AIRCRAFT SIZE AND TYPE IMPACTS ON REGIONAL AIR TRANSPORT DEMAND

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ABSTRACT

Present paper decomposes ceteris paribus effect of aircraft size and type (turboprops/jets) in order to assess if and how they affect demand for regional air transport. Analyzing both engine technologies, it was expected to have jets enhancing demand more than turboprops but achieved results suggest the opposite. Since most of recent articles reports how airlines meet demand selecting the right aircraft and not how the aircraft size affects demand, one contribution from the present study is the analysis of aircraft size as an endogenous variable. It was perceived that flying small aircraft contributes more to demand than flying large aircraft.

Keywords: demand, aircraft, size, jet, turboprop, regional.

1. INTRODUCTION

Present paper investigates if and how aircraft size and aircraft type affect demand for regional air transport. Using Brazilian regional routes database from 2002 to 2012 comprising 75 city pairs and 64 airports, an econometric model was build in order to decompose aircraft *ceteris paribus* contribution to demand generation due to its indirect influence on passengers' decision to fly. Concerning to aircraft type, this study focuses on two different engine technologies: turboprops and jets[1]; due to its effects on fuel consumption and environmental matters. Turboprops have lower fuel consumption and therefore emits lower amount of greenhouse gas[2] (RYERSON and HANSEN 2010), but their advantage over jets ends with distance growth (BRUECKNER and PAI 2009).

Regional air transport is normally considered as regular service operating in low or medium density routes and typically flying aircraft counting no more than hundred seats (BETTINI 2007). Although there are airlines performing regional flights using mainline jets, regional aircraft are most common. Both size and aircraft type are one of major airlines' concern since they affect operational costs and thereby, the price passengers pay to fly. Several examples of airlines' interest about which aircraft best suit their needs can be easily found in recent air transport history. Passaredo, a regional Brazilian airline has moved its fleet from ERJ145 (50-seat jet) to ATR 72 (70-seat turboprop) since 2012. Luxair, from Luxembourg, currently have ERJ145 and Q400 (76-seat turboprop) in its fleet but decided, on February/2015, to replace former by more turboprops. KLM Cityhopper announced, on March/2015, a purchase of fifteen E175+ (88-seat jet) and two E190 (100-seat jet) in order to continue Fokker 70 (80-seat jet) replacement and consequently increase its seat capacity.

Once a significant number of aircraft's models are currently available, airlines face a hard decision when selecting the most suitable one for their planned routes. The choice already involves many aspects like performance, acquisition and operational costs, but could demand generation accrued from aircraft model be a new criterion? Comprehension of this theme could bring more confidence to airlines whilst selecting proper aircraft, mainly in a market segment which has a good range of aircraft options.

According to ARNOULT (2001) apud DRESNER, WINDLE and ZHOU (2002), passengers clearly prefer jets over turboprops, but BRUECKNER and PAI (2009) states that regarding to operating cost per seat per km, turboprops are more economical than regional jets on shorter routes. Thus, if in one hand, jets could attract more passengers; in other hand turboprops' costs savings could attract more passengers if airfares get less expensive than when flying jets. Thinking on aircraft size, WONG, PITFIELD and HUMPHREYS (2005) believe small aircraft could foment frequency since they have low breakeven load factor and according to WEI and HANSEN (2005), adding frequency attracts more passengers than adding seats in one aircraft. At the same time, SWAN and ADLER (2006) report that considering aircraft trip costs alone, operational costs increase across aircraft size for short-haul flights; while GIVONI and RIETVELD (2009) affirm that a profitable operation is extremely dependent on load factor since more passengers means lower fuel per passenger. GIVONI and RIETVELD (2009) still concluded that aircraft size selection depends more on route characteristics as distance, demand and competition than on airport attributes.

Since most of recent articles reports how airlines meet demand selecting the right aircraft and not how the aircraft size affects demand, one scientific contribution from present study is the analysis of aircraft size as an endogenous variable and not exclusively like an outcome of demand. From market point of view, this research attempts to verify whether it is possible to use a demand generation criteria whilst selecting the suitable aircraft model for flying one specific route; and simultaneously, help Government Policies regarding to airport planning and traffic constraints.

From this point, after understanding the theoretical framework, and the empirical model,

[1] Jets technology has evolved and there are at least three different types of them currently available: pure jets, turbojets and turbofans.

[2] Greenhouse gases emissions are strongly correlated with fuel burn (RYERSON and HANSEN 2010).

corresponding results are discussed. Lastly, conclusions are presented.

2. THEORETICAL FRAMEWORK

“Passengers have a clear preference for jets over turboprops, viewing the former as quieter, faster, safer and more comfortable”, remarked ARNOULT (2001) apud DRESNER, WINDLE and ZHOU (2002). But would jets utilization improve air transport demand? Or would have passengers changed their minds and prefer turboprops given recent environmental concerns? When pondering aircraft type, the route demand effects when using either jets or turboprops are not well established. Last sentence is also true for aircraft size since capacity is ordinarily savvied as an answer to demand as suggested by GIVONI and RIETVELD (2009).

