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Intersectoral Requirements and Influences: Assessing the Role of Air Transport Markets in the Brazilian Economy

Requerimentos e influências intersetoriais: avaliando o papel dos mercados de transporte aéreo na economia brasileira

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Abstract: From the mid-1990s onward, microeconomic deregulation and liberalization policies that increased competition drove substantial growth in Brazil's air transport market. Over this period, air transport services have increasingly reached beyond high-income households and capital-intensive industries, extending to lower-income groups and a wider range of productive sectors. This paper examines how air transport markets interact with Brazil's productive structure. Both the open and the closed Input–Output models were employed, applying two complementary analytical techniques — Requirement Coefficients and the Field of Influence. Results indicate that public administration and services tend to exert greater effective pressures and influences on the demand for air passenger transport.
Keywords: Air Transport Markets; Intersectoral Dependence; Input–Output.
JEL Classification: C67, D1, L93.

Resumo: Desde a segunda metade da década de 1990, com o advento das políticas microeconômicas de flexibilização e liberalização que elevaram a concorrência, o mercado de transporte aéreo vem apresentando taxas de crescimento expressivas para a economia brasileira. Estes serviços passaram a atender não somente as famílias de extrato superior de rendimento e atividades econômicas de produção intensiva, mas também novos usuários, como grupo de famílias de rendimento baixo e outros setores produtivos. Nesse sentido, o objetivo do presente trabalho é analisar as interações dos mercados de transporte aéreo com o sistema produtivo brasileiro. Para tanto, utiliza-se um modelo aberto e fechado de insumo-produto do ano de 2010, aplicando-se duas técnicas tradicionais: os coeficientes de requerimento e o campo de influência. Os resultados mostraram que a administração pública e os serviços tendem a exercer maiores pressões efetivas e influências sobre a demanda do transporte aéreo de passageiros.
Palavras-chave: Mercados de transporte aéreo; Dependência intersetorial; Insumo-produto
Classificação JEL: C67, D1, L93.

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1. Introduction

In Brazil, both the air cargo and passenger transport markets have expanded at a remarkable pace over the past two decades. Between 2005 and 2014, for instance, the air cargo sector grew at an average annual rate of 3.6%, accumulating an overall increase of 37% over the period. In contrast, the passenger air transport market expanded by an average of 9.8% per year, reaching a cumulative growth of almost 133% between 2006 and 2015. The number of passengers carried on domestic and international flights rose by 210.8% in real terms between 2000 and 2014, positioning Brazil as the third largest domestic air transport market in the world. The average real price of airfares declined by 43.1% between 2002 and 2014. Both cargo and passenger markets are characterized as derived demand from the productive system, jointly supporting the distribution of final goods, the functioning of supply chains, and the mobility of individuals for leisure, business, or work-related purposes (Anac, 2014; Betarelli Junior, 2007; Button, 2010; Quinet; Vickerman, 2004; Cnt, 2015).

However, in 2014, an economic slowdown in the country directly affected the demand for air transport services, in addition to the impacts of the World Cup in Brazil and the presidential elections that influenced the market. More recently, in 2020, the COVID-19 pandemic also had a significant impact on the sector. In the air passenger market, both domestic and international segments saw a 51% drop in regular and non-regular flights compared with 2019, while the cargo market recorded an 18% decline in the volume of paid freight and mail carried in domestic and international operations (Anac, 2014; Anac, 2020).

Therefore, those markets respond strongly to the business cycle, as their demand depends heavily on fluctuations in the level of activity across other economic sectors and on the real income of households. In the case of passenger air transport, demand is particularly sensitive to income variations (Button, 2010), which classifies air travel as a superior good. In other words, the higher the income level, the greater the quantity demanded and the stronger the willingness to pay for passenger air services (Cnt, 2015). Demographic and migration trends, along with shifts in consumer preferences and habits, also play a secondary role in influencing the financial performance of airline companies. Conversely, the supply of passenger and cargo operations is limited by the number of available flights and by fuel costs, which are denominated in foreign currency.

In general, the air transport mode is characterized by the combination of a fixed and a mobile infrastructure[1], which allows for greater flexibility, efficiency in deliveries, and a broader geographical coverage than other transport services. Its efficiency stems from higher speed and from the strategic location of airports—often close to production centers—which facilitates the just-in-time production model adopted by some firms and

[1] In *Economia do Transporte*, the distinction between fixed facilities and mobile equipment is emphasized. Airports require substantial time and financial resources for construction, whereas services involve lower investment and shorter implementation time. If demand declines, aircraft can be easily reassigned to other routes (Button, 2010).

enables multiple types of travel, such as business and tourism. By shortening distances between remote regions within a country, air transport becomes an essential input for other productive chains (Cnt, 2015; Marchetti *et al*., 2001).

In air cargo operations in particular, the movement of goods is mechanized and relies on highly specialized labor, which reduces the risk of damage. Because of these characteristics, service provision is costly and expensive (with high freight rates) and subject to restrictions on the type of cargo carried, as it does not accommodate bulk shipments and, in some cases, hazardous materials. In general, this type of transport mainly serves markets that are sensitive to delivery time and safety, to the seasonality of their products, or that face accessibility constraints, such as inadequate transport infrastructure or long distances. Typical airfreight includes: (i) perishables, such as flowers, fish, and fashion items; (ii) high-value goods, such as electronics, IT equipment, photographic products, and jewelry; and (iii) products requiring urgent delivery, such as medicines and spare parts (Matera, 2012). These goods are characterized by a low ratio between weight and monetary value (Betarelli Junior; Bastos; Perobelli, 2011).

Between 1990 and 2001, deregulation[2] and low-cost, low-fare[3] policies were implemented to foster competitiveness in the sector and enhance user welfare. As a result, the air passenger transport market became more accessible, increasing the number of domestic and international flights and generating spillover effects in activities related to education, private business, and tourism (i.e., restaurants, hospitality, and urban transport) (Marchetti *et al*., 2001). Domestic demand more than doubled over the past decade. In terms of revenue passenger kilometers (RPK), the sector grew by 133% between 2006 and 2015, carrying 117.8 million paying passengers in Brazil—a record figure that included 96.2 million on domestic flights and 21.6 million on international routes. Consequently, the industry added more than 63 million passengers over the last ten years. Notably, in light of stronger competition in the passenger market, airlines have increasingly concentrated their routes and fleets in a limited number of airports across the country. The economic rationale behind this process of "hub formation" lies in achieving greater operational scale and productivity gains at airports where airlines are able to charge prices above marginal costs (Zimmermann; Oliveira, 2012).

In this context of rapid expansion in the air transport sector, the passenger and cargo markets have become strategic for the Brazilian economy, precisely because of the country's vast territorial dimensions and the limited supply of alternative transport modes (Salgado; Vassallo; Oliveira, 2010). The expansion of both air transport markets has intensified and broadened interactions with other economic sectors within the Brazilian productive system, occupying market niches that previously did not exist. The sector therefore exhibits a dynamic position, generating first- and second-order effects on other productive activities, such as tourism, hospitality, education, business attraction and generation, and the distribution of high-value, perishable, or time- and security-sensitive

2 Further details can be found in Oliveira, Ferreira and Silva (2011) and Zimmermann and Oliveira (2012).

3 An airline offering low fares.

goods. The air transport sector, for example, sells its services to other sectoral activities within the productive system. Thus, the expansion of this type of transport service directly affects the production processes of other sectors of the Brazilian economy. The resulting increase in production in these sectors will raise production requirements, and, in turn, their suppliers will respond to the additional demand by expanding output, and so on. There are, therefore, first- and higher-order effects associated with the air transport sector in the Brazilian productive system, reproduced through intersectoral interactions. This relationship arises from the forward linkage of the air transport sector.

