Japan Bilingual Publishing Co.

Transportation Development Research
https://ojs.bilpub.com/index.php/tdr

COMMUNICATION

Fuel Tankering Practices in Aviation and Average Origin-Airport Fuel Prices: Evidence from the Brazilian Domestic Market

Letícia Alves Tizeu , *Mauro Caetano* * , *Evandro José da Silva*

Brazilian Air Force (FAB), Aeronautics Institute of Technology (ITA), São José dos Campos-SP 1228-900, Brazil

ABSTRACT

Considered one of the most significant costs to aviation, the identification of strategies for aircraft fueling can contribute to optimizing air transportation resources. Therefore, this study investigates the practice of fuel tankering, addressing a theoretical gap resulting from the lack of comprehensive, network-wide route assessments of fuel tankering practices, as current evaluations are predominantly conducted on a per-flight basis. This study employs descriptive analysis combined with regression methods to examine public data from Brazilian aviation, supplied by the Brazilian National Civil Aviation Agency. The data includes details such as origin, destination, aircraft type, and flight times. Additionally, it incorporates fuel price information from the Brazilian National Petroleum Agency, comparing data from 2019—before the pandemic—and from 2022 and 2023—after the pandemic. The findings show that a R$1.00 per liter increase in fuel price at the source is linked to a reduction of about 32,970 kg in the volume of refueled fuel. This suggests that fuel tankering can offer significant cost savings for airlines, especially on routes with high destination fuel prices. However, these benefits are balanced by increased CO^2 emissions, highlighting a conflict between economic gains and environmental sustainability. This study recommends optimizing tankering strategies and aligning them with broader regulatory and environmental goals.

Keywords: Air Transport; Aviation Fuel Price; Economic Strategy; Environmental Impact

*CORRESPONDING AUTHOR:
Mauro Caetano, Brazilian Air Force (FAB), Aeronautics Institute of Technology (ITA), São José dos Campos-SP 1228-900, Brazil; Email: caetano@ita.br

ARTICLE INFO
Received: 29 March 2025 | Revised: 15 April 2025 | Accepted: 26 April 2025 | Published Online: 2 May 2025
DOI: https://doi.org/10.55121/tdr.v3i1.456

CITATION
Tizeu, L.A., Caetano, M., da Silva, E.J., 2025. Fuel Tankering Practices and Average Origin-Airport Fuel Prices: Evidence from the Brazilian Domestic Market. Transportation Development Research. 3(1): 62–71. DOI: https://doi.org/10.55121/tdr.v3i1.456

1. Introduction

Fuel tankering refers to the practice whereby an aircraft transports a greater amount of fuel than necessary for a single leg of its journey, specifically to circumvent the need for refueling at the destination airport. This approach increases the aircraft's weight and the fuel expended during the flight. However, it is regarded as a cost-saving strategy adopted by many airlines globally, as it offers economic advantages in terms of fuel expenses.

The implementation of fuel tankering is chiefly motivated by economic considerations, stemming from substantial discrepancies in state-level aviation fuel taxes, which in this case study in Brazil can vary between 4% and 25%. Airlines typically evaluate each flight in isolation to ascertain whether tankering is advantageous, neglecting to consider the cumulative costs across their broader network. Consequently, the practice is often oversimplified for execution when fuel prices are lower [1], which can even define the strategies adopted by airlines in operations at one airport or another [2], thereby increasing their competitiveness by reducing fuel costs [3].

In this sense, this study examines the specific case of Brazil, owing to the significant market concentration held by only three companies: Latam, Azul, and Gol, which account for approximately 38%, 31%, and 30% of the market, respectively [4]. Airlines engage in tankering to mitigate fuel expenditures, given that 90% of tankering decisions in Brazil are predominantly influenced by fuel prices. This economic strategy enables airlines to maintain fiscal stability and competitiveness, particularly given the projected 5.1% annual growth in air travel over the next two decades, driven by the region's economic advancement. However, this practice contributes to heightened CO_2 emissions, which contradicts global sustainability initiatives. Brazil participates in international agreements, such as CORSIA, and has implemented policies, including the National Biofuels Policy (RenovaBio), to achieve emission reductions [5,6].

This study comprehensively evaluates fuel consumption trends and tankering practices within the Brazilian commercial aviation sector by integrating descriptive analysis with regression methodologies. These analyses establish correlations among variables and assess the influence of critical factors on fuel consumption, facilitating informed decision-making processes and policy formulation within the industry.