2.1. LITERATURE REVIEW

Regional jets tend to connect cities that are beyond turboprops’ practical range (from 650 to 2220 km) or had fewer passengers than minimum required for being profitable when flying mainline jets (WONG, PITFIELD and HUMPHREYS 2005). Research performed by DRESNER, WINDLE and ZHOU (2002) indicates that Continental Express’[3] routes flying to and from Cleveland and Houston hubs in 1999 had an average stage length of 1052 km if flown by jets and of 418 km when turboprops were used. In a nutshell, regional jets fill the gap between turboprops’ and mainline jets’ operation characteristics.

According to manufacturers website[4], recent design of regional jets and turboprops have their range as following: ATR 72-600 have a maximum range of 1528 km when loaded at its maximum capacity (70 passengers); Bombardier Q400 can fly up to 2063 km when loaded with 74 passengers while CRJ700 is able to reach 2553 km with the same load; and EMBRAER 170 model, by its turn, reaches 3982 km when carrying 70 passengers. These data show that turboprops average range is currently inside band quoted by WONG, PITFIELD and HUMPHREYS (2005) as “beyond turboprops’ practical range”[5] and greater than average route flown by Continental Express in 1999 calculated by DRESNER, WINDLE and ZHOU (2002).

Besides range, another difference among jets and turboprops is cruising speed: formers fly around 485 knots and latter travels around 300 knots. Lower speeds at short-haul routes make travel time comparable to other modals, mainly when considering expended time in airport before and after the flight[6], and this way, passengers could shift from regional air transport. Considering operating cost per seat per km, turboprops are more economical than regional jets on shorter routes, but both of them, however, lose to mainline jets (BRUECKNER and PAI 2009) which are recognized for operating costs and passenger service quality balance (RYERSON and HANSEN 2010).

Each aircraft model has its own economical characteristics: acquisition costs, performance and operational costs including pilot, cabin crew, fuel and maintenance. Most of these costs are proportional to flown hours but part of them is related to departure and arrival (SWAN and ADLER 2006). Besides previous costs, environmental fees or economical incentives may arise in the future in order to diminish greenhouse gas emission (RYERSON and HANSEN 2010). It is possible to state then that costs have a fixed amount per departure plus a variable part based on flown distance. Considering aircraft trip costs alone, operational costs also increase across aircraft size for short-

[3] Continental Express was the operating brand name used by a number of independently owned regional airlines providing regional jet feeder service under agreement with Continental, a major U.S. airline founded in 1934 and merged with UAL Corporation, parent company of United Airlines, via stock swap after May, 2010 announcement.

[4] www.atraircraft.com; www.bombardier.com and www.embraer.com. Accessed on June, 13rd, 2015.

[5] Perhaps WONG, PITFIELD and HUMPHREYS (2005) refer to “practical range” as the one where aircraft is profitable. In this case, this value depends on fuel price and airport taxes. Since this data varies through time and place, it was not verified the current “practical range” of turboprops considering this possible terms definition.

[6] Check-in, security scanning, embarking, disembarking and baggage reclaim can easily overcome one hour (KEMP 2009).

haul flights (SWAN and ADLER 2006)[7]. Due to economies of scale, however, operating costs induce large aircraft use once they consume less fuel per seat (GIVONI and RIETVELD 2009) but in places like U.S.A. where pilots' wages are based on aircraft size, airlines tend to prefer small aircraft in order to balance their costs (WEI and HANSEN 2003).

Given that all industries transfer their costs to customer, differences due to aircraft type and size have impact on ticket prices and so, aircraft model flying one specific route may affect demand for that route. Regarding more than 500 routes over U.S.A., Europe and Asia, GIVONI and RIETVELD (2009) concluded that aircraft size selection depends more on route characteristics like length, demand and competition than on airport characteristics. PAI (2010) adds that airliners choose aircraft size and frequency flights based on passengers' characteristics: concentration of business travelers might require small aircraft with high frequency while concentration of leisure travelers might be served by larger aircraft with lower frequency.

In order to support growing demand[8], airlines have basically three options: increase service frequency, use larger aircraft and/or enhance load factor. A profitable operation is extremely dependent on load factor since more passengers means lower fuel per passenger (GIVONI and RIETVELD 2009). Once small aircraft have low breakeven load factor, they foment frequency and carrier's strategy of rightsizing aircraft in reduced demand markets (WONG, PITFIELD and HUMPHREYS 2005), acting on two of three airlines' options. Thereby, airlines are lead to use aircraft smaller than the size which offers least costs per seat since for equal provided capacity, adding frequency attracts more passengers than adding seats in one aircraft (WEI and HANSEN 2005).

