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Article

Air Transportation Income and Price Elasticities in Remote Areas: The Case of Brazilian Amazon Region

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Abstract: The literature, aimed at understanding the income-price elasticity of air passenger demand, bases its analysis on airport movement. The diversity of studies regarding the casualty between air transportation and economic growth are examples. Some studies covering this link, estimate the income-price relationship with the demand considering international traffic. Considering a domestic setting, where this traffic is significant in Brazil, studies related to remote regions are scarce, and the existing ones focus on governmental policies and subsidies. In addition, empirical studies on the theme consenter themselves in developed regions, such as Europe, North America, and Australia. For Brazil, where we find the Amazon region, there are no empirical researches. This paper analyses the price-income elasticity of the demand regarding domestic passengers in air links from remote cities of the Brazilian Amazon. This study uses panel data regression analysis method on a database of domestic scheduled flights of Brazil´s National Civil Aviation Agency. The results show that air passengers involving remote region flights present a lower sensitiveness regarding local income and airline´s price variations than those in flights among capitals. The higher difference is in income-elasticity of the remote city of origin, which is lower than that of the air traffic among capitals.

Keywords: Air transportation; Brazilian Amazon; Demand; Elasticity; Isolated cities

1. Introduction

The structural analysis of the aviation market and the process of prices formation of airlines within their business strategy implantation has been an object of great academic interest (Morlotti et al., 2017). However, the literature targeted to comprehend price-income elasticity of demand for passenger air transportation is still limited (Bijmolt et al., 2005), especially when considered the fact that the sensitiveness of the demand for air transportation and oscillations in prices and income may vary according to the travel characteristics (Brons et al., 2002; Granados et al., 2012a; Granados et al. 2012b; Mumbower et al., 2014).

Despite being important to investigate the price-income elasticity of the demand to comprehend the consumer's decision-making process, the smallest number of studies regarding this issue is understandable because of the shortage of databases containing information on the airfares marketed for the passenger real origin and its destination (Brons et al., 2002). This limitation hinders that estimations for elasticity are calculated beyond the average value of the aviation industry in general, compromising the comprehension of different factors affecting it.

Studies regarding the elasticity in relation to remote cities are also rare - specially in developing countries, where the air transportation assumes an even more strategic character in virtue of the long-distance travels, necessary to ensure connectivity with the rest of the world. This is the case of interior cities of Brazil's North region. Almost the total area of Amazon is located in this region. In addition to the fact of concentrating the biggest biodiversity of the planet, having a central role in the global warming control and in any policy agendas related to the promotion of the sustainable development (Garda et al., 2010), Amazon is also individualized by its logistic void. Interior cities in this region are difficult to access through other means of transportation than the airplane, thus, being the fluvial transportation the most common alternative to it, and, in lesser extent the road transportation, both insufficient and presenting low quality.

In this paper, our goal is to analyse the income-price elasticity of the demand regarding domestic passengers in air links from remote or isolated cities of the Brazilian Amazon. The objective is to discuss such elasticities according to the correspondent elasticities among state capitals of the country, emphasizing the differences found and the necessary factors for the implementation of policies regarding the development of the regional air transportation activity. On the other hand, in a market environment, without subsidies for airlines and passengers, the comprehension of the income-price relationship with the passengers demand is essential for the decision-making concerning the implementation of air links by the companies of the sector.

In order to estimate the income-price elasticity of the passenger demand, this paper uses a methodology of panel data regression analysis for two groups. The first one involves the links with origin in remote cities of the country's North region, while the second involves the links among the capitals of Brazilian states. This analysis achieves a special robustness character in virtue of the provision, by the National Civil Aviation Agency of Brazil (ANAC), of a sample with origin and destination data regarding domestic passengers of regular aviation, as well as the airfares effectively commercialized for each travel, starting in 2011.

In the North region, which is larger than India in territorial extension (it would be the seventh largest in the world if it were a country), the regular domestic air traffic of passengers adopts complex characteristics among its interior cities, within the intra and inter-regional scope, which requires a bigger comprehension among these passenger flows and local economy. In addition of having as case of study a region of international interest and almost unexplored in analysis, which is the Brazilian Amazon, other special characteristic of this paper is that, it considers an openness period of the Brazilian economy and subsequent liberalization of air transportation. For this reason, in addition to estimate and discuss the factors affecting the sensitiveness of the demand regarding the passengers air transportation and the variations in price and income, this paper explores the discussion of market conditions, which, in a liberal scenario, will have a greater influence in the decision of airlines in operating in isolated areas.

The following items of the article are organized this manner: the item 2 shows a review of the articles considered as relevant for the definition of an analytical methodology adequate to the study of remote cities; item 3 describes the methodology adopted; item 4 contextualizes the case of the North Region of Brazil, evidencing its geographic characteristics and the socioeconomic profile; item 5 presents the data used in the research through descriptive statistics; item 6 depicts and discusses the results regarding the application of the methodology; and, concluding, item 7 ends and presents indications for future researches.

2. Materials and Methods

2.1. Literature review

The literature review will focus on a set of articles selected to support the definition of the paper's methodology. The existing approaches aim to scrutinize the passenger air market as a whole (for example, in airports), using the function of demand aggregated by the service as a base of analysis (Oum et al., 1992). The literature related to the theme of this paper is focused on the investigation of geographical, socioeconomic and market factors, which explain a higher (or lower) income-price

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elasticity of demand regarding passengers air transportation, as well as the formation of prices related to this service under a microeconomic perspective (Brons et al., 2002; Granados et al., 2012a; You e Xiong, 2017; Wang et al., 2018).

In general, studies regarding aviation and remote locations are interwoven with regional aviation studies, focusing on the question of subsidies. Then, the following government programs are highlighted: Public Service Obligation (PSO), Social services provided by state-owned airlines, and Essential Air Service (EAS). Such studies are concentrated in specific regions of Asia, Australia, Europe and North America, locations with a transportation network more developed and more integrated than the one found in remote regions of Latin America countries. (Bråthen, 2011; Bråthen e Halpern, 2012; Fageda et al., 2019).