2. Background

Fuel tankering refers to the practice of carrying an excess of fuel beyond what is necessary for a safe flight, thereby minimizing or eliminating the need for refueling at the destination airport. This practice may be motivated by operational necessities, such as the inability to refuel due to technical difficulties or fuel shortages, as well as by economic factors, like capitalizing on lower fuel costs at the departure airport. Fuel tankering can be categorized into two types: full tankering, where the fuel required for the return flight is loaded at the departure airport, and partial tankering, where only a portion of the return fuel is loaded [6].

As fuel prices continue to soar to unprecedented levels, the tankering strategy has emerged as a significant option for airlines seeking financial savings [7]. Fuel tankering expenses account for nearly 23% of global airline expenses, underscoring the pressing need for more efficient and economical refueling strategies [5].

Many factors may influence fuel tankering rates, including policies for the development of air transport and regional aviation [8,9], fuel prices, flight distances, government taxes, and airline operational costs [3,5]. In this sense, regional airports are inducers of both regional and national economic development [10]. In Brazil, the economy is burdened by considerable taxation on consumption, particularly on fuels, resulting in a tax level that is notably higher than that of similar developing nations. These taxes contribute to elevated fuel prices, affecting various economic sectors, including air transportation [11].

Notwithstanding environmental challenges, the fuel tankering strategy significantly enhances fuel and cost efficiency throughout the airline transportation network [12]. Airlines can effectively minimize operational costs by evaluating various refueling options between departure and destination airports [2]. The extension of the tankering issue to encompass different refueling locations along a route, in conjunction with the cost index flight concept, proves particularly advantageous for long-range private flights, freight transport, ferry flights, and military operations. The cost index methodology, which considers time and fuel-related expenses, frequently demonstrates that the route characterized by the lowest fuel consumption does not inherently represent the most cost-effective option. This highlights the relevance of considering fuel and time expenses when developing flight plans [7].

3. Methods

Data collection included public flight information from the Brazilian National Civil Aviation Agency [Agência Nacional de Aviação Civil] – ANAC [13], detailing origin, destination, aircraft type, and flight times for the years 2019—pre-pandemic—and 2022 and 2023—post-pandemic period. Furthermore, the airlines included in this analysis account for 97% of the Brazilian domestic market share, as measured by Available Seat Kilometers (ASK) in 2019 [14]. This study also provided data on fuel tankering quantities (kg) and routes (origin and destination of flights operating under tankering strategies). Additionally, fuel price public data, in Brazilian Real per liter (R$/l), were sourced from the Brazilian National Petroleum Agency [Agência Nacional do Petróleo] – ANP from 2018 to 2023 [15].

To preserve airlines' commercial strategies, all provided fuel tankering data have been aggregated, and the names of the airlines will not be disclosed. All rankings were generated using only the airports involved during 2019, 2022, and 2023, with a focus solely on domestic flights for the analysis. Data from 2020 and 2021 were excluded due to the low volume of flights during that period, a consequence of the pandemic.

A combination of descriptive statistics and regression analysis was employed. Initially, the mean and standard deviation of fuel tankering quantities were computed for each airport and route, providing an overview of fuel consumption patterns. An index was established for each airport to account for the variation in the number of flights at each location, as some airports experience a significantly higher volume of flights. For each route, the index for the airport was calculated according to Equation 1, where X represents the number of flights for a specific route, X_{min} is the minimum number of flights across all routes, and X_{max} is the maximum number of flights across all routes.

$$X = \frac{X - X_{\min}}{X_{\max} - X_{\min}} \quad (1)$$

To avoid considering airports that operate seasonally or account for occasional flights, only routes with a minimum of 48 operations per year, equivalent to at least one flight per week, were evaluated. Subsequently, simple linear regression models were employed to assess the relationship between fuel prices and the volume of fuel tankering at each airport. This methodology quantifies the impact of fuel price fluctuations on tankering practices. Equation 2 was used to adjust the fuel tankering supplied (FTS) according to flight frequency for each route.

$$FTS = \frac{Fuel\ \ tankering\ \ (Kg)}{Number\ \ of\ \ flights.\ \ X} \quad (2)$$

Furthermore, multiple linear regression analysis was employed to investigate the combined effects of factors, including airport size, flight frequency, fuel prices, and geographic location on fuel consumption and tankering strategies. In Brazil, fuel prices fluctuate considerably depending on the state and the taxes applied in that location [7], which is considered a possible source of bias. This multivariate approach facilitated a more comprehensive understanding of the determinants influencing fuel consumption within the Brazilian aviation sector.