Service frequency is an important element in generating demand while reducing schedule delays faced by passengers. Schedule delays are related to time passengers loses when there is no flight meeting their needs[9] (GIVONI and RIETVELD 2009). If one intends to go and come on the same day and there is a single flight connecting a pair of cities each day, other suitable modal or airport could be preferred. In fact, schedule delay importance on attracting passengers depends on the value each one assign for his/her time.

2.2. CONCEPTUAL MODEL

Believing either aircraft size or aircraft type changes demand implies on affirming that aircraft model affects stage costs and tickets price as well. Considering traditional supply-demand curves and equilibrium point, it is expected to have customers flying more when prices decrease and flying less when prices increase. Aircraft's operational and acquisition costs are intrinsic to its model and size (SWAN and ADLER 2006) and, of course, imply on tickets prices. Therefore, aircraft with high operational costs would contribute to diminish air transport demand.

As turboprops flow slowly than jets (BRUECKNER and PAI 2009), their flight duration is longer and trend is that more passengers prefer to use different transport option and thus, number of passenger decreases. In other hand, since jets are faster, it is possible to improve frequency linking two points (BRUECKNER and PAI 2009). Most likely result would be the rise of demand once it would be easier to fit passenger's timetable (WONG, PITFIELD and HUMPHREYS 2005) when flying jets.

Likewise any other market, competition among airline-players is a key factor in establishing prices, which by its turn, affect

[7] It is important to highlight that SWAN e ADLER (2006) have studied aircraft manufactured by Boeing and Airbus which are not normally considered as regional aircraft and by their presented results, they have classified flights greater than 1000 km as short-haul flight. This distance is close to upper limit capability of some turboprops assayed in current work.

[8] Considering only Brazilian airlines, total revenue-passenger-kilometer increased 5.81% from 2013 to 2014 according to "Air Transport Demand and Supply" report from ANAC (Brazilian aviation authority) issued on December, 2014.

[9] Schedule delay has two components: frequency delay and stochastic delay. The first one is the elapsed time between a traveler's preferred time and scheduled flight time. The second is the additional elapsed time when preferred flights are already sold out (WEI and HANSEN 2005).

demand. Since quantity of airlines serving each route is not equal among database, number of operating carriers was added in the analysis in order to have competition effect properly captured. Competition also brings different service level which hinders identification of demand generated due to aircraft type. Analysis of airline's business strategy and market share becomes required. Following strategies are currently known[10]: low cost (LC), ultra low cost (ULC) and full-service. Since passengers, like all other customers, have different weights for service quality and price, it is naturally expected that differences in carriers' service attract travelers with different needs. Proposed model includes, besides LC, major class[11]. Latter represents airlines with meaningful market share.

Regional air transport market understanding may lead to think about regional carriers as feeders of mainline companies. Although this is not necessarily true, the model aggregates data about stopover flights in order to investigate regional air transport feeder usage and more than that how demand changes depending on percentage of passengers remain in aircraft after stopovers. According to PAI (2010), airliners use large aircraft when routes involve hubs: seven seats are added per one percent increase in connecting share.

Demographic characteristics such as population and gross domestic product (GDP) of each origin-destination pair are included in the econometric model as a reference of available customers. It is expected that demand for flights connecting two cities enhances together with population (DRESNER, WINDLE and ZHOU 2002)[12] and GDP of the region around both airports. Proposed model sums up this information through geometric mean of GDP per capita and of population itself. These two variables have influence on aircraft size as well: PAI (2010) found that all of them increase together.

In spite of some aeronautics-insider or some environmental-footprint-concerned passengers that could select the aircraft they prefer to fly, this research does not intend to necessarily identify this kind of generated demand. The current econometric model is more likely to answer which is the indirect contribution of aircraft size and type in generating demand.

Based on exposed information in this section and in literature review, the first two raised hypothesis (H1) are that both jets and turboprops positively affect demand, but (H2) jets enhance demand more than turboprops. Third hypothesis (H3) is related to aircraft size: it is believed that small aircraft enhance demand more than large ones since frequency is more important than size. Proposed econometric model is presented on Figure 1, where hexagons indicate either the output variable (demand) or exogenous variables and ellipses indicate variables endogenous to demand. At the end of this work, all hypotheses will be verified and as a result, concluded if and how aircraft size and type affects regional air transport demand.

3. EMPIRICAL MODEL DEVELOPMENT

3.1. APPLICATION

From considerable existing offer[13] in aviation market, Table 1 provides a couple of regional aircraft models which are normally selected for regional air transport. It lists their corresponding engine type and average size. In this study, those aircraft seating from 30 to 120 passengers were considered as regional. Table 1 also indicates whether any Brazilian airliner has

[10] More common than having a company fitting exclusively one of these classes is having airlines that transit through all described business strategies depending on route and period. While low cost carriers reduce their costs aiming to provide a competitive service, they do not necessary sell the cheapest ticket. Ultra low cost carriers are the ones that have lowest fares providing a no-frills service and charging for almost everything: from extra bag to the option of booking a seat. Full-service carriers normally have a higher service level, including first class and in-flight entertainment.

