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Economic Growth Relations to Domestic and International Air Passenger Transport in Brazil

Manoela Cabo da Silva, Elton Fernandes, Ricardo Pacheco, Heloisa Pires

Abstract**—**This study examined cointegration and causal relationships between economic growth and regular domestic and international passenger air transport in Brazil. Total passengers embarked and disembarked were used as a proxy for air transport activity and gross domestic product (GDP) as a proxy for economic development. The test spanned the period from 2000 to 2015 for domestic passenger traffic and from 1995 to 2015 for international traffic. The results confirm the hypothesis that there is cointegration between passenger traffic series and economic development, showing a bi-directional Granger causal relationship between domestic traffic and economic development and unidirectional influence by economic growth on international passenger air transport demand. Variance decomposition of the series showed that domestic air transport was far more important than international transport to promoting economic development in Brazil.

Keywords**—**Air passenger transport, cointegration, economic growth, GDP, granger causality.

I. Introduction

HOW the air transport industry contributes to countries' economies is a subject for heated debate in the sector. The arguments in this regard rest on economic calculations of direct, indirect, induced and tourism-catalytic impacts on countries' GDP. In Brazil, the Brazilian Airlines Association (Associação Brasileira de Empresas Aéreas, ABEAR) has led this discussion in its periodical reports [1]. In fact, the discussions of the impact of air transport published in technical reports by ABEAR [1] and international institutions, such as the Air Transport Action Group (ATAG) [2], are more related to the air transport's share in the country and world GDPs than to the problem of causality.

The industry is intensive in three scarce economic resources: financial capital, technology, and human capital. Since 2015, Brazil has entered one of the most difficult periods in its economic history, with the economy showing signs of weakening and increasing austerity in capital spending and, in 2015, went into recession, as GDP contracted by 3.8% [1]. A series of air transport-related measures have been taken as one avenue to restoring sustainable economic growth in Brazil. These include the liberalisation of domestic and international air transport, bilateral agreements to distend operating limits and extend freedoms of the air, airport concessions and campaigns to attract international mega-events. Fernandes and Pacheco [3], using passenger-kilometres as a proxy for *domestic* air transport, only transport inside the country, found evidence of cointegration and one-way causality between domestic air transport and GDP. However, their analysis considered neither passengers embarked and disembarked at airports nor international passenger movement. The cutbacks in connections and in Brazilian airline fleets in 2016 demonstrate that their analysis was correct. International and domestic movements display different dynamics. The literature on the subject is in general agreement that there is a relationship between GDP and passenger transport, but the behavior that relationship takes at any given time or country is unknown. This study examined for the existence of cointegration, and the direction of causality, between GDP and domestic and international passenger movement at airports in Brazil. That information is important for decision making on incentives and resource allocation in air transport industry infrastructure in Brazil.

Manoela Silva is with the UFRJ-Federal University of Rio de Janeiro, Brazil (e-mail: mcabo@impa.br).

II. Literature Review

A number of published studies relate air transport growth to government measures to liberalise prices, extend freedoms of the air and privatise infrastructure. Some relate air transport to income expressed by GDP or per capita GDP. However, few studies venture to explain the related causality. In particular, studies of Granger causality among macroeconomic series have been little used in relation to air transport.

Kuledran and Wilson [4] investigated for the existence of a relation between international trade and international travel flows between two countries. They tested relations between Australia and another four countries using the cointegration and Granger causality approaches as technical support. Kuledran and Wilson [4], concluding that such a relationship does exist, proposed research that continues in this direction. Chang and Chang [5], in Taiwan, examined for the existence of a causal relationship between expansion in air cargo movement and economic growth. Their findings showed bi-directional causality between these variables, indicating that expansion in air-transported cargo movement played an important role in promoting Taiwan's economic growth.