Accordingly, the main objective of this study is to analyze the interactions between air transport markets and the Brazilian productive system. Within this research framework, the paper seeks to answer the following question: "*What are the intersectoral interactions and dependencies of passenger and cargo air transport demand with other sectors of the productive system*?" To address this question, it is necessary to employ an economic model that recognizes the interrelations within the productive system.

Input–Output (I–O) modeling reveals this feature and, therefore, allows a structural analysis of the intersectoral interdependencies between air transport markets and the productive system. The structural assessment is carried out using two methodological techniques: (1) Requirement Coefficients and (2) Field of Influence. For this purpose, this study uses the national Input–Output Matrix (MIP – *Matriz de Insumo-Produto*) for the year 2010, compiled by the Brazilian Institute of Geography and Statistics (IBGE – *Instituto Brasileiro de Geografia e Estatística*). In its original version, the matrix identifies air transport but does not distinguish between passenger and cargo markets. To meet the objective of this research, both markets were disaggregated, estimating the demand structure for these services. An opening procedure was applied to the matrix to separate passenger and cargo transport, using data made available by the IBGE. The detailed identification of both markets represents a methodological advancement over applied studies that rely on econometric or partial-equilibrium models.

The main hypothesis of this study is that the Requirement Coefficients will indicate which economic sectors demand the most from air transport services as their output increases. The Field of Influence will identify the main factors affecting air transport demand when the technical production relationships of each sector are modified.

In addition to this introductory section, the paper is organized into four further sections. Section 2 presents theoretical and empirical approaches related to air transport markets. Section 3 outlines the methodology and the database used in the research. Section 4 discusses the main results obtained in the study. Finally, Section 5 provides the concluding remarks and suggests directions for future research.

2. Air Transport and the Economy

Air transport is a service of derived demand, constituting a direct or indirect input for all productive chains. A change in prices or in the frequency of service affects the production costs of various goods and services, thereby influencing the country's competitiveness. The availability of communication and transport connections is a key element of progress for the global economy. Progress and greater speed have made it possible to integrate several regions into the globalization process. The efficiency of service provision depends on the performance of the following segments: regulatory agencies, airports, airlines, and suppliers of technology, fuel, and equipment (Turolia; Lima; Ohira, 2011). However, the sector's performance is vulnerable to exogenous conditions, such as exchange-rate depreciations, which increase input costs in the industry. Such shocks may sometimes lead airlines to focus on profitable routes, reveal bottlenecks that highlight the need for infrastructure expansion, or push them into situations of low demand, excess capacity, and cost pressure (Zimmermann; Oliveira, 2012).

At an accelerated pace, the progress of aviation fostered economic integration. During the First World War (1914–1918), the use of aircraft for military purposes boosted the aeronautical sector. After the conflict, the ensuing global economic crisis led to a contraction in the demand for military aircraft, creating the need for restructuring and giving rise to civil aviation. The Second World War (1939–1945) had a positive impact on aircraft demand, which encouraged technological advancement in the sector, turning it into a strategic segment for economic development and strengthening the productive system, with resulting increases in employment, income, and output (Moura, 1992). This historical evolution turned the air transport sector into a potential market whose performance is linked to economic cycles, expanding during growth periods and contracting during recessions. In Brazil, the period of the authoritarian military governments (1964–1985) led to the development of this market, particularly through advances in aeronautical technology (Bndes, 2017), which culminated in the creation of the brazilian aeronautics company (Embraer – *Empresa Brasileira de Aeronáutica S/A*) (Forjaz, 2005). To this end, in the 1940s, the Ministry of Aeronautics and the Brazilian Air Force were established, followed by the creation of the Aeronautics Institute of Technology (ITA – *Instituto Tecnológico de Aeronáutica*) and the Aeronautics Technology Center (CTA – *Centro Tecnológico de Aeronáutica*) (Forjaz, 2005).

Regarding regulation, air transport in Brazil is strictly linked to the public sector, meaning that the operation of this service requires a concession or authorization granted by the State. Airlines can only operate legally on their routes and offer services if they obtain State authorization, with regular and pre-defined routes and schedules. In 2001, the air transport sector was consolidated under a free-competition regime, focused on fare liberalization for domestic and international flights departing from Brazil. These principles were established by Law No. 11,182/2005 (Brasil, 2005), which also created the National Civil Aviation Agency (ANAC – *Agência Nacional de Aviação Civil*) in 2005, responsible for the certification, regulation, and supervision of Brazilian civil aviation (Cnt, 2015). The free-competition regime has stimulated competitiveness and new markets, linked to economic sustainability. Moreover, this environment tends to foster innovation, cost optimization, and efficiency improvement (Anac, 2016).

Competitiveness can be assessed by looking at the number of aircraft distributed across the different segments of the air transport industry. The methodology, based on corporate data from the National Confederation of Transport (CNT – *Confederação Nacional do Transporte*) (2021), shows that in 2020 a total of 22,409 aircraft were registered, of which 5,735 were experimental. Regarding the commercial fleet, the sector showed an upward trend between 2009 and 2015. In 2016, however, the regular air transport segment experienced a contraction in operational fleets as a result of the economic recession, which reduced demand for air travel (CNT, 2016). Notably, commercial aircraft are registered in categories for control and differentiation of their intended use, namely: (i) experimental; (ii) private; (iii) air taxi; (iv) regular public air transport (domestic or international); and (v) private instruction. More recently, in 2020, according to CNT (2021), a total of 22,409 aircraft were registered, of which 47.1% belonged to the private category, 25.6% were experimental, 7.7% used for private instruction, 5.9% for air taxi services, and 2.9% for regular public air transport.

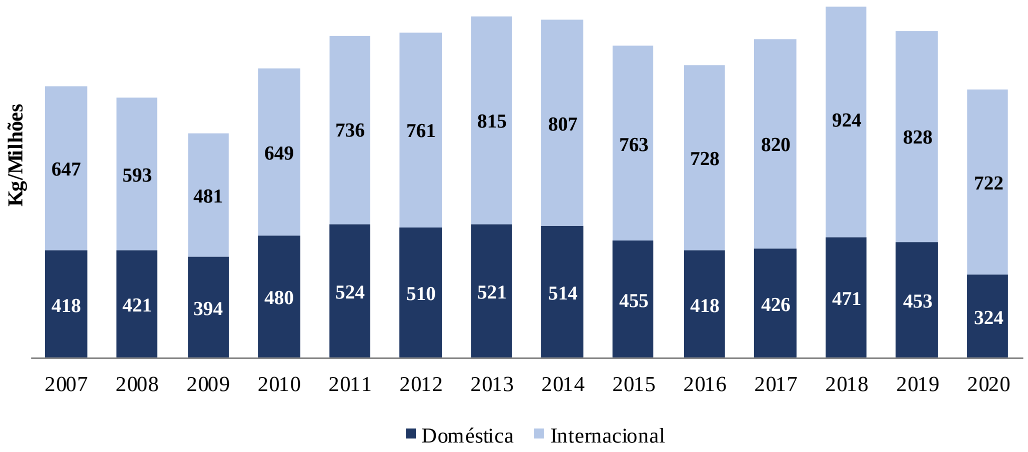
Growth in air cargo transport has been observed over time, particularly in the international market. Nevertheless, the share of road transport in Brazil's freight matrix remains higher than that of other modes, accounting for 64.8% of total freight movement (Cnt, 2024). Rail transport follows with a 14.9% share.