[11] Indeed, all existing classes in database are included through the use of dummy variables.

[12] DRESNER, WINDLE and ZHOU (2002) have used seat capacity instead of demand, but they have considered a constant load factor through all their analysis. Thus, their assumption implies on matching seat capacity to demand.

[13] Not all presented models are still manufactured but old aircraft continue to be sold among airlines until life limit is achieved. Therefore, they remain as an option for airlines when planning their fleet.

operated corresponding model in any domestic route. Figure 2, prepared using Google's resources, presents 64 Brazilian airports which have had at least one commercial regional flight from 2002 to 2012. All flights included herein have both endpoints on two of exhibited airports on Figure 2.

3.2. DATA

This research uses an unbalanced panel data comprising information about 75 Brazilian regional routes from 2002 to 2012. Most of all sampled variables was disclosed by Brazilian state-owned corporations like ANAC (Aviation Authority), IBGE (Statistics and Geography Brazilian Institute), Brazilian Bank of Issue, and INFRAERO (responsible for managing Brazilian airports[14]); and have had 16,501 observations over aforementioned decade. Prior to its inclusion in this study, at least one of each route's endpoint should not be a state's capital.

3.3. EMPIRICAL MODEL

Equation 1, followed by explanation of each used variable, encloses developed model during this research.

$$\begin{aligned} \ln \mathrm{pdew} = \beta_0 &+ \beta_1 \ln \mathrm{yield} \\ &+ \beta_2 \ln \mathrm{quantity\ of\ carriers} \\ &+ \beta_3 \ln \mathrm{\ aircraft\ size} \\ &+ \beta_4 \ln \mathrm{population} \\ &+ \beta_5 \ln \frac{\mathrm{GDP}}{\mathrm{capita}} \\ &+ \beta_6 \ln \mathrm{maxshcond} \\ &+ \beta_7 \mathrm{\ pres\ low\ cost} \\ &+ \beta_8 \mathrm{\ pres\ major\ airline} \\ &+ \beta_9 \mathrm{\ pres\ regional\ TP} \\ &+ \beta_{10} \mathrm{\ pres\ regional\ jet} \\ &+ \beta_{11} \mathrm{\ pres\ mainline\ jet} + \mathrm{u} \end{aligned}$$

"Pdew" contains quantity of passengers per day in each way of the city pair, i.e. demand. Densest route has approximately 1,580 passengers while the one with fewer passengers has thirty ones in each way per day. Source is Infraero, Superintendência de Desenvolvimento Aeroportuário, operational movement data.

"Yield" is a proxy variable for average fares per kilometer per passenger pondered by weekly offered seats. Source: Tarifas Aéreas Domésticas, mid-2013, ANAC attending authors' request. Monetary values updated to December/2013 values through IPCA (Índice Nacional de Preços ao Consumidor Amplo) inflation index calculated by Instituto Brasileiro de Geografia e Estatística (IBGE).

"Quantity of carriers" stands for total amount of airlines flying one specific route. Source is ANAC.

"Aircraft size" represents the average number of seats considering all airplanes flying a specific route. Source: VRA and HOTRAN released by ANAC and some data calculated by authors.

"Population" presents the geometric average using data from both origin and destination cities. Souce is Instituto Brasileiro de Geografia e Estatística (IBGE).

"GDP (gross domestic product) per capita" corresponds to geometric average of origin-destination city pair monthly data. Source: Banco Central do Brasil, Boletim, Seção Atividade Econômica. Gathered in Statistics website Ipea data. Updated to December/2013 values using IPCA inflation index.

"Maxshcond" means percentage of passengers in connection. Souce: INFRAERO.

"Pres low cost" and "pres major airline" are dummies related to airline class and indicate the presence of corresponding class in a specific route. "Major airline" groups TAM and GOL Brazilian airlines, "Low cost carrier" groups AZUL and GOL Brazilian airlines during their initial operating phase. When equal to 1, it indicates the existence of these business strategies in the route while zero means absence. Both equal to zero imply that solely airlines not fitting in these categories such as regional and ultra low cost carriers operate that route.

"Pres regional TP" (turboprops) and "pres regional jet" are dummies variables related to aircraft type and indicate the presence of corresponding aircraft type flying in a specific route. The word "regional" denotes aircraft

[14] Since 2012, INFRAERO shares management of some airports with private companies.

ranging from 30 to 120 seats. When these variables are equal to one, they indicate the presence of airplane models fitting corresponding class; while zero means the absence. Since all routes are obviously served by at least one aircraft, when both “pres regional TP” and “pres regional jet” are equal to zero, either a TP or a jet out of 30-120 seats band is flying that route.