Brons et al. (2002) investigated the determinants regarding the price-elasticity of demand on passengers air transportation sector, aiming to identify the common factors supporting the different estimations found in the literature for the elasticity. The investigation is based on the meta-analysis in which 37 studies were considered, where one or more estimations for price-elasticity of demand regarding passengers air transportation were calculated, leading to a total of 204 observations concentrated in North American, Europe and Australia air markets. In the analysis, Brons et al. consider the elasticity estimations as the dependent variable to be explained by geographical, economic and demographic variables, which information is obtained in each original study investigated. Authors conclude that, in fact, the price-elasticity of demand may vary according to the nature of the travel, the existence or not of other substitute transportation modes, the geographical location for which the elasticity is calculated and cultural differences. Brons et al. also point out that the omission of the income variable in the models analysed introduce a bias in the estimations of price-elasticity of demand, suggesting that it must be systematically maintained in this type of studies.

Bråthen (2011) mapped and analysed seven strategic questions related to the air transportation in remote regions: the need of government support; economies of scale and ticket price process; airport costs and operational costs of airlines; the subsidies level, barriers to entrance and competitiveness in the market environment; bidding process and risk sharing; and remote areas and regional development. The analysis is limited to remote areas within the scope of USA (Essential Air Service) and Canada (Public Service Obligation) government subsidy programs. The author concludes that the quality of the business environment for the promotion of investments in the air transportation system is as relevant as the subsidy policy for the economic development of isolated regions.

Granados et al. (2012a) studied the variation of the price-elasticity of demand regarding passengers air transportation due to the different forms of commercialization (online versus traditional) and due to the different purposes of the travel (leisure versus business). Using a database containing 2.21 million of flight tickets commercialized in USA between September, 2003 and August, 2004 for 47 different routes among North American cities, the empirical analysis used an estimation of ordinary least squares from which it was concluded that, in general, consumers are more sensitive to price variations in markets where research costs are lower, once they have a greater access to the offer of substitute services. The greater access to information causes an increase in the competition through internet, which enables the offer of alternative services inside and outside the airway mode. Authors concluded that the online demand is more elastic than the offline, for passengers air transportation with either the purpose of holiday or business. In addition to this, Granados et al. report that passengers travelling for leisure, present a more elastic demand in relation to the variation in prices than the ones travelling for business.

Bråthen e Halpern (2012) analysed the air transportation in remote regions with the purpose of mapping the critical questions and bottlenecks that must be surpassed so that the sector contributes to the regional economic development in a more efficient form. Authors performed a literature review on the theme and investigated the experience of government programs in Europe and North America. The discussion is limited to situations in which the offer of regional air transportation is only feasible by means of subsidies. Bråthen e Halpern highlight that, in addition to the subsidies, the public policies must be capable of impacting the market environment and operational costs of

airlines as an integral part of a regional development strategy sustained by the air transportation system.

You e Xiong (2017) empirically analysed the sensitiveness of the demand regarding passenger air transportation in China and fluctuations in the income level of the resident population. Considering that there is a strong correlation between the passenger air transportation and economic development, the authors sought to estimate the income-elasticity of demand for the Chinese aviation market. They analysed annual data aggregated for China from the total number of passengers transported by the airlines departing from the country and the available income per capita regarding the resident population between 1995 and 2015. You e Xiong obtained evidences that the demand concerning passenger air transportation in China is elastic in relation to the income for the greater part of the period considered by the research. From the results obtained, authors conclude that, with the accelerated economic growth experienced by China in the last years, the passenger air transportation are becoming, gradually, more popular inside the country.

Wang et al. (2018) sought to analyse the determinants of the price formation process and the demand regarding passenger air transportation in the two most populous and fastest-growing economic countries in the last decades: China and India. Although the both countries present many similarities in several areas, there are substantial differences among their air transport sectors. Private and low-cost airlines dominate the Indian aviation market, while government-controlled airlines are the main operators of the Chinese market. The authors analysed data regarding the main domestic routes inside each country. The sample for India includes the routes connecting the 20 most populous cities of the country, while for China, routes connecting the 20 largest domestic airports were selected. 4.387 observations were considered for the Indian market and 7.865 for the Chinese, which were collected, on a monthly basis, for the period of January 2012 to December 2015. Wang et al. used an approach of two-stage least squares, from which the price-elasticities of the demand, based on a function of structural demand, were estimated. The results reported that the price-elasticity of demand in the Indian passenger air sector (estimated in -2.6) is approximately the double that the one recorded in China (-1.2). Authors conclude that, the greater intra-modal competition in the Indian market, with a higher ingress of low-cost airlines, is a key-factor to explain the higher sensitivity of demand to price variations when compared to the most concentrated Chinese market.

Fageda et al. (2019) investigated the influence of prices and frequencies of different public policies regarding the aerial connectivity in remote regions. Authors highlight that the positive impacts in potential of such policies must be considered in relation to their costs, once the volume of public subsidies may be very elevated. Fageda et al. reinforces that the public policies must play a strategic role in the support to the connectivity in remote areas.

The literature shows that the sensitiveness of demand for air transportation and the oscillations in prices and income may vary according to the characteristics of travel and economic, demographic and geographic factors, which defines its context, in general studies the fluctuation of price-income elasticity of demand throughout the time and their determinants have as a study objective the passengers air transportation as a whole, and focus in international links or air traffic related to the busiest passenger lines. However, the importance of the sector is even higher when it comes to the remote regions, where the air transportation is strategic due to the long-distance travels necessary to connect them to the rest of the world. That way, the lack of studies regarding elasticity in remote regions raises the question: how would this relation be in these locations in which the civil aviation is a key element of the transportation system?

Added to this, is the lack of specific studies regarding Latin America, region presenting a huge territorial diversity, in which the Brazilian Amazon stands out. Located in the macro-region of the North of Brazil, it is a region of international interest by its role in the planet and relevance for the sustainable development. Fenley et al. (2007) discuss the development models in the region, evidencing that the air transportation may play an important role for the sustainability of the Amazon development. Regarding the analytical methodology of the studies, it is observed that the panel data regression analysis has become adequate.