In 2007, 647.3 million tons of paid freight and mail were carried on international flights to and from Brazil, representing an 11.6% increase compared with 2020. In more recent years, however, as shown in Figure 1, there was a 12.8% decline from 2019 to 2020. On the domestic side, air cargo volumes decreased from 418.0 million tons of paid freight and mail in 2007 to 324.4 million in 2020. This drop was even sharper between 2019 and 2020 (28.3%) reflecting the impact of the COVID-19 pandemic (Cnt, 2021).

According to Curiel (2001), the main advantages of this mode are: (i) extensive coverage, (ii) quality, and (iii) speed. Nevertheless, air transport is costly, involving high fixed and variable costs, as well as capacity and storage constraints at airport terminals. It is also important to recognize the need to integrate air transport with other modes in order to reach the final destination of certain goods. In many cases, the use of additional modes—particularly road transport—is required. The air cargo sector has shown the strongest growth in recent years, benefiting in Latin America and Central America from the implementation of trade agreements such as Mercosur in Latin America, the Andean Pact among South American countries in the Andean Region, and the Group of Three, a trade assistance agreement between Venezuela, Mexico, and Colombia.

A modern transport system requires extensive infrastructure across road, rail, river, air, and maritime modes (Button, 2010). In Brazil, road transport continues to dominate passenger mobility, while rail and waterway systems remain limited in scope and insufficiently developed. Although air transport competes directly with intercity bus services, road transport is still more widely used for passenger travel, as ticket prices are more affordable for most of the population and the road network is more extensive (Freitas; Reis Filho; Rodrigues, 2011; Pnlt, 2007).

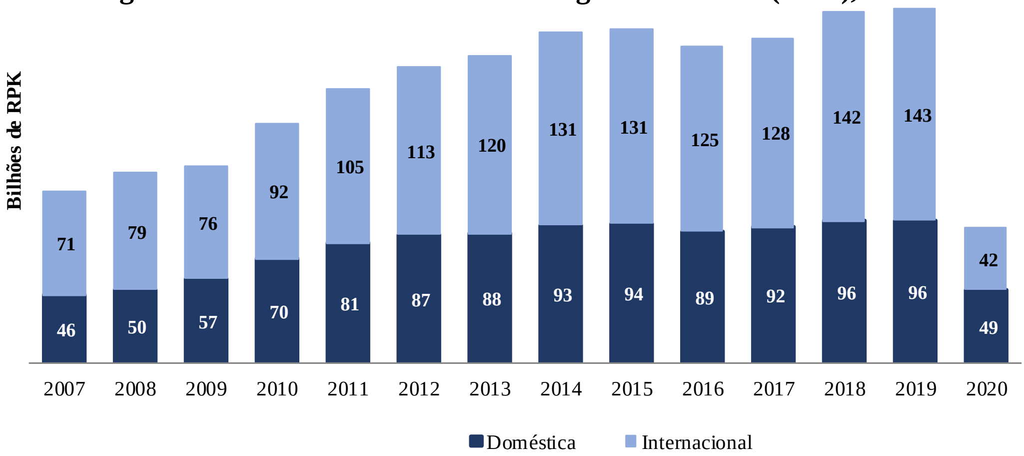
Figure 1: Evolution of Paid Freight and Mail Carried, 2007–2020



Source: Cnt (2021).

For air passenger transport, domestic demand more than doubled over the past decade, increasing by 101% in revenue passenger kilometers (RPK) between 2007 and 2017. Demand continued to grow, reaching its peak in 2018 and 2019, before slowing down in 2020 due to the COVID-19 pandemic. In the international market, the trend was similar, with an 82% increase in demand between 2007 and 2017. However, during the pandemic, this segment was more severely affected, with a 71% decline in RPK compared with a 49% drop in the domestic market from 2019 to 2020 (Cnt, 2016; 2021). Figure 2 illustrates the domestic and international air transport demand, measured in millions of RPK.

Figure 2: Evolution of Revenue Passenger Kilometers (RPK), 2011–2020



Source: Cnt (2016; 2021).

The passenger air transport market is marked by several distinctive features. High operating costs, combined with the strong exposure to substitute modes (i.e., the possibility of using trains, buses, or private vehicles for the same route), lead to intense rivalry and competition, which underpins the ongoing debate on the need for tariff supplementation for airlines (Bettini, 2007). Private interests (profitability) and consumer welfare (quality service and fair prices) are both affected by these specific characteristics of the sector; therefore, the role of air transport regulation is to maintain a balance between the two. The fare liberalization process introduced through deregulation allowed airlines to set their own fares according to supply conditions. This process brought several benefits to airlines, such as greater efficiency, increased demand, lower average operating costs, and consequently, more sustainable financial performance. However, fare liberalization also made it possible to adopt revenue management and price discrimination strategies. As ticket prices fell and fares became more differentiated, a larger share of the population gained access to air transport, promoting social inclusion (Zimmermann; Oliveira, 2012). Moreover, the higher the income level, the greater the quantity demanded and the willingness to pay for air transport services, making this market a superior good (Cnt, 2015).

2.1. Empirical Review

Several national and international empirical studies address air transport markets. Table 1 lists these works and the models used to analyze this service. Curiel (2001), in a study that projected international air cargo demand originating in Venezuela, employed both input–output and econometric modeling. He concluded that air cargo transport would become the mode of the future, given that competitiveness in current markets depends on the rapid and efficient distribution of products. Lee and Yoo (2016) also applied the input–output methodology to conduct a critical assessment of the economic impacts of the rail, road, waterway, and air transport modes in Korea between 2000 and 2010. Their results indicated that, amid high economic growth, the transport sectors were not significantly affected by short-term fluctuations.

In the same modeling framework, Dimitrios and Sartzetaki (2018) examined the socioeconomic effects of air transport in regions of Greece that are highly dependent on tourism, highlighting the contribution of the transport industry to regional development. Their study concluded that investment in air transport infrastructure—essential for Greece—would stimulate growth and directly generate employment, mainly due to the strong link between tourism and air services. More recently, Vukić, Mikulić and Keček (2021) analyzed the economic impact of the transport sector using an input–output model for the Croatian economy for the years 2004, 2008, 2013, and 2015. They found that the sector's multiplier effects were significant over the period, particularly for air transport services.

Glapska, Inchausti-Sintes and Njoya (2016) also applied input–output analysis to measure the effects of air transport activity on the Polish economy. They observed that transport infrastructure is one of several factors influencing regional development but is not sufficient by itself to generate growth. Kudlac, Majercak and Majercak (2017) likewise examined air transport. Since this service is part of the intermodal logistics chain for goods, it is essential to study the constraints that may negatively affect the efficiency of that chain. To this end, the authors employed the multicriteria analysis method. Their results broadened the understanding of logistics chain issues for the purpose of evaluating overall efficiency.