“Pres mainline jet” has the same concept as two other aircraft type dummy variable, but unlike them, indicates jets equipped with more than 120 seats.

“βi” where i ranges from 0 to 11 represents the unknown parameters this study aims to identify.

“u” corresponds to the random error and is assumed as a Gauss curve distributed around zero at a non constant standard deviation (i.e. existence of heteroscedasticity). This error is correlated to endogenous variables.

As shown in Table 2, average size is equal to 106-seat aircraft which is close to seat capacity of planes named as regional aircraft. However, maximum capacity is 221 proving that not only regional aircraft are operated. Both turboprops and jets are used across selected routes.

One interesting point noticed when using Pearsons’ correlation coefficient among yield and other variables is that yield decreases the greater is the aircraft used. Legs operated most by turboprops have greater yield, but the presence of jets diminishes yield.

Regarding to quantity of airlines operating in cities selected for this study, most part of them is served for no more than four airlines. Few city-pairs have even seven carriers, but not necessarily concomitantly. There are airports where no passenger in connection were reckoned and airports where maximum share of 57% was recorded.

Model is formulated in a manner it enables proper hypothesis (H1, H2 and H3) analysis. First hypothesis H1 is related to the leading idea of this work: both jets and turboprops positively affects demand. This hypothesis is easily checked through “pres regional TP”, “pres regional jet” and “pres mainline jet” variables. H2 compares both types of aircraft: jets enhance demand more than turboprops, and is verified through variables “pres regional TP” and “pres regional jet”. Each one of them includes, besides engine type, aircraft size allowing fair comparison between turboprops and jets effects on demand. H3 investigates if small aircraft contribute more to demand than large ones. This belief comes from literature review where demand benefits more from frequency than aircraft size. Last hypothesis is analysed in two steps: first using “ln aircraft size” and secondly, though the same variables mentioned for H1. While “ln aircraft size” provides direct contribution from aircraft’s extent to demand, “pres regional TP”, “pres regional jet” and “pres mainline jet” give the contribution when flying regional aircraft instead of either mainline jets or small turboprops.

3.4. ESTIMATION STRATEGY

3.4.1. STATIONARY AND COINTEGRATION

Presence of unit root on continuous variables (yield, airlines’ quantity, population, GDP per capita, percentage of passengers in connection and aircraft size) was investigated through Augmented Dickey-Fuller and Im-Pesaran-Shin tests. Achieved results did not reject existence of unit root leading to conclusion that data is nonstationary. Panel cointegration is then verified using Pedroni’s test, and as outcome indicates, null hypothesis of no cointegration was rejected.

3.4.2. MULTICOLINEARITY, HETEROSKEDASTICITY, AUTOCORRELATION

It was verified that there is no multicollinearity in used database since variance inflation factor (VIF) was equal to 2.27 while existence of multicollinearty requires VIF greater than 10 as a rule of thumb.

Heteroskedasticity was identified in used data base through White/Koenker and Breusch-Pagan/Godfrey/Cook-Weisberg tests. Due to that, estimator Huber-White-Sandwich was used in order to avoid risk of indication of significance when one variable does not have.

Once autocorrelation on lag 19 was identified using Cumby-Huizinga test, Newey-West procedure was employed in order to adjust standard error estimates.

3.4.3. ENDOGENEITY AND INSTRUMENTAL VARIABLES

Framework estimation was accomplished considering that demand is not solely driven by yield, quantity of airlines (competitors) and aircraft size but demand also drives them. In other words, they may be correlated with unobserved error term u in Equation 1. This is totally true when remembering supply and demand curves from where prices (approximated as yield) are specified. Another unobserved factor is airport features which can limit aircraft size depending on runway length and field level or distort airfares if capacity is lower than demand. When an airport cannot receive more flights, airliners tend increase aircraft size in order to meet demand, while airlines could just improve frequency keeping aircraft size if an airport can receive more flights. Therefore, simply using OLS estimation would provide biased βi coefficients (Equation 1); damaging estimation of aircraft size and type contribution for generating demand. Once main wish is to have coefficients correctly estimated, instrumental variables were employed[15].

Both structural (non-correlated to endogenous variables) and non-structural (correlated to endogenous variables) instruments were selected during model estimation. Whilst latter group includes lagged data of yield, number of carriers and aircraft size; former group lists fuel costs and landing fees per seat and per flight, navigation fees per flight and insurance cost per seat. Whether fuel, insurance and landing fee are related to both aircraft size and yield, navigation costs normally do not depend on aircraft model. Therefore, it is possible to identify effects of each one of the endogenous variables. Through KP, J, CD, KP, Weak_CD and Weak_KP statistics, it is noticed that selected instruments did work well.