Fernandes and Pacheco [3] tested for a causal relationship between economic growth and domestic air passenger-kilometres in Brazil. Using the Granger causality methodology, they found a unidirectional relationship between GDP and domestic revenue-passenger kilometre. Marazzo et al. [6], studying the behavior of domestic air passenger-kilometres demand and GDP in Brazil, reached findings quite similar to those of Fernandes and Pacheco [3].

Button and Yuan [7] examined the potential for air transport to play a role in economic development in the United States. They analysed trends in employment and income in metropolitan areas with airports processing air cargo. Using Granger causality on panel data from 35 airports and 32 metropolitan areas, they concluded that air transport is a positive driver for local economic development. Mehmood and Kiani [8] examined the hypothesis that, in Pakistan, growth in aviation preceded economic growth. They tested for Granger causality between these variables and concluded that aviation demand contributed positively to economic growth. Mehmood and Shahid [9] tested for causality between aviation and economic growth in the Czech Republic. Their empirical results revealed cointegration between aviation demand series and economic growth. Applying the Granger test to discover the direction of the causal relationship among these series revealed that aviation demand contributed positively to economic growth.

Van De Vijver et al. [10] analysed trade and passenger traffic on selected Asian-Pacific links. Using Granger causality analysis, they discovered – among other things – that, on the South Korea link to the Philippines, passenger traffic was facilitated by trade and that the opposite occurred on the Australia-Malaysia link. Hu et al. [11] examined the Granger causal relationship between domestic passenger traffic and GDP in 29 provinces in China, using heterogeneous panel data models. Granger causality tests indicated bidirectional causality between GDP and passenger movement. In the short run, however, only domestic passenger traffic displayed a causal effect on GDP.

Rodríguez-Brindis et al. [12] analysed for long-run effects between air transport demand and economic growth in Chile. They concluded that a long-run relation does exist between airport passenger movement and economic growth, in addition to there being positive bidirectional Granger causality between these variables in Chile. Baker et al. [13] ascertained the catalytic impacts of regional air transport on regional growth in Australia. Their analysis used passenger movement at 88 airports to represent the activity, whereas representing economic growth by real aggregate taxable income. They found a two-way relationship between regional air transport and local economic growth, pointing to a need for investment in regional airports.

From the literature review, it can be seen that research analyzing causal relations between air transport and macroeconomic variables, such as GDP and foreign trade, are still quite scarce and directed towards specific problem, leaving various lines of research under-explored. The studies reviewed show that causal relations behave differently in different regions. The few studies show that it is important to learn how passenger movement behaves in specific regions in order to develop public policies for the air transport industry.

III. Methodology

The methodology of this study follows the procedures for analysing causality among time series known as Granger causality. As noted by Soytas and Sari [14], Granger causality tests relate to the causality observed in the period of the series under study. In order to investigate the dynamic behaviour of the model, the variance decomposition in these series must be analysed. Accordingly, the methodology described below is designed as a robust test for causality in the time series presented for Brazil, by analysing for stationarity, cointegration and, lastly, causality in the explanatory series, as regards variation in international passenger demand in Brazil. The short-run impact of the explanatory variables was assessed by way of variance decomposition analysis (VDC) for the models used. VDC provides information about the relative importance of each random innovation affecting the variables in the model. Examination of the inverse impact, i.e. impact of international passenger movement on the explanatory variables, lies outside the scope of this study. The inverse effect would not be significantly representative, given the small percentage of GDP represented by air transport in the Brazilian economy. Accordingly, the VDC analyses the impact of innovations in the explanatory variables on international passenger, *PAXINT*.

The first step in the analysis was to ascertain whether the series are stationary, which is a necessary condition for time series analysis. If the hypothesis of non-stationarity I(1) is confirmed, the series have to be transformed in order to proceed with the analysis. A first transformation is the natural logarithm (log) of the series. Following that, the Augmented Dickey-Fuller (ADF) test [15]-[17] can be performed to determine the number of differences that make the series stationary. However, two or more non-stationary series may have a linear combination that is stationary. In that situation, they would be cointegrated. Accordingly, a second step is to test for cointegration among the series, with a view to assessing long-run relations among them. This step is required in order to determine the type of Granger causality test to be applied. The test of cointegration used a p-order Vector Autoregressive (VAR) model, as in (1) [18], [19].