Njoya and Nikitas (2020) estimated the economy-wide impact of air transport expansion in South Africa using a Computable General Equilibrium (CGE) model based on a Social Accounting Matrix (SAM). Their findings indicate that the effects on income and employment are unevenly distributed across the economy, with the highest-spending households emerging as the main beneficiaries—an outcome that could exacerbate income inequality in South Africa. Njoya and Ragab (2022) also employed a CGE model to examine the short- and long-term effects of increased public capital investment in Egypt's air transport infrastructure. The results from the model revealed modest growth in several variables, including GDP, employment, income, consumption, private investment, and trade.

For the Brazilian economy, Betarelli Junior, Bastos and Perobelli (2011) investigated the effects of exports to various destinations on the interdependencies and linkages among economic sectors and transport modes (i.e., road, rail, river, air, and maritime). They used a hybrid Input–Output (I–O) matrix for the year 2005. The authors observed that the sectors with the highest demand for rail transport are also those that most require the maritime mode, as in the case of the iron ore sector. In another study, Betarelli Junior *et al*. (2019) evaluated the extent to which transport modes (i.e., land, air, and waterborne) are required by other economic sectors, using the 2014 interregional Input–Output matrix. Their results showed that, on average, imported air transport services accounted for 48% of the total demanded by all economic activities worldwide.

To assess the effects of the Commercial Aviation Deregulation Policy of the 1990s, Oliveira, Ferreira and Silva (2011) applied econometric modeling to identify the determinants of the price–cost markups of Brazilian airlines. The results indicated a deadweight loss of approximately R$ 3.7 billion between 1993 and 2002 due to regulation. Following the same line of research, Zimmermann and Oliveira (2012) examined the evolution of the number of airports and the characteristics and consequences of post-deregulation in the Brazilian air transport market using an econometric model. Deregulation allowed airlines to manage their own fares and routes, as well as increasing competition among carriers. The authors concluded that rising passenger demand, combined with the decline in the number of airports, has led to the concentration of aircraft in specific cities, thereby limiting access to several regions of the country.

Finally, this study differs from the aforementioned works by analyzing the intersectoral dependence of both the air cargo and passenger markets using traditional Input–Output (I–O) techniques for the year 2010. Accordingly, the research carried out the disaggregation of the corresponding air transport markets. By employing the Input–Output model, the study accounts for the feedback effects within the Brazilian productive system through well-defined transmission channels, whose methodological features are not captured in a partial-equilibrium approach.

Table 1: Summary of Empirical Studies

Source	Country	Modeling Approach	Objective
Curiel (2001)	Venezuela	Input–Output	To study projections of international air cargo demand
Lee and Yoo (2016)	Korea	Input–Output	To examine the socioeconomic effects of air transport
Dimitrios and Sartzetaki (2018)	Greece	Input–Output	To examine the socioeconomic effects of air transport
Vukić, Mikulić and Keček (2021)	Croatia	Input–Output	To analyze the economic impact of the transport sector
Glapska, Inchausti-Sintes and Njoya (2016)	Poland	Input–Output	To measure the effects of changes arising from air transport activity
Kudlac, Majercak and Majercak (2017)	Slovakia	Multicriteria Analysis	To study the constraints that may negatively affect the logistics chain
Njoya and Nikitas (2020)	South Africa	Computable General Equilibrium	To estimate the impact of air transport expansion
Njoya and Ragab (2022)	Egypt	Computable General Equilibrium	To examine the impacts of increased public capital investment in air transport infrastructure
Betarelli Junior, Bastos and Perobelli (2011)	Brazil	Input–Output	To map the interactions and linkages between the productive structure and transport modes for different export destinations
Betarelli Junior *et al*. (2019)	Brazil	Input–Output	To investigate the extent to which transport modes are required by other economic sectors
Oliveira, Ferreira and Silva (2011)	Brazil	Econometrics: Difference-in-Differences Estimation, Instrumental Variable, Generalized Method of Moments	To evaluate the effects of the Commercial Aviation Deregulation Policy
Zimmermann and Oliveira (2012)	Brazil	Econometrics: Multiple	To analyze the evolution of the number of airports served by regular

		Regression Model	air transport and the concentration indices of operations

Source: Authors' own elaboration (2025).

3. Methodology and Database

The Input–Output (I–O) model, developed in the 1940s by economist Wassily Leontief, was applied to analyze the trade interactions of air transport markets within the Brazilian productive system. This methodology is based on several assumptions, such as the unlimited supply of production factors, a Leontief production function, exogenous components of final demand, and fixed prices. Accordingly, the analysis focuses on an economic environment characterized by productive structures with fixed input proportions, in which no substitution effects occur in response to price variations in factor or goods markets. The I–O model can be interpreted from two complementary perspectives: the output perspective (rows), which represents the production of each sector and how its output is distributed among users; and the input perspective (columns), which represents the inputs required for production, including taxes, imports, and value added. For a more detailed theoretical formalization, see Miller and Blair (2009). Formally, a national Leontief model recognizes the interactions among economic sectors, and the total demand of each sector can be expressed in matrix form as:

$$X = Z + Y \qquad (1)$$

where $X = \{x_i\}$ is the vector of total demand for sector i; $Z = \{z_i\}$ represents the intermediate consumption matrix, whose elements are monetary values and indicate the purchases by sector j of product i; and $Y = \{y_i\}$ is the vector of final demand, which encompasses the components of domestic absorption (i.e., household consumption, government demand, investment demand, exports, and changes in inventories). The I–O model is a general equilibrium framework. Thus, the total demand for product i equals the gross value of production for each sector j. $\{x_i\} = X = \{x_j\}$. It is important to note that the technical coefficients are fixed, meaning that sectors use inputs in fixed proportions. The technical relationship for a given input z_{ij} can be expressed as $a_{ij} = \frac{z_{ij}}{x_j}$ or, in matrix form, $A = Z(\hat{X})^{-1}$, where $\hat{X}$ is the diagonalized matrix of X and $A = \{a_{ij}\}$ is the matrix of technical coefficients for sector j by input–output i. Therefore, $AX = Z$ and substituting this definition into (1), we obtain:

$$X = AX + Y \qquad (2)$$

Solving equation (2) in matrix terms yields:

$$X = (I - A)^{-1}Y \quad (3)$$

The identity matrix I and the matrix of the direct and indirect coefficients of sector i per monetary unit of final demand for the production of sector j, which is represented by $(I - A)^{-1} = B = [b_{ij}]$, and its matrix is B, also known as the Leontief inverse matrix. Equation (3) indicates how much total production (X) is required to meet final demand Y. Equations (1), (2), and (3) therefore describe an open input–output model. In the closed version, household consumption and compensation are endogenized within the intermediate consumption matrix, allowing the induced effect of the domestic absorption component to be obtained from the difference between the two versions (Miller; Blair, 2009).