3.4.4. ESTIMATOR

The estimation method employed is the equation-by-equation two-step feasible efficient generalized method of moments (2SGMM) estimator with statistics robust to arbitrary heteroskedasticity and autocorrelation. Bandwidth used in the estimation with a Newey-West (Bartlett) kernel was set equal to 19. ANGRIST and PISCHKE (2008) suggest the use of LIML as a crosscheck of over-identified estimates. They specifically refer to crosschecking 2SLS with LIML results, arguing that LIML is less precise but also less biased than 2SLS. Once 2SGMM was used in present paper, its results robustness was crosschecked with the two alternative estimators[16].

4. RESULTS

Table 3 presents two empirical models prepared during this research, being the second one the most preferred (by authors) to understand aircraft size and type contribution to demand generation. Only difference between them is the manner they treat average aircraft size. Whilst the first considers it as exogenous to demand, second one considers it endogenous.

Demand’s dependence on GDP/capita, presence of low cost and major carries, and yield are according to expected results on both models. While increase on ticket prices diminishes demand, higher GDP/capita improves demand. Concerning to airlines business strategy, presence of low cost carriers contribute more for having great demand than presence of major airlines. Both classes, however, contribute to demand generation since service exists.

[15] For comparison purposes, OLS estimation results are presented on Table 4.

[16] Results are available on Table 4.

[17]Reduction on demand contribution from city-pair population, presence of major airlines (Δ = -1.35%) and presence of regional jets (Δ = -1.23%) was perceived when having endogenous aircraft size. Regional TP contribution, however, has augmented 0.76%; while presence of mainline jets diminishes demand 2.2% more. Competition contribution to demand is greater when having endogenous aircraft size. Probably because larger aircraft are normally allows major airlines to specify market price, imposing difficulties to small companies. As discussed in literature review, frequency is more important to demand generation than aircraft size (WONG, PITFIELD and HUMPHREYS 2005) and; although second model has aircraft size more relevant to demand generation than on first model, perception is that frequency effect due to small aircraft usage is clearer when aircraft size is considered endogenous to demand.

One relevant econometric point when comparing both models is related to J p-value. It should be greater than 0.25 in order to have the best GMM2S estimation. Decision by keeping model this way lies on keeping same used instruments on both models in order to allow fare comparisons.

Returning to raised hypothesis, it was confirmed that both jets and turboprops positively affect demand (H1) and small aircraft really enhance demand more than large ones (H3), but jets do not enhance regional air transport demand more than turboprops (H2). All three hypothesis together show that, despite of mainline jets' lower operating cost per seat per km (BRUECKNER and PAI 2009), airlines benefit more from small aircraft on low demanded routes. Furthermore, flying turboprops does not diminish demand even though passengers clearly prefer jets instead of TPs (ARNOULT, 2001, apud DRESNER, WINDLE and ZHOU, 2002).

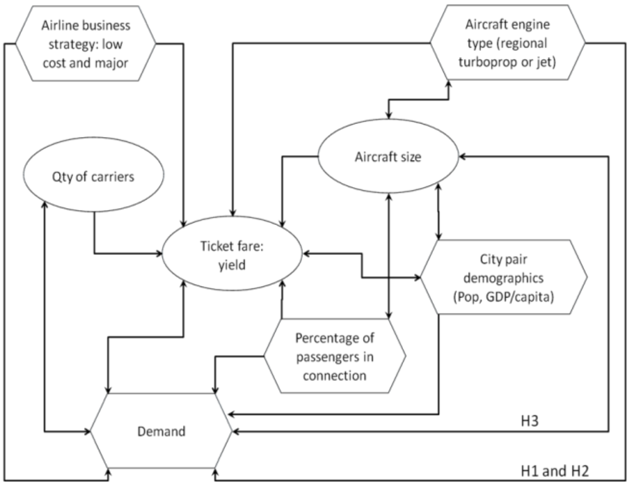

Figure 1 – Econometric model for influences on air transport demand

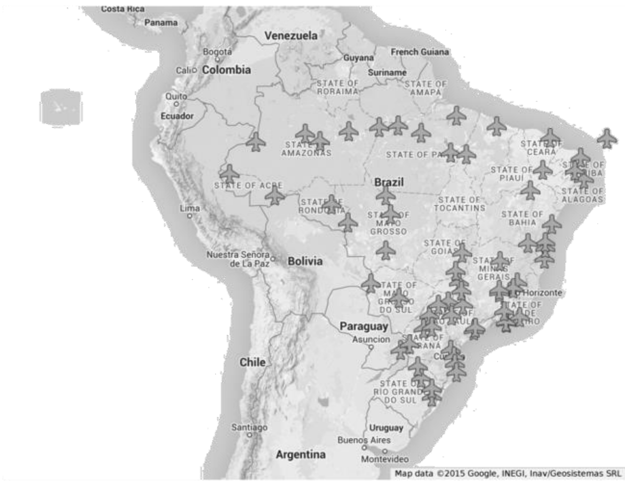

Figure 2 – Studied regional airports

[17] Percentage ratios presented on this paragraph are accrued from Table 3 by index comparison since each variable index indicates variable contribution to the output in analysis.