4. Results

Initially, a descriptive analysis of fuel tankering practices and fuel prices in Brazilian domestic flights was conducted for 2019, 2022, and 2023. **Figures 1**, **2**, and **3** illustrate the comparative evolution of aviation fuel prices in Brazil, based on the average distribution prices in the airport region, as published by the ANP for each year under study [15]. This analysis considers state taxes and the Tax on the Circulation of Goods and Transportation and Communication Services (ICMS), which can be defined as a value-added tax applied at each stage of the fuel supply process whenever a sale occurs [16]. The color scale represents the variance in fuel prices, ranging from R$4.2 / liter to R$10.5 / liter, with locations exhibiting the lowest fuel prices depicted in green. In contrast, areas with higher prices are expressed in progressively redder hues.

Figure 1 shows that in 2019, the highest prices were in the southeastern region of the country, especially in São Paulo state, the most developed in the country. This is also clear in **Figure 2** for 2022.

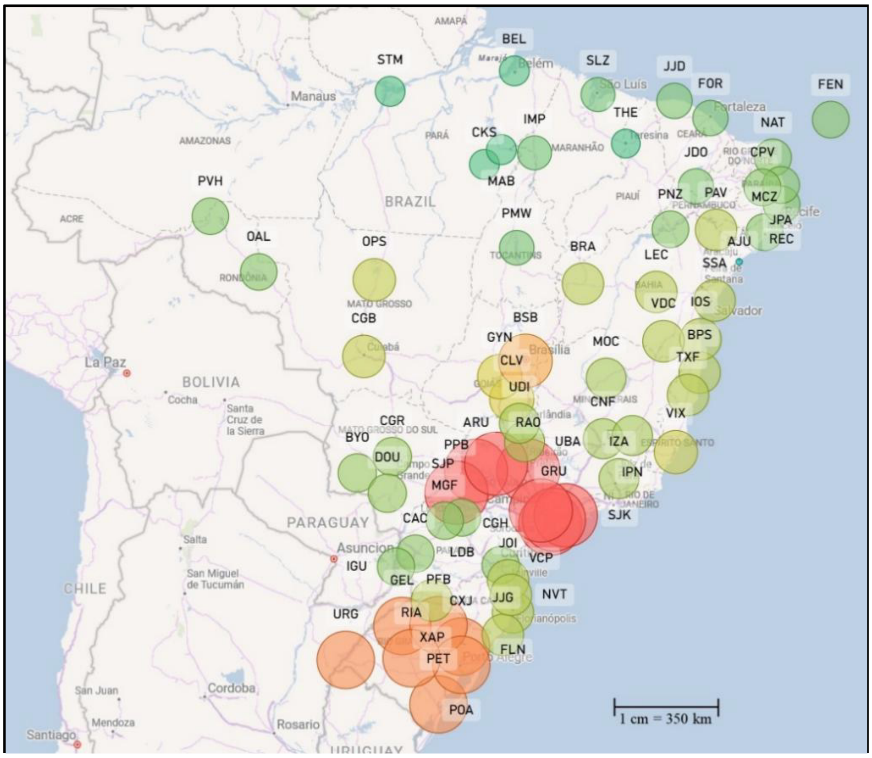

Figure 1. Average Price (R$/l) of Aviation Fuel in 2019.

Note: The color scale in **Figure 1** displays fuel prices from R$4.2 per liter (green, lowest) to R$6.3 per liter (red, highest).