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + Bx_t + \in_t \tag{1}$$

where y_t is a k-vector of non-stationary variables I(1), x_t is a d-vector of deterministic variables and $\in_t$ is a vector of innovations. The widely-used Johansen methodology rewrites (1) as in (2) [18], [19].

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \in_t \tag{2}$$

where

$$\prod = \sum_{i=1}^{p} A_i - I \quad \text{and} \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j \tag{3}$$

The Granger representation theorem states that if a matrix of Π coefficients has the rank $r<k$, then there exist matrices α e βk x r, each with rank r, such that $\prod = \alpha\beta'$ and $\beta' y_t$ is stationary, I(0) [20]. The rank r is the number of cointegration relations and each column of β is the cointegration vector. The likelihood ratio tests the hypothesis that there are at least r vectors of cointegration and is known as the Trace statistic test.

In the event the series are not cointegrated, the direction of causality can be determined by the F-standard test on the VAR. That is achieved by estimating the bivariate equations (4) and (5):

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + ... + \alpha_l y_{t-l} + \beta_1 x_{t-1} + ... + \beta_l x_{-l} + \varepsilon_t \quad (4)$$

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + ... + \alpha_l x_{t-l} + \beta_1 y_{t-1} + ... + \beta_l y_{-l} + \upsilon_t \quad (5)$$

for all possible pairs of the series *(x,y)* in the group. Thus, the Wald F-statistic test is used to detect whether Granger X causes Y [21]-[23] for the joint hypotheses (6).

$$\beta_1 = \beta_2 = ... = \beta_l = 0 \quad (6)$$

The Granger representation theorem states that, if two series are cointegrated, their long-run equilibrium will be represented by the Error Correction Model (ECM) [20], [24].

Equations (7) and (8) of the ECM indicate the short- and long-run relations among the cointegrated series:

$$\Delta Y_t = \lambda + \alpha_1 \Delta Y_{t-1} + ... + \alpha_i \Delta Y_{t-i} + \beta_1 \Delta X_{t-1} + ... + \beta_j \Delta X_{t-j} + \varphi z_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta X_t = \lambda + \alpha_1 \Delta Y_{t-1} + ... + \alpha_i \Delta Y_{t-i} + \beta_1 \Delta X_{t-1} + ... + \beta_j \Delta X_{t-j} + \varphi z_{t-1} + \varepsilon_t \quad (8)$$

where λ is a constant, both *i* and *j* are the numbers of lags that are sufficiently large to make the disturbance term, ε_t, is the white noise and Z_{t-1} is the cointegration vector, as in (9):

$$z_{t-1} = Y_{t-1} - \omega_0 - \omega_1 X_{t-1} \quad (9)$$

All terms in the equation are I(0). Z_{t-1} is included in the ECM as an error-correction term. The coefficients β_j's of ΔX_{t-j} in (7) reflect the immediate response of *Y* to a change in *X*. In the same way, in (8), the α_i's of ΔY_{t-i} reflect the immediate response of X to a change in Y. These coefficients represent the short-run elasticities of their variables with respect to the corresponding dependent variables. In the error-correction term, the cointegration vector, Z_{t-1}, represents the long-run equilibrium among the variables. The coefficient, ω_1, of X_{t-1} is thus the long-run elasticity of *Y* with respect to *X*. The ρ-coefficient of Z_{t-1} measures the speed of adjustment to short-run equilibrium as compared to long-run equilibrium. The t-statistic tests of the coefficients show whether or not each is different from zero.

In Granger causality testing, it is important to bear in mind that the expression "Granger *X* causes *Y"* does not entail that *Y* is an effect or result of *X*. Granger causality measures precedence but does not in itself indicate causality in the common-sense meaning of the term. The economic argument is fundamental to accepting causality in the common sense.