The requirement coefficient, in turn, identifies which productive sectors exert the greatest influence on the demand for air transport. The matrix of direct requirement coefficients (A) corresponds to the technical input–output coefficient matrix itself, as shown below:

$$A = Z(\hat{X})^{-1} \quad (4)$$

The matrix of total net requirement coefficients (R) is the Leontief inverse matrix (B) minus the identity matrix, that is:

$$R = B - I \quad (5)$$

Based on the definitions of matrices R and A, it is possible to obtain the matrix of indirect coefficients (Q):

$$Q = R - A \quad (6)$$

The matrices A, R, and Q capture information about the degree of interdependence and interaction among productive activities. The decomposition of the impact on air transport demand can therefore be carried out between direct effects (A) and indirect effects (R). By examining the share of direct and indirect effects within total requirements, it is possible to assess whether a given productive sector or household exhibits weak, moderate, or strong multiplier power over air cargo and passenger transport demand. As a rule, for an economic sector to show greater multiplier power, the share of indirect coefficients should exceed that of direct coefficients within the total coefficients (Betarelli Junior; Bastos; Perobelli, 2011).

The calculations of requirements in a closed input–output model are similar and can be represented by $\bar{R}$, $\bar{A}$, and $\bar{Q}$, respectively. The difference between $\bar{R}$ and R represents the matrix of induced effects H, that is, the inclusion of households:

$$H = \bar{R} - R \quad (7)$$

From equations (7) and (6), it follows that:

$$\bar{R} = A + Q + H \qquad (8)$$

In general terms, it is also possible to evaluate the share of household-induced effects within the intersectoral coefficients of the total net requirement for air transport in the closed input–output model.

To address the difficulty of identifying the impact of a specific sector within the productive system, Sonis and Hewings (1994) introduced the concept of the field of influence methodology, which highlights the technological coefficients that, after a small variation, have the greatest effects on other economic sectors (Guilhoto, 2011). This methodological technique allows mapping the sectoral activities that exert the strongest influence on the demand for transport services in Brazil (Betarelli Junior; Perobelli; Vale, 2011).

The formalization follows Sonis and Hewings (1994) and Betarelli Junior, Perobelli and Vale (2011). The calculation is based on the matrix of technical production coefficients, $A = \{a_{ij}^{k}\}$ where $k = [r, s]$, and a matrix of incremental variations in these technical coefficients given by $E = \{\varepsilon_{ij}^{k}\}$. Based on these definitions, the Leontief inverse matrix (B) can be derived in two forms: $B = [I - A]^{-1} = [b_{ij}]$, as usual, without perturbations; and $B(E) = [I - (A + E)]^{-1} = [b_{ij}(E)]$, incorporating the incremental changes in the technical coefficients a_{ij}. If the variation is small and occurs in only one technical coefficient, then:

$$\varepsilon_{ij} \begin{cases} \varepsilon \\ 0 \end{cases} \text{if } \begin{matrix} i=i_1;\, j=j_1 \\ i\neq i_1; j\neq j_1 \end{matrix}, \varepsilon>0 \qquad (9)$$

Therefore, an approximation of the field of influence can be obtained, where $F(\varepsilon_{ij})$ is the matrix representing the field of influence of a change in the technical coefficient a_{ij}:

$$F(\varepsilon_{ij}) = \frac{B(\varepsilon_{ij}) - B}{\varepsilon_{ij}} = \{f_{kl}(\varepsilon_{ij})\} \qquad (10)$$

This procedure is repeated for all coefficients of A, that is, the matrices F are calculated for each technical coefficient of A. To identify which technical coefficients have the largest field of influence, the following indicator is computed for each corresponding matrix $F(\varepsilon_{ij})$:

$$S_{ij} = \sum_{k=1}^{n} \sum_{i=1}^{n} [F_{kl}(\varepsilon_{ij})]^2 \qquad (11)$$

After performing all calculations, each technical coefficient a_{ij} in A will have an associated value S_{ij}. The coefficients with the highest S_{ij} values are those exhibiting the largest fields of influence within the economy as a whole. These coefficients indicate the sectoral relationships most sensitive to change, thus producing greater impacts on the economy and, consequently, on the level of consumption.

3.1. Database

The database used in this research was drawn from the national Input–Output Matrix (MIP) for 2010, compiled by the IBGE, which regularly publishes Input–Output information. The MIP consists of a set of tables—namely, the Supply and Use Tables (SUT)—and for 2010 it comprises 67 economic activities and 127 products. Table 2 presents the procedures used to adapt the MIP to the research problem: the disaggregation of the air transport activity, the construction of the open model, and the inclusion of households in the closed model (Stage 1); the selection and grouping of activities (Stage 2); and, finally, the application of the requirement and influence coefficients to both the open and closed models (Stage 3).

Table 2: Adopted Strategies

Stages		Definitions
1	1.1	Initial Database: MIP 2010 Data
		↓
	1.2	Open Model: Disaggregation of Air Transport into Passenger and Cargo
		↓
	1.3	Closed Model: Inclusion of Households Using Microdata from the 2008/2009 Household Budget Survey (POF – *Pesquisa de Orçamentos Familiares*)
2	2.1	Correspondence
		↓
	2.2	Grouping of Activities and Products
3	3.1	Requirement Coefficient
		↓
	3.2	Field of Influence

Source: Authors' own elaboration (2025).

In Stage 1.1, the air transport service was disaggregated into passenger and cargo segments. For this purpose, data from Brazil's foreign trade system, Comex Stat, were used, detailed by the Mercosur Common Nomenclature (NCM – *Nomenclatura Comum do Mercosul*) and the Harmonized System position (HS4). The database includes approximately 5,860 export NCMs and 7,171 import NCMs. To compile the data, the IBGE translator was employed to reproduce the structure of final demand at market prices for the air passenger and cargo markets, by municipality of the exporting or importing company. This information was standardized for air transport and aggregated by FOB value in US dollars. Stage 1.2 presents the proportion between the original MIP air transport data and the disaggregation into passenger and cargo transport, ensuring the consistency of final demand in the 2010 IOM. The disaggregation of the sector's final demand was based on the annual revenue of airlines from domestic cargo and passenger transport, using data from the financial statements of Brazilian Airlines published by ANAC, which include quarterly and annual data for Brazilian companies operating regular and non-regular public air transport services, except for air taxi operations. Subsequently, the remaining MIP components were expanded, resulting in a matrix of 128 activities by 128 products.

In Stage 1.3, households were disaggregated into per capita income classes using the microdata from the 2008/2009 Household Budget Survey (POF – *Pesquisa de Orçamentos Familiares*). Published by the IBGE, this survey is conducted through sampling of private permanent households and aims to measure the structure of household consumption, expenditures, income, and part of wealth variation. Within each household, the basic unit of the survey—referred to by the IBGE as a "family"—is defined as the consumption unit, comprising either a single resident or a group of residents sharing the same food source or housing expenses (Ibge, 2010). The POF places greater emphasis on income and includes variables capturing consumption habits, expenditures, and household receipts. It is important to note that families allocate their income according to the products and services that compose their typical consumption basket. Wealthier Brazilian households are therefore more likely to consume air passenger transport than poorer families, as they have a larger budget share available to include this service in their consumption basket. Table 3 presents the ordering of sectors and households (Stage 2), resulting from the diagonalization (market-share) process of economic activities.

In other words, in order to group the 128 activities and 10 family groups according to income in Stage 1, the matrix of 128 economic activities by 128 products was transformed into a new dimension of 28 economic activities by 28 products, together with the 10 representative families, transforming them into 6 family categories. The purpose of this correspondence is to facilitate the analysis of the results of this research (Stages 2.1 and 2.2).