Table 1 – Regional aircraft

Aircraft	Engine Type	Average Pax[18]	Manufacturer	Flown in Brazil?
EMB 120	Turboprop	30	Embraer	Yes
ATR 42	Turboprop	48	ATR	Yes
F-50	Turboprop	58	Fokker	Yes
ATR 72	Turboprop	70	ATR	Yes
Q400	Turboprop	74	Bombardier	No
ERJ 145	Jet	50	Embraer	Yes
E170	Jet	72	Embraer	No
CRJ 700	Jet	74	Bombardier	No
E175	Jet	80	Embraer	Yes
CRJ 900	Jet	88	Bombardier	No
E190	Jet	100	Embraer	Yes
CRJ 1000	Jet	100	Bombardier	No
E195	Jet	116	Embraer	Yes
F-100	Jet	119	Fokker	Yes
A 318	Jet	120	Airbus	Yes

Table 2 - Descriptive statistics

Variable	Unity	Mean	Std.Dev.	Min.	Max.
demand (pdew)	pax	175.76	186.22	30	1580.58
yield	BRL	0.71	0.32	0.19	1.99
quantity of airlines	-	2.20	1.04	1	7
city-pair pop	persons	3814.73	2347.48	261.13	9166.66
city-pair GDP/cap	BRL/person	1968.97	747.56	489.19	5510.17
maxshcond	%	14	9	0	57
aircraft size	seats	106.27	44.80	18	221

[18] Seating capacity depends both on aircraft size and on configuration selected by airline when buying an aircraft. This table presents average/most typical seat capacity for each model.

Table 3 – Empirical model results estimation using GMM2S[19]

	(1) GMM2S_EXO	(2) GMM2S_ENDO
ln yield	-0.2090***	-0.2002***
	[0.032]	[0.032]
ln quantity of carriers	0.3074***	0.3215***
	[0.026]	[0.026]
ln av aircraft size	0.2818***	0.3804***
	[0.032]	[0.037]
ln city-pair pop	2.8122***	2.6717***
	[0.339]	[0.339]
ln city-pair gdp/cap	0.8252***	0.8202***
	[0.094]	[0.094]
ln maxshcond	0.1062***	0.1101***
	[0.017]	[0.017]
pres young LCC	0.2297***	0.2281***
	[0.020]	[0.020]
pres major	0.0705***	0.0570***
	[0.020]	[0.020]
pres regional TP	0.0956***	0.1032***
	[0.026]	[0.026]
pres regional jet	0.0667***	0.0544**
	[0.022]	[0.022]
pres mainline jet	-0.0097	-0.0317
	[0.026]	[0.027]
Adj_R2	0.8658	0.8660
RMSE	0.3141	0.3139
F	150.145	150.177
KP	395.4973	391.3958
KP_PValue	0.0000	0.0000
J	37.9074	5.2600
J_PValue	0.0000	0.5109
Weak_CD	1.9e+03	1.8e+03
Weak_KP	494.6272	459.3777
N_Obs	13970	13970

[19] Results produced by the two-step feasible efficient generalized method of moments estimator (2SGMM); 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 on Table 4.

Table 4 – Empirical model results estimation using OLS[20], 2SLS[21] and LIML[22] estimators

	(1) OLS	(2) 2SLS	(3) GMM2S	(4) LIML
ln yield	-0.1654***	-0.1976***	-0.2002***	-0.1977***
	[0.027]	[0.033]	[0.032]	[0.033]
ln quantity of carriers	0.2700***	0.3134***	0.3215***	0.3136***
	[0.020]	[0.027]	[0.026]	[0.027]
ln av aircraft size	0.3156***	0.3905***	0.3804***	0.3906***
	[0.033]	[0.037]	[0.037]	[0.037]
ln city-pair pop	2.4715***	2.7056***	2.6717***	2.7058***
	[0.339]	[0.340]	[0.339]	[0.340]
ln city-pair gdp/cap	0.9264***	0.8314***	0.8202***	0.8313***
	[0.091]	[0.096]	[0.094]	[0.096]
ln maxshcond	0.0998***	0.1068***	0.1101***	0.1068***
	[0.017]	[0.017]	[0.017]	[0.017]
pres young LCC	0.2436***	0.2351***	0.2281***	0.2350***
	[0.021]	[0.020]	[0.020]	[0.020]
pres major	0.0925***	0.0586***	0.0570***	0.0586***
	[0.019]	[0.020]	[0.020]	[0.020]
pres regional TP	0.1085***	0.1031***	0.1032***	0.1030***
	[0.026]	[0.026]	[0.026]	[0.026]
pres regional jet	0.0787***	0.0574***	0.0544**	0.0574***
	[0.022]	[0.022]	[0.022]	[0.022]
pres mainline jet	-0.0003	-0.0347	-0.0317	-0.0347
	[0.027]	[0.027]	[0.027]	[0.027]
Adj_R2	0.8643	0.8661	0.8660	0.8661
RMSE	0.3203	0.3137	0.3139	0.3137
F	150.497	148.637	150.177	148.635
KP	.	391.3958	391.3958	391.3958
KP_PValue	.	0.0000	0.0000	0.0000
J	.	5.2600	5.2600	5.2603
J_PValue	.	0.5109	0.5109	0.5109
Weak_CD	.	1.8e+03	1.8e+03	1.8e+03
Weak_KP	.	459.3777	459.3777	459.3777
N_Obs	14706	13970	13970	13970

[20] 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.