IV. Case Study

Brazil ranks as one of the world's largest national passenger air transport markets and, by 2029, is forecast to become the fourth largest after the USA, China and India. As regards international traffic, Brazil lies off the world's major air transport routes, reducing the potential for interaction with leading markets [25].

This study examines how GDP relates to total domestic passengers embarked and disembarked (*PAXDOM*) from 2000 to 2015 and to total international passengers embarked and disembarked (*PAXINT*) from 1995 to 2015. The GDP series was obtained from Brazil's Instituto de Pesquisas Econômicas Aplicadas (IPEA), which publishes aggregate economic data, whereas the domestic and international passenger series were drawn from the Agência Nacional de Aviação Civil (ANAC). GDP is given in million reals at constant 2013 prices. Domestic and international passengers transported are expressed in millions. The study was conducted using the natural logarithm of the historical series. The variables are thus represented by the natural logarithms of PAXDOM (*logpaxdom*), of PAXINT (*logpaxint*) and of GDP (*loggdp*).

A. GDP and Domestic Passenger Movement

For the stationarity test, it was opted to use Augmented Dickey-Fuller (ADF) unit root test [15]-[17]. The null hypothesis considered: "GDP has unit root" – indicates that they are not stationary at level and a first difference was applied. The ADF test statistic with a first difference was -3.634 and a p-value of 0.0126, the null-hypotheses was rejected with 90% of confidence. Similar was observed in PAXDOM, as shown in Table I, a first difference was necessary to became stationary.

TABLE I
AUGMENTED DICKEY-FULLER UNIT ROOT TEST

Null Hypothesis: Series has a unit root		
ADF test Statistic	t-Statistic	Prob.*
D(LOGGDP)	-3.634	0.0126
D(LOGPAXDOM)	-2.717	0.0974
D(LOGPAXINT)	-3.524	0.0182

*MacKinnon one-sided p-values [26].

The Johansen test of cointegration was then applied. As shown in Table II, the results revealed that, for the various models tested, there exists at least one valid equation of cointegration and that, in two cases, there are two equations. It can thus be assumed that the series are cointegrated.

TABLE II
JOHANSEN COINTEGRATION TEST SUMMARY FOR *PAXDOM*

Number of Cointegrating Relations by Model (0.05 level*)					
Data Trend:	None No Intercept No Trend	None Intercept No Trend	Linear Intercept No Trend	Linear Intercept Trend	Quadratic Intercept Trend
Test Type			Series: *loggdp, logpaxdom*		
Trace	1	2	2	1	0
Max-Eig	1	2	2	0	1

*Critical values based on MacKinnon-Haug-Michelis [27]

The finding that the series are cointegrated recommends causality analysis using vector error correction (VEC). Table III shows the VEC results for Brazilian *loggdp* and *logpaxdom*. The cointegrating equation selected for the model was linear, intercept and no trend.

TABLE III
VEC ESTIMATES FOR *PAXDOM* - PERIOD 2000-2015

Cointegrating Equation	z_{t-1}	
loggdp(-1)	1.000000	
logpaxdom(-1)	-0.360499	
	[-38.4282]*	
C	-17.96177	
Error Correction:	*D(loggdp)*	*D(logpaxdom)*
z_{t-1}	1.450173	3.127088
	[2.69362]*	[3.46858]*
D(loggdp(-1))	-1.623752	-2.884983
	[-2.21517]**	[-2.35031]**
D(loggdp(-2))	-1.082929	-1.645512
	[-1.78679]**	[-1.62132]***
D(logpaxdom(-1))	0.205288	0.841251
	[1.48012]***	[3.62204]*
D(logpaxdom(-1))	0.302482	0.132436
	[1.79382]**	[0.46901]
C	0.067240	0.144609
	[2.51066]**	[3.22443]*
R-squared	0.525590	0.788706
Adjusted R-squared	0.186727	0.637782

