1126***	-0.3314***	0.1499***	-0.0039***	-0.0135***	-0.0315***
	[0.014]	[0.009]	[0.031]	[0.007]	[0.001]	[0.004]	[0.006]
global financial crisis	-0.1544***	-0.1703***	-0.0097	0.0496***	0.0176***	0.0351***	-0.0873***
	[0.025]	[0.017]	[0.055]	[0.013]	[0.002]	[0.007]	[0.010]
post_srun_300	-0.0691***	-0.0863***	-0.1178**	-0.0040	-0.0951***	0.0021	0.0621***
	[0.024]	[0.016]	[0.047]	[0.011]	[0.002]	[0.006]	[0.009]
post_srun_600	-0.1805***	-0.1587***	-0.0340	0.1230***	-0.0889***	0.0282***	0.0595***
	[0.024]	[0.016]	[0.047]	[0.011]	[0.002]	[0.006]	[0.009]
post_srun_900	-0.7517***	-0.0063	0.1978**	0.0598***	-0.0899***	0.0208**	0.1530***
	[0.040]	[0.026]	[0.086]	[0.021]	[0.003]	[0.010]	[0.016]
post_srun_900m	-0.4488***	-0.0722***	-0.2539***	0.1102***	-0.0733***	0.0570***	0.1499***
	[0.031]	[0.021]	[0.067]	[0.016]	[0.003]	[0.008]	[0.012]
post_lrun_300	-0.1843***	-0.2956***	0.0347	-0.0097	-0.0285***	-0.0514***	-0.0290***
	[0.027]	[0.018]	[0.039]	[0.009]	[0.002]	[0.005]	[0.007]
post_lrun_600	-0.2314***	-0.3703***	0.0605	0.1533***	-0.0269***	-0.0253***	-0.0420***
	[0.028]	[0.018]	[0.040]	[0.009]	[0.002]	[0.005]	[0.007]
post_lrun_900	-0.9932***	-0.1936***	0.4019***	0.1110***	-0.0289***	0.0072	-0.0365***
	[0.038]	[0.025]	[0.070]	[0.017]	[0.003]	[0.009]	[0.013]
post_lrun_900m	-1.3296***	-0.2559***	0.4174***	0.1620***	-0.0251***	0.0109	-0.0171
	[0.033]	[0.022]	[0.064]	[0.015]	[0.003]	[0.008]	[0.012]
Observations	0.9259	0.8216	0.6921	0.7812	0.6772	0.3310	0.2020
RMSE	0.3416	0.2249	0.7491	0.1796	0.0314	0.0910	0.1392
F	721.963	264.098	130.791	207.718	122.049	28.582	14.620
KP	.	.	.	.	.	.	.
KP_PValue	.	.	.	.	.	.	.
J	.	.	.	.	.	.	.
J_PValue	.	.	.	.	.	.	.
Weak_CD	.	.	.	.	.	.	.
Weak_KP	.	.	.	.	.	.	.
N_Obs	8343	8285	8343	8343	8343	8343	8343

[8] Results produced by the ordinary least squares estimator (OLS); statistics robust to arbitrary heteroskedasticity and autocorrelation; figures are representative of the estimated elasticities calculated at the sample mean; P-value representations: ***p<0.01, ** p<0.05, * p<0.10.

Table 5 - Estimation results (LIML)[9]