2.2. Methodology

The behaviour of prices and income during the last decades, featured by constant variations and some abrupt changes, makes the use of temporal series beneficial for the calculation of estimations regarding price-income elasticities of the demand for passenger air transportation (Brons et al., 2002). In addition to the time dependency, the price analysis considers the real origin-destination (O-D) of air links, connecting isolated cities, situated in remote areas, with other locations. By virtue of the temporal dependence of explanatory variables, price and income, and with the availability of information for a set of units (O-Ds) under the form of cross-section, the technique of panel data was used.

Also known as longitudinal data, this approach is characterized by repeated observations of a given set of units in cross-section. Therefore, the panel refers to data with the same cross-section units throughout the time. In this, the interest, predictor and explanatory variables are measured on different occasions, commonly, throughout the time, for a same individual or element (in the case of this study, the air links). It is worth mentioning that, in longitudinal studies, the observations of an individual throughout the time are correlated, and the technical statistics considering this dependence are necessary (Twisk, 2013). Among the benefits of the panel data analysis, the possibility of studying the dynamic relations throughout the time and modelling the differences among the individuals is highlighted (Frees, 2004).

It is important to note that, in this study, only links coming from interior (remote) cities of the Brazilian North region are considered the target for the analysis. The links between capitals of Brazilian states (mentioned in this article as trunk-links) are employed as an analysis reference.

The standard linear model used for longitudinal data may be defined by:

$$Y = X\mathrm{B} + \mathrm{E} \tag{1}$$

Where,

$$Y_{NTx1} = \begin{bmatrix} Y_1 \\ \vdots \\ Y_N \end{bmatrix},\ X_{NTxk} = \begin{bmatrix} X_1 \\ \vdots \\ X_N \end{bmatrix},\ \mathrm{E}_{NTx1} = \begin{bmatrix} \mathrm{E}_1 \\ \vdots \\ \mathrm{E}_N \end{bmatrix},\ \mathrm{B}_{kx1} = \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_N \end{bmatrix}. \tag{2}$$

Where:

$$Y_i = \begin{bmatrix} Y_{j1} \\ \vdots \\ Y_{jT} \end{bmatrix},\ X_i = \begin{bmatrix} X_{j11} & \cdots & X_{jk1} \\ \vdots & \ddots & \vdots \\ X_{j1T} & \cdots & X_{jkT} \end{bmatrix},\ \mathrm{E}_i = \begin{bmatrix} \mathrm{E}_{j1} \\ \vdots \\ \mathrm{E}_{jN} \end{bmatrix},\quad \begin{matrix} i = 1, \dots, N, \\ j = 1, \dots, n. \end{matrix} \tag{3}$$

The assumptions made by this model correspond to the ones defined by the classic model of multiple linear regression, however this one does not use the structure of panel data. So, the errors must be *iid* (independent and identically distributed), in addition to homoscedasticity, i.e., for a given individual, the observations are not correlated and, between individuals and time, the variance of the error is constant.

However, the advantage of using the panel data structure is to obtain the analysis of the individuals behaviour in the course of time, resulting in the existence of differences among them (Frees, 2004). This disadvantage may be interpreted as a bigger similarity among observations of the same individual when compared to other individual. The failure in the inclusion of this factor to the model may cause problems of bias in estimators.

Thus, a new model is proposed, which presents a differentiated structure for the term of error, assuming that the differences among the units may be captured through differences in the constant term:

$$Y_{it} = X_{it}\mathrm{B} + \varepsilon_{it}, \quad (4)$$
$$\varepsilon_{it} = \alpha_i + \mathrm{N}_{it}, \qquad \mathrm{N}_{it} \sim iid(0, \sigma^2).$$

So, the equation is summarized in:

$$Y_{it} = \alpha_i + X_{it}\mathrm{B} + \mathrm{N}_{it}. \quad (5)$$

In this formulation, α_i represents the individual effect, presenting variation among individuals and constancy over time, while N_{it} ranges regardless of the individual or time. It is possible to capture the heterogeneity among individuals with a model characterized by this manner (Johnston, 1988). This model, however, may be segmented in others according to the assumptions made regarding the individual effect.

Then, the hypothesis of a fixed or aleatory annual effect must be tested in the model selection. Other important aspect is the characteristic of each link between two airports.

In the panel data analysis, it is necessary to consider in the modelling the existence of fixed or aleatory effects of cross-sections - in this study, the O-Ds of passengers - and time series of data. In order to select the most appropriate model, the following tests are performed: redundant fixed effects (Chow test), omitted random effects (Breusch-Pagan test) and correlated random effects (Hausman test) (Hisao, 2014).

The dependent variable considered in the model is the number of seats sold (PAX), representing the demand for air transportation. The independent variables are the GDP (Gross domestic product) of the origin city (GDPO) and destination city (GDPD), representing the income, and the weighted-average fare of the tickets in the link (PRICE), representing the price. The appropriate effects of each O-D and each period are defined according to the results suggested by the statistical tests performed (fixed or aleatory effects). The tool used to perform the regressions was the econometric software for statistical modelling, Eviews 11 (EViews, 2019).

All variables are related to the annual data, and, regarding the fare, it is the weighted-average in the link. The general model used to estimate the regression parameters is shown in Equation 6. The presence of cross-section effects was significant from the statistical tests performed in the process of selection concerning the most appropriate model.

$$ln\,PA\,X_{i,j,t} = c + \omega_{i,j} + \alpha\, lnGDPO_{i,j,t} + \beta lnGDPD_{i,j,t} + \varphi lnPRICE_{i,j,t} + \varepsilon_{i,j,t} \quad (6)$$

Where,

c: constant

ln: the natural logarithm of the variables;

$\omega_{i,j}$: estimated fixed effect coefficients of cross-sections;

α, β and $\mathfrak{r}$: estimated coefficients in regression model;

$GDPO_{i,j,t}$: GDP of the origin city;

$GDPD_{i,j,t}$: GDP of the destination city;

$PRICE_{i,j,t}$: weighted-average fare of O-D;