Sample (adjusted): 2003 - 2015. Included observations: 13 after adjustments
t-statistics in [ ] (*) 99%, (**) 95%, (***) 90%

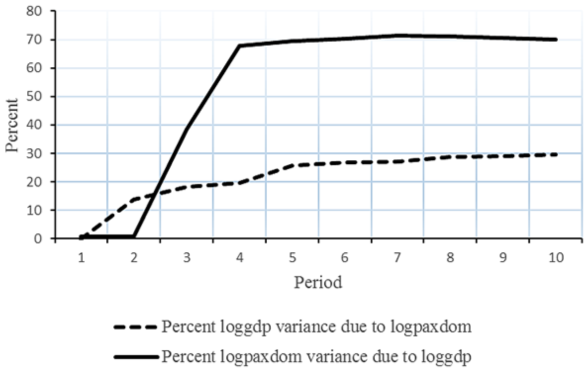

Fig. 1 Variance decomposition of *loggdp* and *logpaxdom*

Table III shows a long-term, two-way relation between the two variables, which can be ascertained by the tests of significance of the Z_{t-1} coefficients of *D(loggdp)* [2.69362] and of *D(logpaxdom)* [3.46858]. Short-term relations also proved to be significant and two-way in tests of the coefficients of the lag variables. However, it can be seen from the coefficients that the impacts are of differing proportions. The short-term relation of *D(logpaxdom)* to *D(loggdp)* is inelastic, with coefficients of 0.205288 for the first lag and 0.302482 for the second. In the opposite direction, the relation can be seen to be elastic, i.e., 1% variation in *D(loggdp(-1))* produces 2.88% first-lag and 1.64% second-lag variations in *D(logpaxdom)*. From the decomposition of accumulated variance shown in Fig. 1, the percentage variance of l*oggdp* due to *logpaxdom* can be seen to increase to around 30% over 10 periods. In the opposite direction, accumulated variance decomposition also shows increasing influence, already reaching around 70% in the fourth period, where it stabilises.

B. GDP and International Passenger Movement

The first difference of PAXINT can be considered stationary, the ADF test statistic was -3.524 and a *p-value* of 0.0182, rejecting null hypotheses of unit root, as shown in Table I. Previously, it was observed that the first difference of LOGGDP is stationary.

The Johansen test of cointegration was then performed. The results shown in Table IV indicated at least one cointegrating equation in each of the five models. Three models returned two cointegrating equations.

TABLE IV
JOHANSEN COINTEGRATION TEST SUMMARY FOR *PAXINT*

Number of Cointegrating Relations by Model (0.05 level*)					
Data Trend:	None No Intercept No Trend	None Intercept No Trend	Linear Intercept No Trend	Linear Intercept Trend	Quadratic Intercept Trend
Test Type	Series: *loggdp, logpaxint*				
Trace	1	2	2	2	1
Max-Eig	1	2	2	2	1

* Critical values based on MacKinnon-Haug-Michelis [27]

Given that the series are cointegrated, causality analysis using VEC is recommended. Table V shows VEC results for Brazilian *loggdp* and *logpaxint*. The cointegrating equation selected for the model was linear, intercept and no trend.

TABLE V
VEC Estimates for *PAXINT* - Period 1995-2015

Cointegrating Equation	z_{t-1}	
loggdp(-1)	1.000000	
logpaxint(-1)	-0.453098	
	[-14.2843]*	
C	-17.81063	
Error Correction:	*D(loggdp)*	*D(logpaxint)*
z_{t-1}	0.142902	1.319728
	[1.12499]	[5.56746]*
D(loggdp(-1))	0.048717	-1.729380
	[0.10907]	[-2.07486]**
D(loggdp(-2))	0.030429	-2.571034
	[0.06385]	[-2.89115]*
D(logpaxint(-1))	-0.052779	0.284944
	[-0.48710]	[1.40919]***
D(logpaxint(-2))	0.007174	0.365173
	[0.07199]	[1.96381]**
C	0.023249	0.125058
	[1.21538]	[3.50330]*
R-squared	0.171400	0.781325
Adjusted R-squared	-0.173849	0.690210