Table 3: Economic Sectors and Representative Households

Correspondences			
Productive System		**Households**	
Activities	Code	Class*	Code
Agriculture	S1	0–3	R1
Extractive Industries	S2	3–6	R2
Food, Beverages, and Tobacco	S3	6–10	R3
Textile and Apparel Industry	S4	10–20	R4
Paper, Pulp, and Wood	S5	20–30	R5
Petroleum Refining	S6	Above 30	R6
Chemicals	S7		
Pharmaceutical and Cleaning Products	S8		
Iron and Steel Industry	S9		
Information and Communication Equipment	S10		
Electronics and Electrical Equipment	S11		
Machinery, Equipment, and Repairs	S12		
Automobiles and Light Vehicles	S13		
Vehicle Parts and Transport Equipment	S14		
Miscellaneous Industries	S15		
Public Utility Services (SUP – *Serviços de Utilidade Pública*)	S16		
Construction	S17		
Commerce	S18		
Air Cargo Transport	S19		
Air Passenger Transport	S20		
Transport, Storage, and Mail	S21		
Financial and Real Estate Intermediation	S22		
Telecommunications and Information	S23		
Business Services	S24		
Household Services	S25		
Private Education	S26		
Public Administration	S27		
Other Services	S28		

Source: Authors' own elaboration (2025).

4. Results and Discussion

Table 4 presents the results for total net requirements and the shares of direct, indirect, and induced effects. The total net requirements indicate how much each economic activity and household directly and indirectly demands from air passenger transport for every additional unit of production and consumption. This additional unit corresponds to R$ 1 million.

Table 4: Sectoral Requirements of Air Passenger Transport

Código	Atividades econômicas	Transporte aéreo de passageiros				
		Total (R$)	Ordem*	Direto (%)	Indireto (%)	Induzido (%)
S1	Agropecuária	2.675	28	0,3	31,6	68,1
S2	Indústrias extrativas	6.361	9	53,7	17,1	29,2
S3	Alimentos, Bebidas e Tabaco	4.584	25	7,8	34,1	58,2
S4	Indústria Texteis e Vestuário	4.679	21	4,9	23,4	71,7
S5	Papel, celulose e madeira	4.832	19	9,2	29,0	61,9
S6	Refino de petróleo	3.773	27	4,2	53,9	41,9
S7	Químicos	4.590	24	14,5	35,5	50,0
S8	Produtos farmacêuticos e limpeza	4.749	20	9,5	31,0	59,4
S9	Siderurgia e metalurgia	4.842	18	5,2	35,2	59,7
S10	Prod. de informática e comunicação	4.640	22	21,3	26,5	52,2
S11	Eletrônicos e elétricos	5.419	12	11,4	27,8	60,7
S12	Máquinas, equipamentos e reparos	4.921	17	11,4	24,6	63,9
S13	Automóveis e utilitários	5.255	14	16,5	29,2	54,3
S14	Peças e equipamentos de transporte	4.984	15	6,1	26,6	67,3
S15	Indústrias diversas	4.597	23	5,1	29,9	65,0
S16	Serviços de utilidade pública (SUP)	4.559	26	27,2	27,7	45,1
S17	Construção civil	5.810	10	34,2	19,7	46,2
S18	Comércio	6.441	8	34,7	15,4	49,9
S19	Transporte Aéreo Carga	5.510	11	6,0	29,3	64,7
S20	Transporte Aéreo Passageiros	5.307	13	6,0	29,3	64,7
S21	Transporte, Armazenagem e Correios	6.550	7	31,8	20,9	47,3
S22	Intermediações financeiras e imobiliárias	4.974	16	42,5	15,4	42,0
S23	Teleconominicações e informações	6.984	5	28,0	25,0	47,0
S24	Serviços prestados às empresas	8.429	4	39,5	16,1	44,4
S25	Serviços prestados às famílias	6.642	6	20,7	13,7	65,6
S26	Educação privada	23.152	1	68,7	4,7	26,6
S27	Administração pública	9.317	3	14,9	10,7	74,4
S28	Outros serviços	19.380	2	72,1	8,6	19,2
	Total	183.955		31,4	20,4	48,2

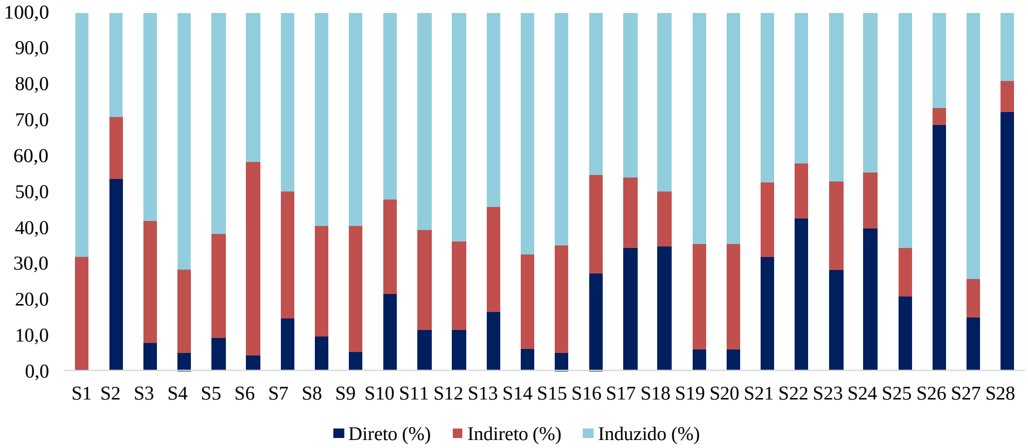
Note: * Order refers to total requirements, total column (R$).

Source: Research results.

Among the economic activities, Private Education (S26), Public Administration (S27), Household Services (S25), Business Services (S24), and Telecommunications and Information (S23) are those that tend to exert the greatest influence on air passenger transport demand. For instance, an additional increase in the output of Private Education (S26) would generate a direct and indirect requirement for air passenger transport of approximately R$ 23.1 thousand. Service activities are typically those that make greater use of air passenger transport for business travel (face-to-face) (Button, 2010). The exception lies in Public Utility Services (SUP – *Serviços de Utilidade Pública*), which typically provide locally based (urban) services under municipal contracts or regulations, resulting in a lower need for business travel. In general, the direct effects were relatively greater than the indirect ones in service activities, meaning that first-order effects are more prominent.

Figure 3 illustrates these shares in total net requirements, providing a clearer visualization of intersectoral differences. Service sectors, therefore, exhibit a weak multiplier effect on air passenger transport demand, although some of them show a relatively strong weight in this type of air transport demand. Compared with industrial and agricultural sectors, services typically display a lower degree of commercial interaction within the Brazilian productive system, which helps explain, to some extent, the smaller share of the indirect effect. The induced effect generated by the income and consumption of typical household groups in the composition of total net requirements is relatively high across most economic sectors. The activities that stand out in household consumption baskets are also those showing stronger induced effects, such as Public Administration (S27), Household Services (S25), Textile and Apparel Industry (S4), and Agriculture (S1). Furthermore, the share of high-income households accounts for 8.7% of the direct requirements for air passenger transport, which explains the strong induced effect.

Figure 3: Air Passenger Market: Direct, Indirect, and Induced Effects (%)



Source: Research results.

On the other hand, Agriculture (S1), Petroleum Refining (S6), Food, Beverages and Tobacco (S3), and Chemicals (S7) are the activities that least directly and indirectly require air passenger transport in the event of production expansion—that is, they exert a relatively small weight on demand in this market. The indirect effects, however, are relatively larger than the direct ones. Therefore, these economic activities tend to display a strong multiplier effect on the air passenger transport market.