[21] Results produced by the two-stage least squares estimator (2SLS); 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.

[22] 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.

5. ROBUSTNESS CHECKS AND LIMITATIONS

Comparing shown results on Table 4, it is possible to note that found coefficients using GMM2S are consistent with those achieved with OLS, 2SLS and LIML estimators, although differences are perceived among all regressors coefficient.

This study relies on assumption that aircraft are chosen according to the route and etc. This way, not all routes have different models and size of aircraft operating. It would be interesting to have the same route operated by dissimilar aircraft for a good period of time.

One limitation from present work is derived from economic and social differences over portrayed decade by used panel data. Technological differences among flown aircraft during this period exist as well: Fokker 100, ATR 72, ERJ-145, Embraer 195 and A318 are based together but they clear have different operational costs and prestige. F100, for example, has been involved in several accidents in Brazil and due to that, its demand could be diminished due to passengers' memoirs. By other side, Embraer aircraft could have been favored by a patriotic choice.

Since analysis considers only the presence of one aircraft type and not how many passengers are effectively transported by each one of them, distortions would be perceived if there is one airline operating a single turboprop flight in a route where dozens of jet flights are operated. Last restriction is related to yield collection: since Brazilian airlines do not publish this data, it was approximated through average data supplied by ANAC, Brazilian aviation authority. Thus, possible differences due to aircraft and carrier practices are not properly captured.

6. CONCLUSION

One scientific contribution from present study is the analysis of aircraft size as endogenous variable and not only like an outcome of demand since most of recent articles reports how airlines attend demand selecting the right aircraft and not how the aircraft size affects demand. The second contribution is the attempt to verify whether it is possible to use a demand generation criteria whilst selecting the suitable aircraft model for flying one specific route.

Although it is perceived that enlarging aircraft size in 1%, the demand enhances in at about 0.38%, when comparing jets at different sizes, it is noted that in-between the same technology, flying small aircraft contributes more to demand than flying bigger aircraft in accordance to WONG, PITFIELD and HUMPHREYS (2005). While the latter observation confirms studies which states that increasing frequency improves demand more than increasing size, the former is more likely to be credited to the decision of enlarging aircraft when demand increases.

Concerning to aircraft types, it was expected to have jets enhancing demand more than turboprops once passengers have a clear preference for jets (ARNOULT, 2001, apud DRESNER, WINDLE and ZHOU, 2002). Achieved result suggests the opposite: when comparing similar aircraft size, the presence of turboprops raises demand 4.88% more than the presence of jets; leading to the conclusion that aircraft type could indirectly be a preponderant factor for generating demand, mainly because airlines usually fly the model with optimal economic performance for each specific route and not because passengers prefer one type than another. The optimal aircraft, from costs economics point of view, is normally the aircraft able to provide the greater return on investment and being able to offer, at the same time, the lowest ticket price which is the most important factor for any supply and demand curve.

Among airlines' business strategy, it was noticed that their existence in its own contributes to demand since they offer the service. Probably due to the lower airfares, low cost carriers, however, play a greater role in generating demand when compared to other business strategies.

Considering all analyzed regressors in this study, population and GDP per capita were the top demand drivers: increment of 1% on them, generates growth of 2.67% and 0.82% in demand respectively. This result is aligned with the common expression: “air transport demand is derivate of economics”.

Several studies could be performed in order to continue present research: 1) analysis of aircraft economics among turboprops and jets in order to identify the optimal operational profile for each one, understanding their costs from different perspectives: from crew to maintenance, going through environmental footprint; 2) investigate relationship among yield, return on investment and aircraft size; 3) check this study using a different country data base and 4) perform a similar study counting transported passengers by each aircraft model instead of amount of passengers per route.

Assaying the main goal of this study which is the understanding if and how aircraft size and type impacts on demand for regional air transport, it is concluded that both aircraft type and size are relevant for generating demand. Pondering Brazilian database, aircraft capacity ranging from 30 to 120 seats contribute much more for improving regional air transport demand than aircraft able to carry more passengers. Twigged differences on aircraft model contribution to demand generation allow stating that a demand generation criteria could be used when selecting an aircraft. Nevertheless, this criterion is more relevant during size decision than on engine type decision.

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