Sample (adjusted): 1998 2015. Included observations: 18 after adjustments
t-statistics in [ ] (*) 99%, (**) 95%, (***) 90%

Table V shows that, even though the series are cointegrated, Z_{t-1}does not influence *D(loggdp)*, indicating no long-term effect, and nor do the lag coefficients of *D(logpaxint)* return significant t-statistics, indicating no short-term influence. Indeed, none of the coefficients of the equation for *D(loggdp)* returned significant t-statistics of the variable coefficients. In the opposite direction, Table V shows that Z_{t-1} has a significant coefficient for *D(logpaxint)*, indicating long-term causality. In the short term, the coefficients of the lag variables of *D(loggdp)* also have significant t-statistics. The coefficient values indicate that the relation is elastic, i.e., 1% variation in *D(loggdp)* results in 1.72% first-lag and 2.57% second-lag variation in *D(logpaxint)*. Accumulated variance decomposition shows that percentage variance in *logpaxint* due to *loggdp* in the early periods is a little over 40%, reaching around 90% over 10 periods (Fig. 2). There can thus be said to be a strong one-way relation between *loggdp* and *logpaxint*.

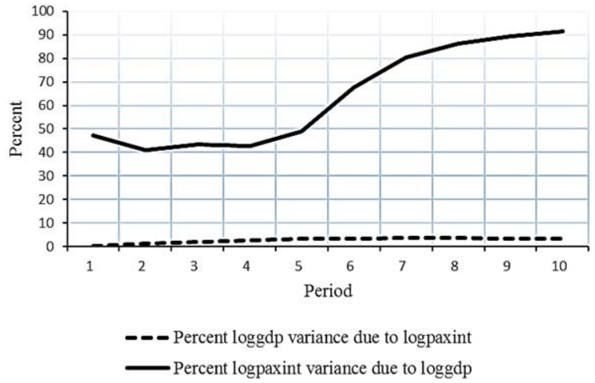

Fig. 2 Variance decomposition of *loggdp* and *logpaxint*

V. Discussion

The series examined is proven to be stationary at their first differences. Cointegration was observed among the series in both cases studied, showing causality between domestic passenger movement and GDP and between international passenger movement and GDP. However, GDP had much stronger impact on domestic and international passenger movement than passenger movement on GDP. Variance decomposition gave the magnitude of the impacts of percentage variance from series to series. Variance in GDP due to domestic passenger movement reached around 30%, whereas variance in domestic passenger movement due to GDP reached around 70%. No causal relation was observed between international passenger movement and GDP. Variance in GDP due to international passenger movement was no more than about 3%, whereas variance in GDP produced up to 90% variance in international passenger movement. As for the case of GDP in relation to international passenger movement, the VEC equation returned no significant statistical test, international passenger movement cannot be claimed to have any influence on GDP. Accordingly, one-way causality can be said to exist from GDP to international passengers. As regards Granger causality, this evidence indicates that the variation in GDP is prior and of great importance to variation in both domestic and international passenger movement and that there is a feedback process of lesser proportions from domestic passenger movement to GDP.

This study confirms that the previous findings on the relationship between GDP and domestic passenger transport in Brazil remain at present. However, it adds the vision of the international passenger movement which is an important element of the formulation of air transport policy in the country.

VI. Conclusion

The results indicate that economic development is precedent to development of air transport and that, to a certain extent, domestic passenger movement feeds back into economic growth. In that light, caution is recommended in investing in air transport in Brazil, because returns on such investment may be frustrated by economic downturns. This has been seen in Brazil in the copious investment made to support mega-events and airport expansion, particularly with a view to international traffic, in the expectation that this would draw international air passengers to stimulate the economy. Investment to develop the domestic air transport network seems to promise better returns than when directed to stimulating international passenger traffic. Not only is this emphasis on international air transport apparently mistaken, the question remains as to whether better investment options may exist for leveraging Brazil's GDP. One air transport policy option in Brazil could be to set up secondary airports, with an emphasis on domestic transport, in areas of influence of Brazil's major metropolises. These could decongest large international airports embedded in dense urban networks and yield better results for the economy. This would certainly expand availability of flight times in Brazil's large metropolises, which would in turn be extremely favourable to development of a regional network in Brazil.