$\varepsilon_{i,j,t}$: regression error

3. Results

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3.1. Case study

Brazil is a country with continental dimensions, classified as the world's fifth-largest country in geographical extension and seventh in population size (IBGE, 2018; IBGE, 2019a; CIA, 2020). The country is organized under a form of a federative republic composed by 26 states and a Federal District (the nation's capital), distributed in 5 macro-regions (Appendix A - Annex 1). The North is one of these macro-regions and comprises seven states: Acre (AC), Amapá (AP), Amazonas (AM), Pará (PA), Rondônia (RO), Roraima (RR) and Tocantins (TO). Its biggest and main cities are the capitals Manaus (AM) and Belém (PA), the only ones with a population of more than one million inhabitants (IBGE, 2019a). The following state capitals are also important regional centres: Porto Velho (RO), Macapá (AP), Palmas (TO), Rio Branco (AC) and Boa Vista (RR),

The North has the largest territorial extension among the five macro-regions, covering approximately 45% of the national territory. Amazonas is the largest Brazilian state. It exceeds the sum of the territories of South and Southeast macro-regions. The largest Brazilian municipality is Altamira, in Pará, which is larger than several Brazilian states. The ten cities with the largest territorial dimension in Brazil are located inside the Amazon region (IBGE, 2018). On the other hand, the North region population, accounts for only 9% of the national total. Consequently, the North presents the lower population density among the largest regions of the country (IBGE, 2019a).

The economy of the region contributes with 5,6% of the Brazilian GDP. Five out of the six states presenting the lowest GDP's of Brazil are in the North region. Thus, the economic density and the GDP per capita of the region are also below the national average (IBGE, 2019b).

The major part of the so-called Legal Amazon1 is located in the North region. This is a region of international interest due to its relevance and role regarding the sustainable development of the planet. Its growing importance in the worldwide agenda concerning sustainability is due to the carbon stock, weather, water and biodiversity existing in the region (Araújo e Léna, 2011). Amazon has the largest drainage basin of the planet (one fifth of the world's freshwater reserves) and comprises one of the greatest biodiversity in the world (one third of the world's broadleaf forest reserve), which makes the region strategic for the global weather regulation (Garda et al., 2010; Kauano et al., 2020). Among the potentialities of Amazon, we highlight the mineral reserves found in the region, with emphasis in iron ore, manganese, niobium, oil and natural gas (Araújo e Léna, 2011).

Table 1 illustrates the socioeconomic profile of the North region in comparative terms to the national average.

Table 1 - Socioeconomic profile of the North region and Brazilian Legal Amazon: comparative analysis with the national average

Region	Cities, 2019	Area, 2018	Population, 2019	GDP, 2017	Population density	Economic density	GDP per capita

[1]Legal Amazon is comprised by seven states which are part of the North region, by the state of Mato Grosso (included in the Central-West region), and by the cities of Maranhão state (Northeast region) located at east of the meridian 44º. Legal Amazon covers about 61% of the Brazilian territory (IBGE, 2014b).

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	No.	%	Millions km²	%	Millions inhab.	%	BRL billions	%	(inhab./ km²)	(BRL thousand/ km²)	(BRL thousand)
Brazil	5570	100	8.5	100	210	100	6583.3	100.0	24.7	774.5	31.7
North	450	8	3.8	45	18	9	367.9	5.6	4.7	96.8	20.6
Legal Amazon	772	14	5.0	59	27	13	574.8	8.7	5.4	114.5	21.2

Source: IBGE - Brazilian Institute of Geography and Statistic

The North region presents the most humid weather in Brazil, with a period of a large volume of rains, flooding several areas and roads, which makes access only possible by air. Consequently, since the arrival of the first colonizers to the Brazilian territory, it may be verified that the occupation of Amazon has, as one of its main bottlenecks, the precarious link to the rest of the country (Lima et al., 2012). It is in this Amazonian immensity that the logistics, especially with regard to transportation, face big challenges and barriers to be operationalized, due to the characteristics of the region. The large distances to be crossed are combined to the deficiencies existing in different modes (IBGE, 2017).

The study of Territory Flows and Networks, performed by IBGE, points out an uneven distribution of the density regarding transport logistics network between the North region and the rest of the country, resulting in a complete isolation of certain areas of Brazilian Amazon (Appendix A - Annex 3). In Brazil, the road mode in the transportation logistics prevails, however, the Amazon region is an exception to this rule. In the North region, the passengers water transportation prevails and the distances among municipal capitals are long, resulting in long journey times. The interaction among urban centres is rare, once the transportation is predominantly performed through waterways and therefore slower, considering the fact that the municipal capitals are distant.

The air modal is essential in the transportation logistics of the North region. The regional highway network is insufficient, with low-quality and not so integrated, which makes the North states more dependent of the aviation system for the socioeconomic development and for humanitarian activities (IBGE, 2017). In 2019, 59% of Brazilian roads were assessed as regular, bad or terrible in a research performed by the Brazilian National Confederation of Transport (CNT). In the North region, this percentage was even higher: 77% (CNT, 2019).

Table 2 shows some statistics related to the regular domestic air transportation in remote cities of the North region of Brazil for the period analysed.

Table 2 – Evolution regarding the coverage of regular domestic air transportation in remote locations of the Brazilian North region

Year	Cities	PAX	POP (millions)	GDPO (BRL billions)	PRICE (BRL)
2011	31	633,805	2.526	73.793	290.31
2012	28	680,136	2.340	69.380	311.63
2013	27	781,275	2.376	73.399	300.41
2014	26	755,907	2.335	64.237	355.40
2015	26	746,508	2.409	58.180	323.32
2016	20	482,963	2.084	50.112	314.15

Source: ANAC micro data

It is observed that the number of cities covered by regular air transportation reduces over the years, minimizing the population quantitative (POP) potentially covered by the civil aviation system. The reduction in the total of passengers boarding in airports of the region (PAX) is a result of two movements: first, the economic crisis experienced by the country in the second half of the period, visible in the GDP reduction in remote cities (GDPO), and the second, the reduction of the service offer regarding the air transportation according the lowest number of cities served. The price analysis of air tickets (PRICE) considers the weighted-average of fares practiced in each link of the sample. In order to allow a better comparison among the years, all monetary values used in the study were deflated. The average price of tickets was directly influenced by the behaviour of the Brazilian economy in the period. Between 2012 and 2014, the Brazilian GDP recorded an average growth of +1.8% per year. This rhythm was reduced to an average variation of -3.4% per year in 2015 and 2016.