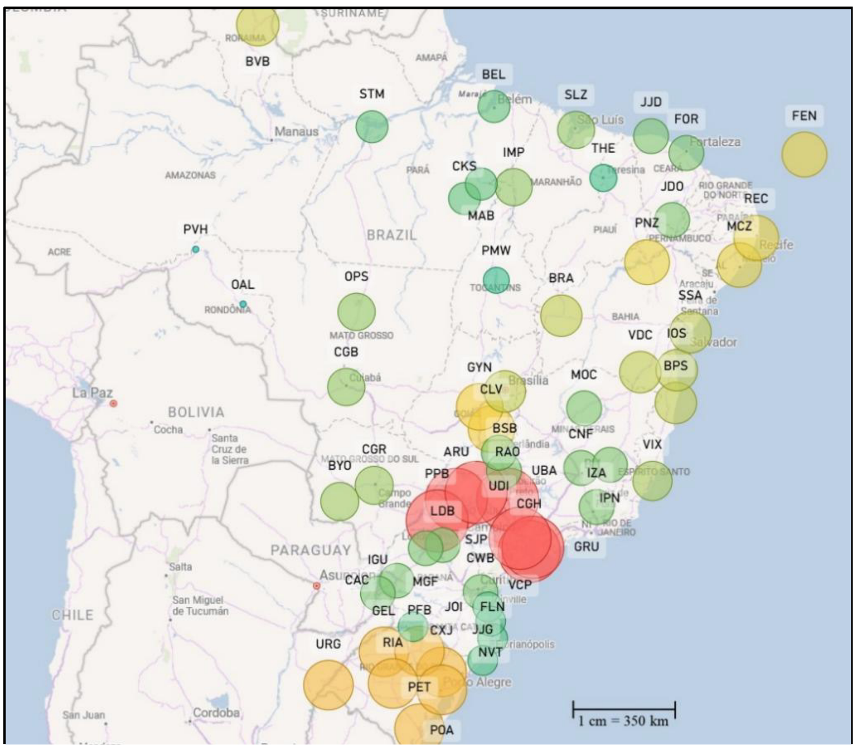

Figure 2. Average Price (R$/l) of Aviation Fuel in 2022.

Note: The color scale in **Figure 2** displays fuel prices ranging from R$7.7 per liter (green, lowest) to R$10.5 per liter (red, highest).

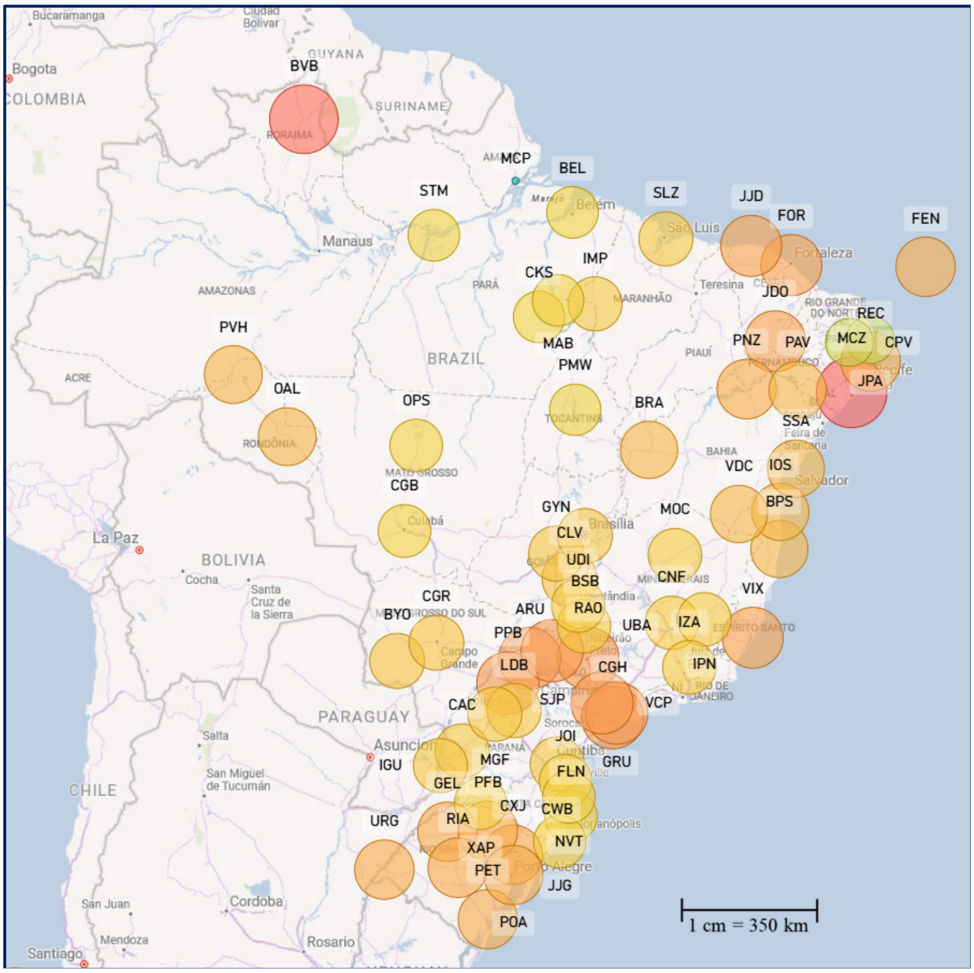

Figure 3. Average Price (R$/l) of Aviation Fuel in 2023.