	(1) ln pax daily	(2) ln pax per flight	(3) ln flights	(4) ln aircraft size	(5) proportion connect pax (max)	(6) proportion delayed flights	(7) proportion cancelled flights
ln income (mean)	1.0725***	1.5103***					
	[0.174]	[0.109]					
ln yield	-0.1542***	-0.0250	-0.1393**	0.0103	-0.0038	-0.0258***	0.0038
	[0.034]	[0.023]	[0.065]	[0.017]	[0.003]	[0.006]	[0.010]
ln pax daily			0.1216*	0.0330***	0.0035**	0.0129***	-0.0353***
			[0.069]	[0.013]	[0.002]	[0.005]	[0.008]
ln flights	0.0227	-0.0156**		0.0139	0.0006	-0.0020	-0.0081**
	[0.016]	[0.008]		[0.016]	[0.001]	[0.002]	[0.004]
ln aircraft size	0.1264**	0.9378***	0.2410		-0.0062***	-0.0591***	-0.0355*
	[0.051]	[0.042]	[0.256]		[0.002]	[0.016]	[0.020]
proportion connect pax (max)	0.9317***	0.5822***	0.3256	-0.2025**		0.0821*	0.2314***
	[0.235]	[0.133]	[0.311]	[0.089]		[0.044]	[0.071]
codeshare FSC	0.0057	-0.0119	-0.1803***	-0.0141	-0.0024***	0.0123***	0.0186***
	[0.020]	[0.013]	[0.033]	[0.009]	[0.001]	[0.003]	[0.005]
presence LCC	0.3938***	0.1126***	-0.3314***	0.1499***	-0.0039*	-0.0135**	-0.0315***
	[0.033]	[0.027]	[0.111]	[0.026]	[0.002]	[0.006]	[0.010]
global financial crisis	-0.1544***	-0.1703***	-0.0097	0.0496***	0.0176***	0.0351***	-0.0873***
	[0.036]	[0.023]	[0.068]	[0.018]	[0.004]	[0.013]	[0.015]
post_srun_300	-0.0691	-0.0863***	-0.1178**	-0.0040	-0.0951***	0.0021	0.0621***
	[0.055]	[0.032]	[0.050]	[0.026]	[0.005]	[0.013]	[0.015]
post_srun_600	-0.1805***	-0.1587***	-0.0340	0.1230***	-0.0889***	0.0282***	0.0595***
	[0.045]	[0.029]	[0.080]	[0.026]	[0.005]	[0.010]	[0.015]
post_srun_900	-0.7517***	-0.0063	0.1978	0.0598*	-0.0899***	0.0208	0.1530***
	[0.084]	[0.077]	[0.134]	[0.033]	[0.009]	[0.022]	[0.045]
post_srun_900m	-0.4488***	-0.0722**	-0.2539	0.1102***	-0.0733***	0.0570***	0.1499***
	[0.075]	[0.034]	[0.192]	[0.028]	[0.005]	[0.018]	[0.032]
post_lrun_300	-0.1843***	-0.2956***	0.0347	-0.0097	-0.0285***	-0.0514***	-0.0290**
	[0.066]	[0.046]	[0.053]	[0.026]	[0.002]	[0.008]	[0.014]
post_lrun_600	-0.2314***	-0.3703***	0.0605	0.1533***	-0.0269***	-0.0253***	-0.0420***
	[0.069]	[0.044]	[0.108]	[0.025]	[0.003]	[0.006]	[0.011]
post_lrun_900	-0.9932***	-0.1936***	0.4019**	0.1110***	-0.0289***	0.0072	-0.0365
	[0.102]	[0.074]	[0.165]	[0.041]	[0.004]	[0.014]	[0.024]
post_lrun_900m	-1.3296***	-0.2559***	0.4174**	0.1620***	-0.0251***	0.0109	-0.0171
	[0.106]	[0.048]	[0.170]	[0.031]	[0.004]	[0.008]	[0.015]
Observations	0.9259	0.8216	0.6921	0.7812	0.6772	0.3310	0.2020
RMSE	0.3416	0.2249	0.7491	0.1796	0.0314	0.0910	0.1392
F	518.128	62.798	241.973	241.272	73.110	14.137	8.822
KP	.	.	.	.	.	.	.
KP_PValue	.	.	.	.	.	.	.
J	.	.	.	.	.	.	.
J_PValue	.	.	.	.	.	.	.
Weak_CD	.	.	.	.	.	.	.
Weak_KP	.	.	.	.	.	.	.
N_Obs	8343	8285	8343	8343	8343	8343	8343

[9] Results produced by the limited-information maximum likelihood estimator (LIML); statistics robust to arbitrary heteroskedasticity and autocorrelation; figures are representative of the estimated elasticities calculated at the sample mean; P-value representations: ***p<0.01, ** p<0.05, * p<0.10.