3.2. Data

The air transportation data used in this study – information regarding origin and destination (O-D) of seats sold and prices of air tickets - is obtained in ANAC microdata base[2], which comprises the value of the fare effectively commercialized and the volume of seats sold per link and per level of fare, per month, in the period from 2011 to 2016. The first step in the sample preparation was the identification of the isolated cities and the annualization of the movement data among O-Ds and the calculation of the weighted-average fare in each link per year. The analysis of the Brazilian territory indicates the North region as the one presenting the largest number of cities located in isolated and remote regions, concentrated in the so-called Legal Amazon.

According to ANAC, this data represents around 50% of the total movement in each year, once the tickets purchased through frequent-flyer programs and specific agreements celebrated between purchasers and airlines do not integrate the basis. The socioeconomic data used in the study, i.e., the GDP regarding the origin and destination municipalities of the travels contained in the sample, are obtained from IBGE.

The database is directional, i.e., it considers the one-way ticket from the interior (remote) city of the North region to intra and interregional destinations. The data refers to the 33 airports with 1.372 O-Ds validated for the analysis in the period. Appendix A presents the map of Brazilian regions, with the location of airports considered in the study (Annex 2), as well as the ICAO acronym of airports, the cities related to each one of them and the identification of the name regarding the corresponding Brazilian state (Table A1).

The analysis model will investigate the relation among four variables, two representing the regular aviation and two representing the economy. The first is the PAX natural logarithm of the city classified as remote or isolated for other in the national territory (LPAX), and the second is the natural logarithm of the average fare applied in air links of the sample (LPRICE). The other two variables represent the economic context through natural logarithms of GDPs of origin (LGDPO) and destination (LGDPD) cities. Table 3 shows the descriptive statistics of the variables considered for analysis in the model.

[2] Available at: www.anac.gov.br/assuntos/dados-e-estatisticas/microdados-de-tarifas-aereas-comercializadas.

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Table 3 - Descriptive statistics of the model variables

	LPAX	LGDPO	LGDPD	LPRICE
Mean	3.67	14.60	16.60	6.75
Maximum	11.47	17.20	20.41	8.34
Minimum	0.00	11.64	10.76	3.68
Std. Dev.	2.41	1.09	1.72	0.47
Observations	5231	5231	5231	5231

The standard average and deviation of the LPAX variable indicate an accentuated variety of flow in links of remote cities. The small standard deviation observed in LPRICE indicates a certain uniformity in the price of tickets. This is because these cities, in general, are distant from economic centers, at distances not so diversified. The difference observed between LGDPO and LGDPD is because the latter includes the economic centers interacting with remote cities. The small standard deviation of both indicates a small size variation of cities.

Some selected cities are touristic cities or cities presenting strategic interest for the country. Tabatinga, in Amazonas state, for example, is a city bordering Colombia, with the city of Leticia beside it - strategic city for the control of Brazilian borders. Tucuruí, in Pará state, is the host city of the municipality where one of the biggest hydroelectric plants in Brazil is located. Santarém, also in Pará state, is a historic city, founded in 1661, which is located at the junction of the Amazonas and Tapajós rivers. Ourilândia do Norte is a city in a mining area in Pará state. Parauapebas, as well in Pará state, is settled in one of the biggest mineral provinces of the planet called Serra dos Carajás, with iron ore, manganese, copper and gold reserves. Coari, in Amazonas state, where there is a significant production of natural gas. Parintins, also in Amazonas state, holds the Parintins Festival (Festa do Boi), which is an annual famous manifestation of the local culture acknowledged and appreciated internationally. In general, each city has an attractive feature which demands more efficient transportation, where public and private interests are connected.

3.3. Results

As described in the methodology, Chow, Breusch-Pagan and Hausman tests were applied for the definition of the effects regarding the model used (no effect or pool; fixed effects; and aleatory effects). The Chow test (Table 4) rejected (value of $p < 0.05$) the null hypothesis of pool estimation for the cross-section, suggesting that the fixed effects would be more appropriate.

Table 4 – Redundant fixed effects tests (Chow test)

Test cross-section and period fixed effects			
Effects Test	**Statistic**	**d.f.**	**p-value**
Cross-section F	11.29	- 13,713,856	0.00
Cross-Section/Period F	8,434.62	1,371	0.00

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The Breusch-Pagan test (Table 5), performed with the purpose of verifying the presence of aleatory effects versus no effect (pool), also rejected the null hypothesis of the pool modelling (value p <0.05), suggesting, in this case, that the aleatory effect would be more appropriate.

Table 5 – Lagrange Multiplier Tests for Random Effects (Breusch-Pagan LM)

	Test Hypothesis		
	Cross-section	**Time**	**Both**
Breusch-Pagan	4220.44	136.29	4356.74
p-value	0.00	0.00	0.00

The next step was the application of the Hausman test. The purpose of this test is to compare the estimation of aleatory effects with the ones of fixed effects. Significant differences among them suggest the inconsistency of aleatory effects estimators. The results of Hausman test (Table 6) point out that the null hypothesis for aleatory effects (value of p <0.05) is rejected, recommending that the modelling developed considers the existence of fixed effects for transversal sections and periods.

Table 6 – Correlated Random Effects - Hausman Test

Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**p-value**
Cross-section random	76.093436	3	0.00

Therefore, the selection process of the most adequate estimator for the proposed analysis in this work pointed out, in this order, that: a model of fixed effect would be more appropriate than the pool approach (Chow test); analogously, an aleatory effect model would be more appropriate than the pool approach (Breusch-Pagan test); and, finally, that the fixed effect model would be more appropriate than the aleatory effect for the section and period (Hausman test). The fixed effect of period was not considered, bearing in mind the fact that the historical series is six years. Thus, after examining different possible options, the regression model of ordinary least squares with panel data and with fixed effect in cross-section was selected as the most appropriate estimator for this analysis.