Note: The color scale in **Figure 3** displays fuel prices ranging from R$6.8 per liter (green, lowest) to R$10.4 per liter (red, highest).

Although **Figure 3** shows more uniformity in the prices charged across different regions of Brazil, it is evident that the prices for a liter of fuel are relatively higher in less economically developed areas such as the North and Northeast. The average price (R$/l) of aviation fuel distribution per airport, as shown in **Figures 1–3**, exhibits significant fluctuations between 2019 and 2023, mainly due to the COVID-19 pandemic [17]. Prices were generally significantly higher in the southeastern states, as most airline hub airports are concentrated there. In 2023, a notable increase in fuel prices was observed across all states, with elevated values in the northeast, a region typically highly touristic for travelers in Brazil, as noted in literature from the study of Raeder [18].

To evaluate the relationship between fuel prices and supplied fuel tankering, linear regression was employed, considering the fuel prices at the departure airports and the quantities of fuel tankering refueled. **Figures 4**, **5**, and **6** illustrate the volume of fuel tankering supplied per origin airport and the average fuel price at each analyzed location for 2019, 2022, and 2023.

Analyzing **Figure 4** shows that in 2019, Aracaju International Airport (SBAR) in the Northeast had the lowest relative fuel price, but it also had a low tankering rate. Conversely, airports in the Southeast, such as São Paulo/Congonhas Airport (SBSP) and São Paulo/Guarulhos International Airport (SBGR), both serving São Paulo, display the opposite trend, as shown in **Figure 5** for 2022.

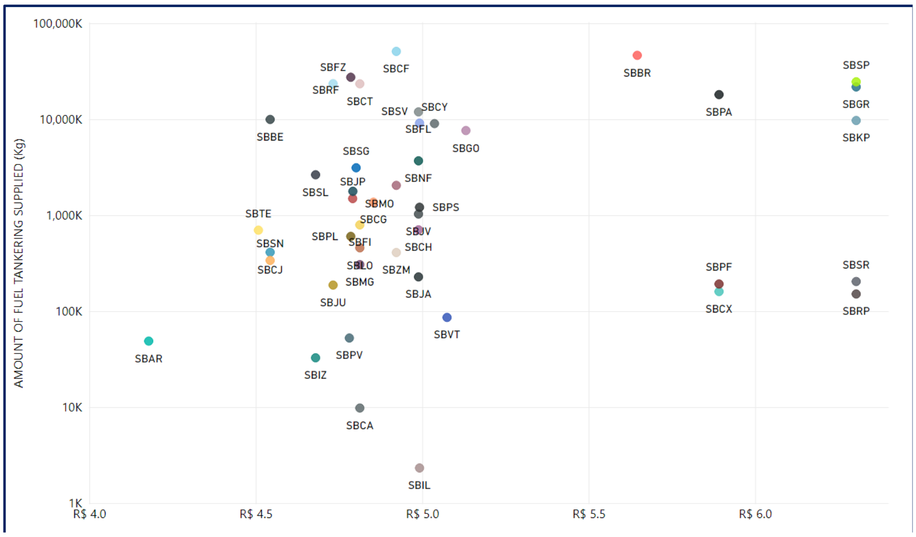

Figure 4. Fuel Price at Departure Station (R$/l) and Amount of Fuel Tankering Supplied (Kg) in 2019.