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Manoela Cabo da Silva is a DSc student in Production and Transport Engineering from COPPE/UFRJ, her MSc degree in Mathematics from IMPA - National Institute of Pure and Applied Mathematics (2007) and her Bachelor's degree in Statistics from the ENCE- National School of Statistical Sciences (2001) and Mathematics from UFF – Federal Fluminense University:

Currently she is a researcher of the IBGE - Brazilian Institute of Geography and Statistics Institution. She has experience in the area of probability and statistics, Finance Actuary and Insurance with emphasis on Risk Management, with more than 20 years of working experience for big companies as Bank of America, Dresdner Bank, IRB-Brazilian Reinsurance Institute and others. For many years, she is teaching statistics and finance subjects in under-graduate and graduate courses. She also participates in many seminar and congresses.

Elton Fernandes is a Full Professor of the Production and Transport Engineering Programs at COPPE/UFRJ and a CNPq Research Productivity Scholar. During his career, he coordinates several R&D projects with public and private funding. He got his PhD degree in Manufacturing and Engineering Systems from the University of Brunel, Great Britain (1993), his MSc degree in Transport Engineering from COPPE/UFRJ, Brazil (1980) and his Bachelor degree in Architecture and Urbanism from FAU/UFRJ, Brazil (1977). He is a co-author of the book: Transporte aéreo no Brasil: uma visão de mercado, Elsevier, Rio de Janeiro (2016). He is also co-author in chapters of some others national and international books. He is co-author of more than 70 articles in national and international scientific events and more than 30 articles in national and international scientific journals. He has supervised more than 40 master's dissertations and more than 30 PhD theses in the areas of Production Engineering, Transportation Engineering, and Management. He is recurrently interviewed by the Brazilian media, newspapers and TV channels, in order to give his opinion on issues related to air transport in Brazil, and his interviews are registered and catalogued by COPPE's Communications Department. His research focus is on innovation in organization management, corporate strategy and air transport.

For many years, his main teaching subject has been corporate and service strategy in under-graduate, graduate and specialization courses. He also has an active participation in academy and research management during his career, as coordinator of post-graduation courses and as member of private and public organizations management and scientific councils. He received a Fellowship award from the World Academy of Productivity Science in 1997. Since his PhD degree at Brunel University, in 1993, he has been a referee for many scientific activity proposals, as for scientific journals, scientific meetings, and scientific funding institutions, both private and public. He currently coordinates the Nucleus of Studies on Technology, Management and Logistics (TGL) at the Production Engineering Program of COPPE/UFRJ.

Ricardo Rodrigues Pacheco received a DSc in Production Engineering from COPPE/UFRJ. He also received a MSc in Transportation Engineering from the Federal University of Rio de Janeiro (COPPE/UFRJ) and a MSc in Airport Planning and Management from Loughborough University. He joined Infraero in 1986 and his research interests include Airport Productivity, Management and Tourism. He has published in Journal of Air Transport Management, Transportation, Transportation Research Part A, Journal of Transport Geography and others.

Heloisa Márcia Pires has a DSc degree in Production Engineering by Federal University of Rio de Janeiro (UFRJ), received a Master degree in Business Administration and is graduated in Economics. She currently is a professor of UFRJ. She has been teaching finance for the last thirty years for graduate and undergraduate students. Some of her work is published at the Transportation Research Part A and E and at the Journal of Air Transportation Management. Her research includes the following subjects: capital structure, financial performance and civil aviation. She also manages a real state family enterprise for more than thirty years.