Table 7 shows the results of the regression model applied, containing the GDPO, GDPD and PRICE elasticities of the demand (LPAX) in O-Ds of remote cities.

Table 7 – Remote Cities Elasticity - Panel least squares regression model

Dependent Variable: ln(PAX)

Cross-section fixed (dummy variables)

Total panel (unbalanced) observations: 5231

Variable	**Coefficient**	**t-Statistic**	**Prob.**

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ln(GDPO)	0.66	6.74	0.00
ln(GDPD)	0.55	3.23	0.00
ln(PRICE)	-0.93	-18.26	0.00
C	-8.88	-2.99	0.00
Adjusted R-squared		0.821	

The explanation level of estimated model (*Adjusted R-square*) is reasonable for the passengers flow in O-Ds of remote cities, given the complexity of estimation. Statistical tests confirm the significance of the income indicators regarding the cities involved in O-D, and the ticket price. All coefficients were inelastic, i.e., lower than 1. However, if we consider the two income indicators ranging together in the same direction, an income-elasticity higher than 1 may be observed. If they range in different directions, one may cancel the other. The price-elasticity of the demand is almost unitary, so that in the case of remote cities, a variation in the demand of an O-D in the same proportion of the price may be expected.

Figure 1 shows the dummy variation of the cross-section fixed effects of remote cities, sorted in ascending order. It shows that the introduction of this dummy absorbed the effect of density difference regarding O-Ds of the sample, allowing the model to estimate the real effect on the passengers demand, from the variations in the income of cities, and from the price of air tickets. The basic motivation for the implantation of links with remote cities will always occur by specific motivators, isolated or jointly, among the O-D locations, as: tourism, energetic resources, mining, agricultural activities, migrations, regional development policies, national defence logistic, among others.

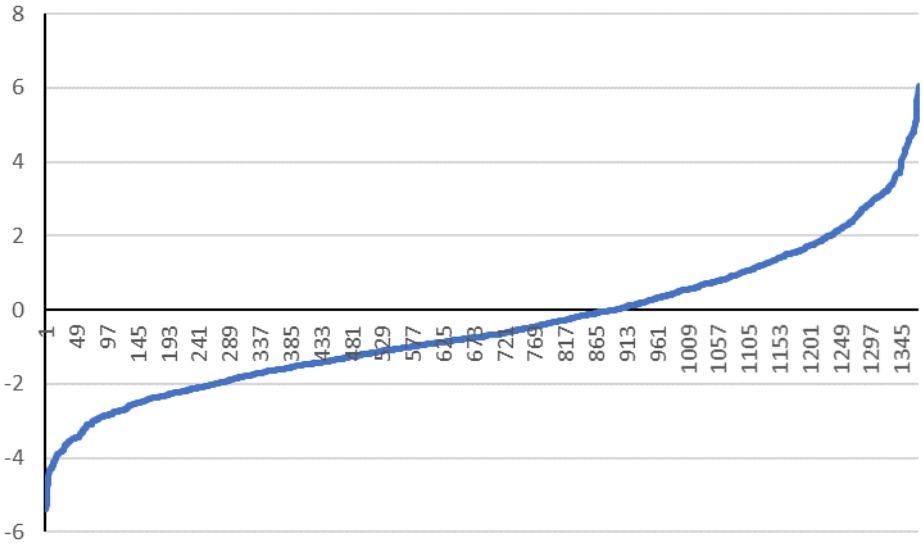

Figure 1 – Cross-section fixed effects remote cities

4. Discussion

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For purposes of comparative analysis and discussion, the same model of regression was applied in the trunk-links, or among capitals. Table 8 shows the results for such links. In this case, 865 O-Ds with valid data were identified.

Table 8 – Main Trunk Elasticity - Panel least squares regression model

Dependent Variable: LPAX

Cross-section fixed (dummy variables)

Total panel (unbalanced) observations: 5141

Variable	Coefficient	t-Statistic	Prob.
LGDPO	1.15	10.54	0.00
LGDPD	0.62	7.11	0.00
LPRICE	-1.03	-32.63	0.00
C	-15.89	-7.51	0.00
Adjusted R-squared		0.956	

The model of O-Ds among capitals (Table 8) shows a level of explanation higher than the one of remote cities (Table 7), observed in the Adjusted R-square of 0.956. All explanatory variables of the demand (LPAX) present statistical tests confirming the significance of estimated coefficients. Figure 2 shows the same characteristics of Figure 1 for the capitals. It is observed that few links have a large adjustment promoted by the dummy. This is due to the case of positive adjustment to the O-Ds observations with the cities of São Paulo, Rio de Janeiro and Brasília. In case of negative adjustments, they are applied to links with state capitals of less developed states, as Roraima and Tocantins.

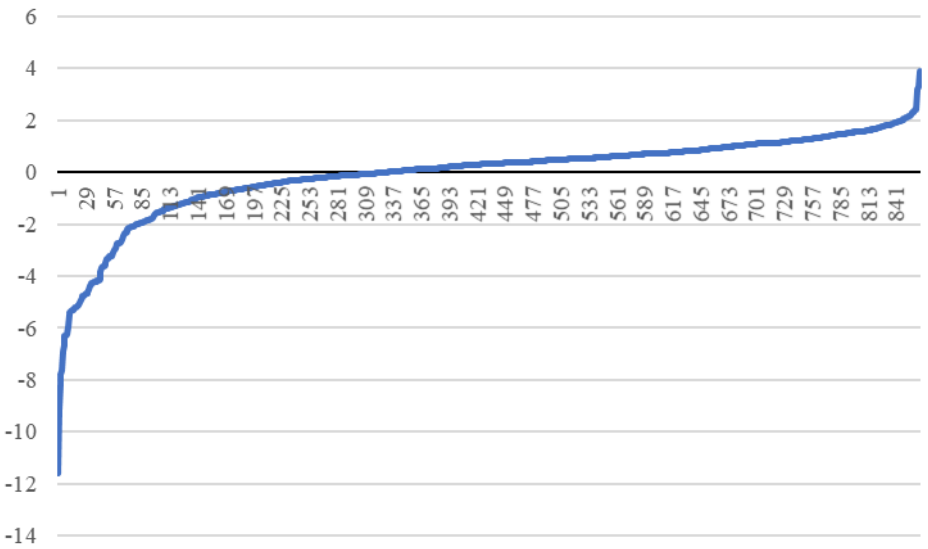

Figure 2 – Cross-section fixed effects capital cities

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Different from the remote cities model, the elasticity of demand in relation to the city of origin is higher than 1, i.e., elastic. Although it is bigger than the one for remote cities, the income elasticity for the destination city is still lower than 1, i.e., inelastic demand. The result of trunk lines is similar to the one observed in You e Xiong (2017), which obtained evidence that the demand for passenger air transportation in China is elastic in relation to the income for the majority of the period considered in the research (1995-2015).