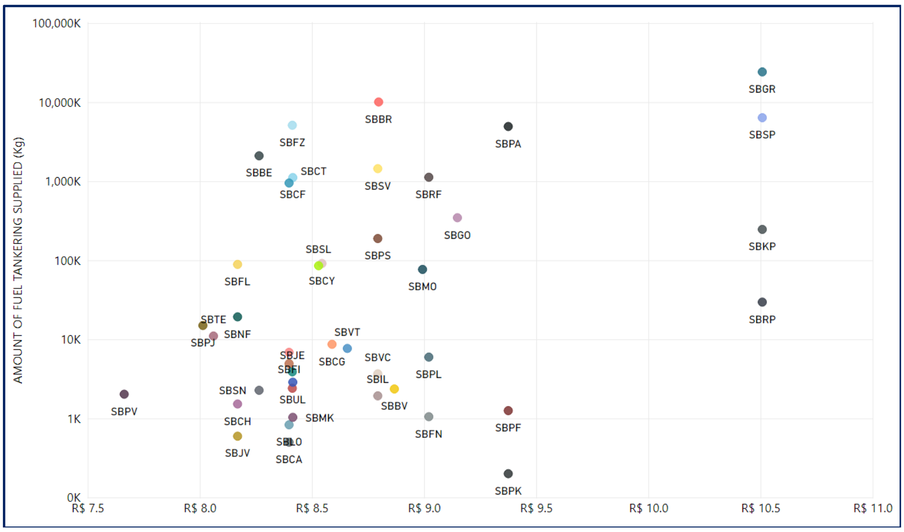

Figure 5. Fuel Price at Departure Station (R$/l) and Amount of Fuel Tankering Supplied (Kg) in 2022.

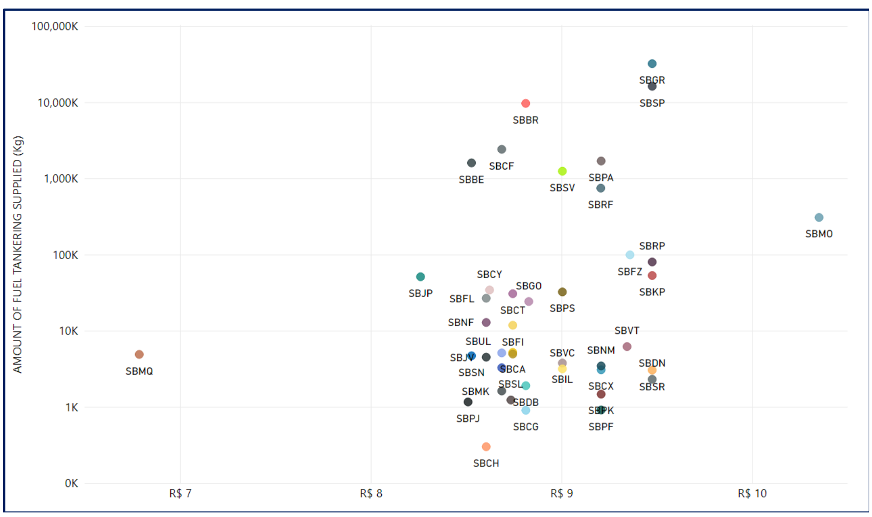

Figure 6. Fuel Price at Departure Station (R$/l) and Amount of Fuel Tankering Supplied (Kg) in 2023.

What stands out in **Figure 6** is that, even with the high fuel price at Maceió International Airport (SBMO), which is R$10.4 per liter, a significant amount of fuel tankering was supplied in 2023. Although not considered in this study, this may be related to airport infrastructure issues or specific strategies adopted by airlines at this airport.

In summary, the amount of supplied tankering tends to be higher at airports with lower fuel prices. **Table 1** highlights the 20 routes with the highest tankering volumes for 2019, 2022, and 2023.

Table 1. Top 20 Most Representative Fuel Tankering Routes by Supplied Quantity (Kg) in 2019, 2022, and 2023.

Route	Tankering (Kg) 2019	Tankering (Kg) 2022	Tankering (Kg) 2023	Total Tankering (Kg)
SBCF/SBGR	10,229,628	5,534	842,721	11,077,883
SBGL/SBGR	4,750,325	1,800,502	3,771,082	10,321,909
SBPA/SBSP	4,811,510	3,737,631	439,041	8,988,182
SBCF/SBSP	8,356,921	4,260	14,178	8,375,359
SBBR/SBGR	7,660,365	3,351	6,867	7,670,583
SBBR/SBSP	7,615,687	13,695	13,461	7,642,843
SBCT/SBSP	6,585,851	819,189	9,132	7,414,172
SBCT/SBGR	6,910,432	8,669	3,913	6,923,014
SBSP/SBNF	2,163,273	1,344,921	3,319,468	6,827,662
SBPA/SBGR	5,650,233	601,556	170,868	6,422,657
SBRF/SBGR	6,399,639	4,613	4,886	6,409,138
SBSP/SBVT	1,899,941	2,243,270	1,924,063	6,067,274
SBGR/SBVT	2,214,247	1,496,753	1,925,515	5,636,515
SBFL/SBGR	5,405,846	6,410	3,460	5,415,716
SBBR/SBKP	4,581,437	290,365	381,275	5,253,077
SBRF/SBFZ	4,192,546	766,006	183,044	5,141,596
SBBR/SBTE	2,742,370	1,153,810	1,022,170	4,918,350
SBGR/SBCY	893,594	2,439,702	1,522,779	4,856,075
SBGR/SBNF	1,027,726	1,841,146	1,901,821	4,770,693
SBBE/SBMQ	2,706,954	979,807	804,631	4,491,392