On average, the direct effect is greater than the indirect one, a structure explained by sectors with particularly high direct effects, such as Services (S28), Private Education (S26), and Extractive Industries (S2). However, when comparing the number of sectors for which the direct effect exceeds the indirect one, this characteristic is offset: of the 28 sectors, 11 exhibit this pattern, while the remaining 17 show a higher indirect effect than the direct effect—thereby amplifying the overall demand multiplier in this market. In turn, in air cargo operations, industrial activities tend to exert a stronger influence on demand, as shown by the results in Table 5.

Table 5: Sectoral Requirements of Air Cargo Transport

Código	Atividade econômica	Transporte aéreo de carga				
		Total (R$)	Ordem*	Direto (%)	Indireto (%)	Induzido (%)
S1	Agropecuária	333	13	2,6	71,2	26,2
S2	Indústrias extrativas	223	22	6,9	60,8	32,3
S3	Alimentos, Bebidas e Tabaco	781	10	55,2	29,9	15,0
S4	Indústria Texteis e Vestuário	896	8	51,1	32,4	16,5
S5	Papel, celulose e madeira	996	6	56,0	31,2	12,8
S6	Refino de petróleo	194	24	10,0	57,5	32,5
S7	Químicos	1.820	2	71,4	23,5	5,1
S8	Produtos farmacêuticos e limpeza	1.055	4	69,7	20,4	9,9
S9	Siderurgia e metalurgia	630	12	48,1	33,6	18,3
S10	Prod. de informática e comunicação	2.392	1	84,1	12,1	3,7
S11	Eletrônicos e elétricos	1.697	3	73,0	19,9	7,1
S12	Máquinas, equipamentos e reparos	953	7	61,2	26,1	12,6
S13	Automóveis e utilitários	670	11	34,7	49,2	16,1
S14	Peças e equipamentos de transporte	1.021	5	58,4	28,9	12,7
S15	Indústrias diversas	867	9	50,0	35,7	14,3
S16	Serviços de utilidade pública (SUP)	176	27	0,1	56,3	43,7
S17	Construção civil	313	15	0,0	63,4	36,6
S18	Comércio	225	21	6,6	32,7	60,7
S19	Transporte Aéreo Carga	190	25	0,0	41,1	58,9
S20	Transporte Aéreo Passageiros	183	26	0,0	41,1	58,9
S21	Transporte, Armazenagem e Correios	222	23	0,0	40,0	60,0
S22	Intermediações financeiras e imobiliárias	110	28	10,0	27,7	62,3
S23	Teleconominicações e informações	236	19	18,3	33,6	48,1
S24	Serviços prestados às empresas	233	20	13,5	31,4	55,1
S25	Serviços prestados às famílias	263	17	0,0	25,6	74,4
S26	Educação privada	257	18	0,0	14,2	85,8
S27	Administração pública	284	16	0,0	17,0	83,0
S28	Outros serviços	332	14	19,1	32,5	48,4
	Total	17.552		51,8	28,7	19,5

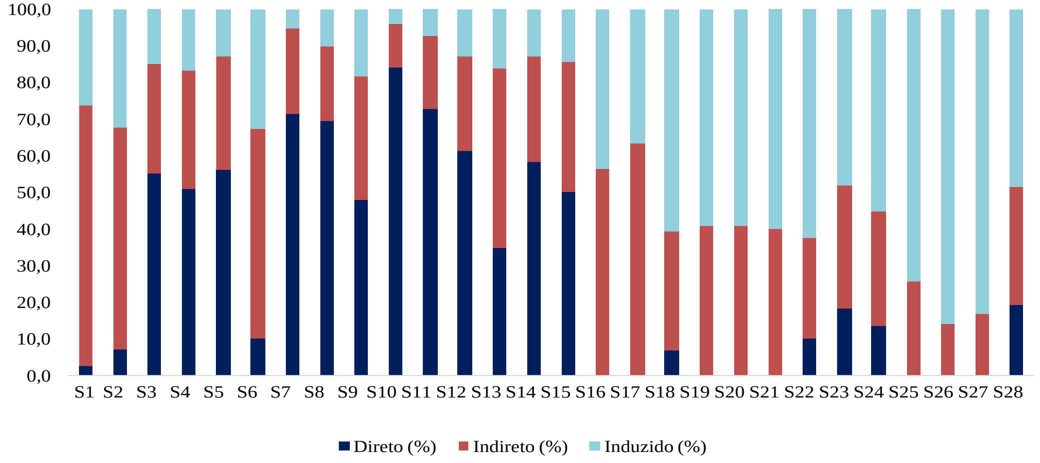
Note: * Order refers to total requirements, total column (R$).

Source: Research results.

The total net requirements of these industrial sectors are relatively higher for every additional R$ 1 million of production. The most prominent sectors include Information and Communication Products (S10), Chemicals (S7), Electronics and Electrical Equipment (S11), Pharmaceutical and Cleaning Products (S8), and Vehicle Parts and Transport Equipment (S14), whose activities are typically the most intensive users of air cargo transport in Brazil. These are industrial sectors that produce high-value goods and therefore tend to prioritize transport security up to the consumer market. Despite their strong weight on air cargo demand, these industrial activities generally exhibit a weak demand multiplier effect. The share of induced effects is also relatively smaller when compared with direct effects. However, productive sectors with the lowest weight on air cargo demand include Financial and Real Estate Intermediation (S22), Public Utility Services (S16), Air Passenger Transport (S20), and Petroleum Refining (S6). Even so, the share of the indirect effect is considerably higher than that of the direct effect, indicating a substantial multiplier effect.

Figure 4 shows which sectors experience the greatest direct, indirect, and induced impacts in relation to the air cargo market. Induced effects are lower among industrial sectors and higher among service sectors—meaning that household influences on industrial segments are weaker compared with service segments. In this case, the sectors that stand out are Private Education (S26), Public Administration (S27), and Household Services (S25). Similar to the air passenger market, the air cargo market generally exhibits larger direct effects than indirect ones. However, when comparing the number of sectors exhibiting this pattern, the results are reversed: of the 28 sectors, 11 have higher direct effects, while the remaining 17 show a predominance of indirect effects—amplifying the demand multiplier effect in this market. The sectors that stand out for their direct effects are, respectively, Information and Communication Products (S10), Chemicals (S7), and Vehicle Parts and Transport Equipment (S14). In contrast, Agriculture (S1), Construction (S17), and Petroleum Refining (S6) show higher indirect effects.

Figure 4: Air Cargo Market: Direct, Indirect, and Induced Effects (%)



Source: Research results.