The income-elasticity of the destination city in the demand, on the other hand, is close in both estimated cases. Differences among the income-elasticities of demand regarding links between capitals and remote cities may be considered by planners and decision-makers in the air transportation sector, under penalty of having their demand expectations frustrated, mainly in the case of remote cities. Other question that must be observed is the neutralizing effect in relation to the evolution of the demand that the drop in the income of one of the link cities may have on the growth of the other.

According to the report from Brazilian Secretariat of Civil Aviation (SAC, 2014), most part of domestic air travels in the North region of the country are for business/study purposes. This finding indicates a lower sensitiveness to price, mainly in remote cities, where there is no competition of other modes and, in many cases, only one company is able to offer the service. Consequently, the estimation of non-elasticity price regarding the demand in remote cities is expected. The movement among capitals presents a small price-elasticity, which may be interpreted as an inefficiency of the Brazilian market, which shows a low competitiveness in the sector. Brazil presents one of the lowest price-elasticities of demand among the estimations of related studies. For example, Brons et al. (2002), considering 37 studies regarding air links in North America, Europe and Australia, found values for price-elasticity of demand concentrated in the range of -1.0 to -2.0. Mumbower et al. (2014), considering the main North-American airlines, estimated in -1.97 the price-elasticity of the demand. Wang et al. (2018), upon assessing the main airports and cities of China and India, conclude that, in the Chinese market, this elasticity is -1.2, while in Indian market is -2.6.

The geographical extent and the logistical void of the Brazilian North region are important explanatory factors for the different estimations regarding price-income elasticity of demand. The possibility of alternative modes of transportation and, consequently, the value of elasticities is directly related to the access difficulty. Long distances and difficulties of construction regarding terrestrial accesses, due to the geographical conditions of Amazon, are associated to less alternative possibilities of displacement, resulting in a greater stiffness in the demand regarding air transportation to variations in price and income (Brons et al., 2002).

5. Conclusions

Results show that the demand for passengers air transportation for links coming from remote cities of Brazilian Amazon is inelastic to variations in price and income. This is an important factor for the planning of the air transportation in the region, once the major part of studies indicates elasticities bigger than 1 of these two items. Other important evidence is that the income has a bigger influence than the ticket price on the decision regarding the use of air transportation. The separation between income-effect of the origin city and destination city offers a new perspective to the planner, once future scenarios regarding the income evolution may differ from one city to another.

Although the estimations of the representativity regarding price income elasticity of demand related to the air transportation are lined up with other studies, it is observed that, in Brazil, such

elasticities are found in the lowest levels observed in the literature. This indicates a fragility in the country regarding the competitiveness in the domestic air market. The standardization of the fleet of Brazilian airlines in large-size airplanes (Cabo et al., 2020) may be a limiting factor to the competition in low-density routes.

Therefore, this paper also contributes for the analysis of the demand behaviour for passengers air transportation in a market situation without the presence of subsidies. It offers elements for the discussion regarding the market conditions, which will have a major influence in the decision of airlines to operate in remote areas. In a market environment, without subsidies for airlines and passengers, the comprehension of the price-income relation with the demand of passengers is essential for the decision-making related to the implementation of air links by the companies of the sector, as well as for the implementation of policies for the development of the regional air transportation activity. In addition to subsidies, the public policies must be capable of developing the market environment for the airlines as an integral part of a regional development strategy for the Brazilian Amazon, leveraged by the air transportation system.

The research on air transportation and remote cities in the Latin America is still limited and has relevance on different aspects, and the most prominent of them is the environmental concern regarding the occupation of areas as the Brazilian Amazon. However, the sustainability of the development requires the concern with the environment to be always combined with the socioeconomic agenda, which is what defines people's living conditions. In the study line of this article, it may be suggested that an item to be strongly discussed would be the identification of some seasonal pattern for the behaviour of elasticities according to the characteristics of the region. The analysis may be also enhanced by some segmentation related to the travel motivation (business versus tourism) and the behaviour of the elasticities for each passenger profile.

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Appendix A

Annex 1

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Fig. A1. Macro-regions of Brazil.