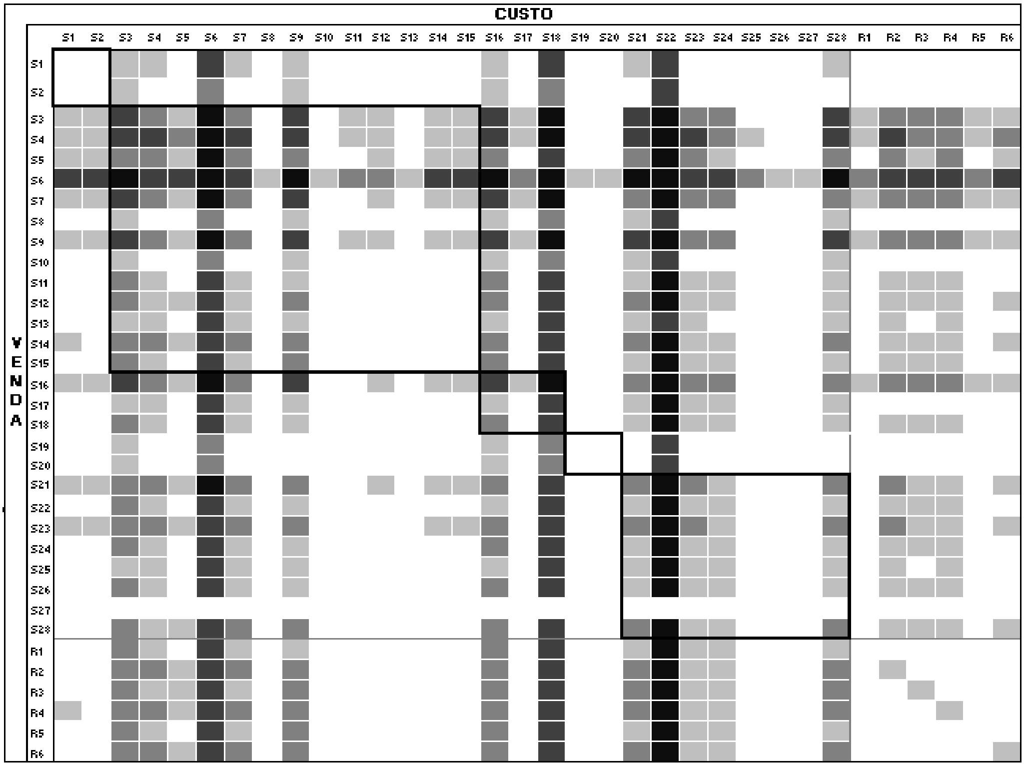
The total share of induced effects in the matrix amounts to 19.5%, indicating a market with still-incipient interdependence in relation to household consumption. The share of indirect effects is 28.7%, compared with 52.8% of direct effects, which supports the strategic position of interdependent sectors. However, the predominance of direct effects over indirect ones reduces the potential magnitude of the demand multiplier in this cargo market.

Having discussed how productive sectors require air passenger and cargo transport as their production expands, it is important to identify which technical production relationships exert the strongest influences within the Brazilian productive system, considering both direct and indirect effects. This makes it possible to reveal the main sources of intersectoral influence, with particular attention to air passenger and cargo transport. Table 6 presents two panels: Panel A reports the influences within the Brazilian productive system as a whole, while Panel B shows the influences specific to the air cargo and passenger transport markets.

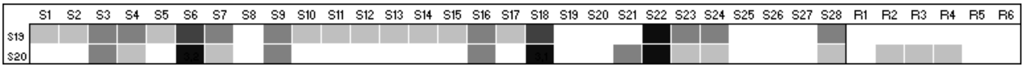
In both panels, six groups of representative households are identified according to income ranges. The mapping of the coefficients shown in Panel A was based on the average of the productive system's coefficients, where less influential sectors exhibit coefficients greater than the mean and lower than the mean plus one-half of a standard deviation; intermediate sectors exhibit coefficients greater than the mean plus one-half and lower than the mean plus two standard deviations; and the most influential sectors exhibit coefficients greater than the mean plus two standard deviations. In the overall mapping of the productive system, from the output perspective, the air passenger and cargo markets do not display interdependencies that significantly influence the productive system compared with other service segments, such as Transport, Storage, and Mail (S21) and Telecommunications and Information (S23).

Table 6: Technological Coefficients

Painel A: Sistema Produtivo



Painel B: Mercado Aéreo



Legenda:

Source: Research results.

However, when the coefficients are compared with the average of the air passenger and air cargo markets, a different structure emerges, as shown in Panel B. Air passenger transport is influenced by the following sectors: Commerce (S18), Financial and Real Estate Intermediation (S22), and Transport, Storage, and Mail (S21). Conversely, air cargo transport is more strongly affected by sectors such as Information and Communication Products (S10), Electronics and Electrical Equipment (S11), Machinery, Equipment, and

Repairs (S12), Automobiles and Light Vehicles (S13), and Chemicals (S7)—that is, sectors that require speed and safety in product transportation and would have the greatest impact on the productive system if their output were reduced. Regarding households and air passenger transport, high-income families—although they demand a larger volume of high value-added goods and services, such as Private Education (S26) and Automobiles and Light Vehicles (S13)—are less influential in this segment than middle-income families. This is due to the size and scope of the middle-income group, which generates a greater quantitative effect. As expected, households do not exert influence on air cargo transport, given the availability of lower-cost substitute services such as mail delivery.

Conclusion

This paper analyzed the intersectoral interactions and dependencies of air passenger and air cargo transport demand with other sectors of the Brazilian productive system. These markets are sensitive to the business cycle and their demand is highly dependent on changes in the level of productive activity and on the real income of typical Brazilian households. The analysis was conducted using the Input–Output (I–O) model, based on Brazil's 2010 national matrix officially published by the IBGE. In addition, two traditional techniques were applied: the requirement coefficient and the field of influence. The main methodological innovation consisted in disaggregating the air transport sector into two separate sectors—air passenger transport and air cargo transport. This advance allowed for a specific assessment of these sectors in relation to their behavior within the system and the influences of economic activities. The topic explored in this study is relatively new, making this research one of the first contributions to applied economics in this area. Thus, the study contributes to the debate on air transport market demand in Brazil by employing structural input–output analysis, whose approach differs from applied partial equilibrium models.

The results showed that, for the air passenger transport sector, the most significant intersectoral relationships are with service segments and public administration—that is, sectors for which air transport is a derived demand. In contrast, sectors such as iron and steel generate indirect effects, while textile and apparel and agriculture generate induced effects. As expected, the air cargo sector exhibited stronger linkages with industries that demand speed and safety, such as those producing information technology, electronics, and food products. The indirect effect is driven by sectors such as construction and petroleum refining, whereas, in contrast to the direct effects of air passenger transport, the service and public administration sectors are responsible for the induced effects in the air cargo market. This study highlights the potential of air transport for national development, through the stimulation of this sector, which can yield economy-wide benefits.

In terms of households, high-income families exhibit greater requirements than lower-middle-income families. However, although they demand more air passenger transport, wealthier families are not those that exert the greatest influence on the air transport market within the productive system—this role belongs to middle-income households. This result is explained by differences in household profiles: most Brazilian households belong to the lower- and middle-income classes, which gives them greater overall influence on the productive system. In contrast, households do not directly affect air cargo transport, but they generate induced effects on service sectors that depend on air cargo transport. This is to say households indirectly amplify the demand multiplier effect of air cargo transport in Brazil.

Future research should advance the characterization of air passenger market demand using the 2015 MIP, assessing whether the policies of deregulation and market expansion have maintained their influence over the years. Regarding cargo transport, further analysis could focus on the logistical and technological structure of the productive system to identify which products have higher added value and therefore demand more air transport, even given its higher cost compared with road transport. Household classes can also be reassessed using the 2017–2018 POF, allowing for the construction of a new profile of households demanding air transport and their influence on the Brazilian productive system.

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