Annex 2

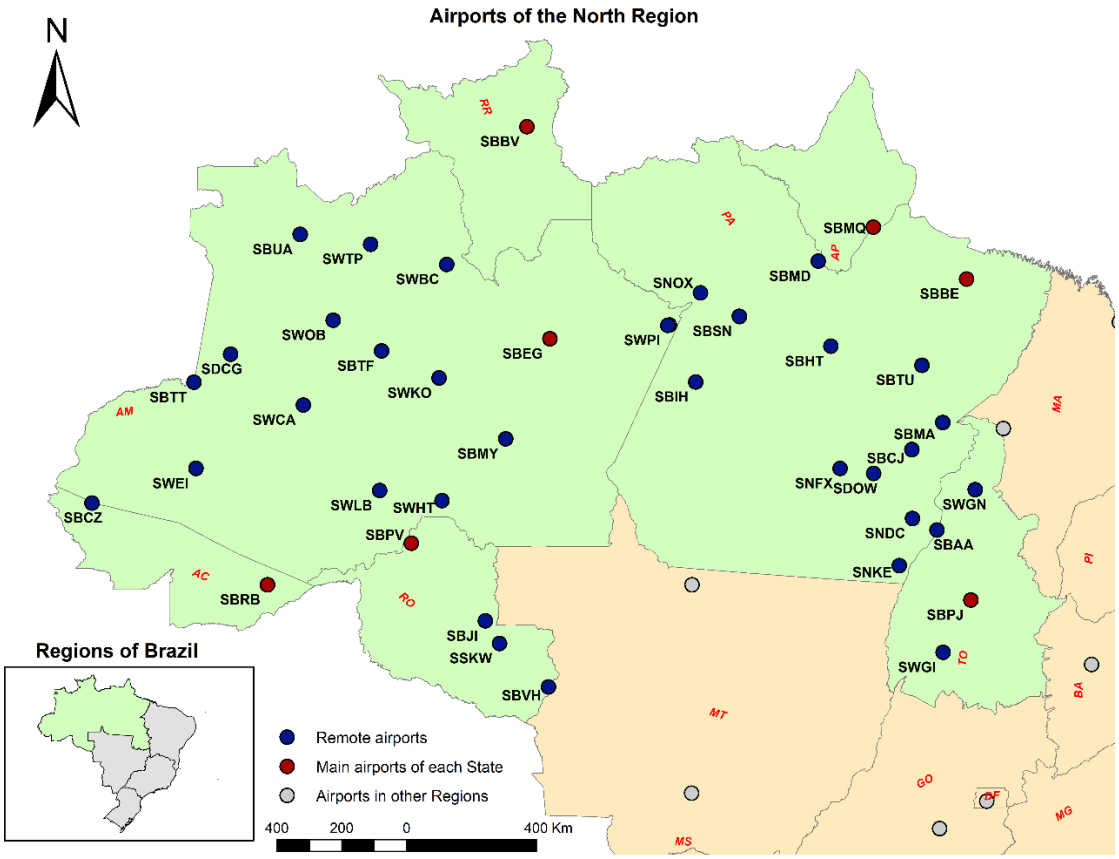

Fig. A2. Location of the Brazilian North region airports with regular air transport during the period of analysis.

Annex 3

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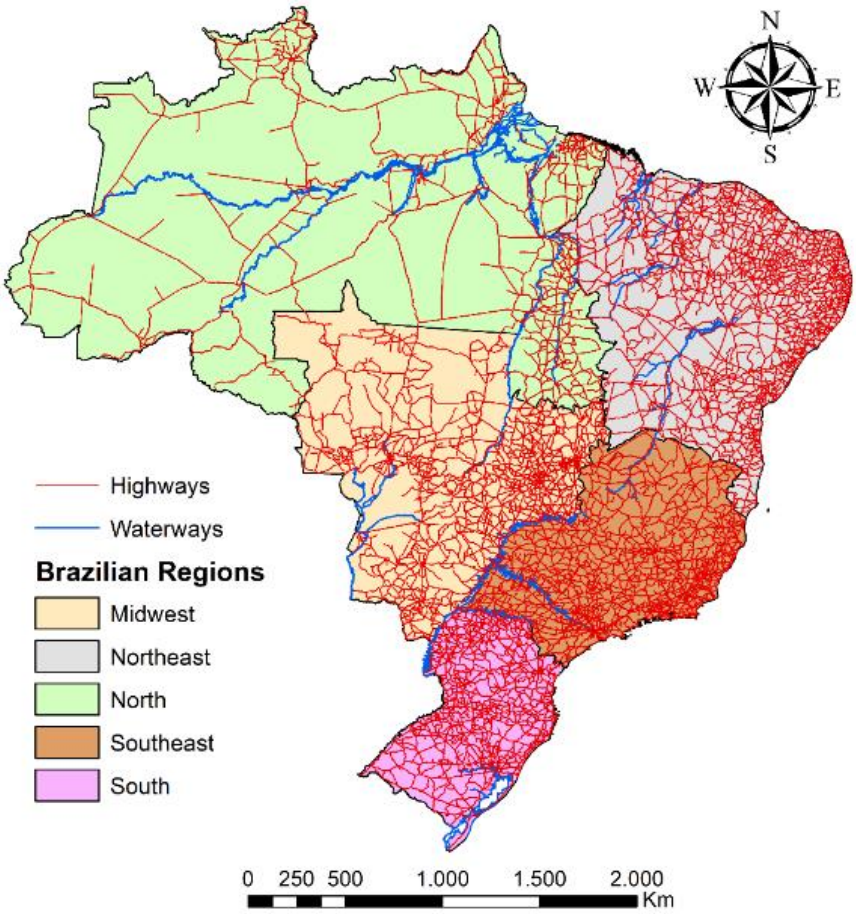

Fig. A3. Infrastructure of roadways and waterways in Brazil (IBGE, 2014a).

Table A1 Airports in each city. State and number of cities of North region – ID related to Fig. A2.

ICAO	City/County*	State	Number of cities/counties
SBCZ	Cruzeiro do Sul	Acre (AC)	1
SWBC	Barcelos	Amazonas (AM)	14
SWCA	Carauari		
SWKO	Coari		
SWEI	Eirunepé		
SWOB	Fonte Boa		
SWHT	Humaitá		
SWLB	Lábrea		
SBMY	Manicoré		
SWPI	Parintins		
SWTP	Santa Isabel do Rio Negro		
SBUA	São Gabriel da Cachoeira		
SDCG	São Paulo de Olivença		
SBTT	Tabatinga		
SBTF	Tefé		
SBMD	Almeirim	Pará (PA)	13

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SBHT	Altamira		
SBAA	Conceição do Araguaia		
SBIH	Itaituba		
SBMA	Marabá		
SNOX	Oriximiná		
SDOW	Ourilândia do Norte		
SBCJ	Parauapebas		
SNDC	Redenção		
SNKE	Santana do Araguaia		
SBSN	Santarém		
SNFX	São Félix do Xingu		
SBTU	Tucuruí		
SSKW	Cacoal	Rondônia (RO)	3
SBJI	Ji-Paraná		
SBVH	Vilhena		
SWGN	Araguaína	Tocantins (TO)	2
SWGI	Gurupi		

* In this study, the municipality host city has the same name of the municipality, and the socioeconomic data are those regarding the municipality.

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