Table 1 demonstrates that tanker decisions have a significant impact on fuel prices at destination airports. Among the 20 routes exhibiting the highest tankering demand, 60% lead to airports in São Paulo (SBGR, SBSP, or SBKP), where fuel prices are comparatively elevated. This trend highlights the need for meticulous analysis of economic and operational conditions to maximize the financial benefits of this strategy.

The analysis indicates that an increase of R$1.00 per liter in the fuel price at the origin correlates with a reduction of approximately 32,970 kg in the volume of refueled fuel. The negative and statistically significant coefficient ($p < 0.05$) implies that airlines are likely to refuel less when prices at the origin are heightened. Nonetheless, the R-squared value (0.018) suggests that only 1.8% of the variation in the refueled fuel quantity can be attributed to the price at the origin.

Likewise, an increase of R$1.00 in the fuel price at the destination is associated with a decline of approximately 44,540 kg in the volume of refueled fuel. The coefficient remains statistically significant and negative, reinforcing the observed trend. The R-squared value (0.022) is marginally higher, indicating a weak correlation.

Considering the prices at both the origin and destination, both coefficients stay negative and statistically significant. A R$ 1 increase in fuel prices at either location leads to a reduction of about 23,260 kg and 35,260 kg in refueled fuel volumes, respectively. The R-squared value (0.030) indicates that fuel prices explain 3.0% of the variation in fuel quantity. This confirms that although the relationship is statistically significant, it is weak, implying that other factors also influence the decision to engage in tankering.

In addition to affecting the financial competitiveness of airlines, decisions about tankering can also influence greenhouse gas (GHG) emission reduction targets [12], especially when using Sustainable Aviation Fuel (SAF) [19], because even if refueling at a lower cost, the extra fuel consumption can undermine the sector's environmental goals [20, 21]. This can also guide efforts in the aeronautical industry to develop alternative aviation fuels, such as those extracted from forest residues [22], hydrogen-based fuels [23, 24, 25], or even power-to-liquid fuel [26].

To sustain a competitive aviation market across diverse regions and to mitigate the costs associated with transporting fuel in aircraft tanks to areas with higher prices—thereby increasing weight and aircraft consumption [7]—regulatory agencies might formulate public policies aimed at standardizing pricing throughout the country's various regions through the implementation of legal taxation measures, primarily aimed at reducing taxes in the sector. Furthermore, enhanced monitoring of the prices charged could serve to prevent opportunistic behaviors within the fuel supply sector.

5. Conclusions

This study has explored the economic potential and operational impacts of fuel tankering in the Brazilian commercial aviation industry, providing valuable insights into its feasibility and effects. By analyzing fuel prices, operational costs, and regulatory policies, the study pinpointed the conditions where fuel tankering can provide economic benefits for airlines.

The findings show that while fuel tankering offers significant cost-saving opportunities, especially due to the differences in state-level aviation fuel taxes, it also poses challenges because of increased CO^2 emissions. The analysis demonstrated that higher fuel prices at both departure and destination airports greatly reduce the amount of fuel tankered, indicating that airlines respond to price changes while balancing economic benefits with environmental concerns.

Moreover, the study emphasizes the relevance of thorough planning and a comprehensive evaluation of network-wide impacts instead of relying only on isolated flight-by-flight decision-making. This approach can enhance operational efficiency and cost-effectiveness, especially in a competitive and growing market like Brazil. The contributions of this research cover both theoretical and practical aspects. Theoretically, it enhances the understanding of the dynamics of fuel tankering and its economic effects. It offers practical insights for airlines aiming to optimize their fuel strategies and for policymakers trying to regulate practices that balance economic interests with environmental goals.

Future research should focus on detailed modeling of environmental impacts and explore alternative strategies that balance cost savings with sustainability. Such efforts could also include comparative analyses across different countries. Additionally, investigating the long-term effects of regulatory changes on fuel tankering practices and broader industry trends will be essential in guiding policy and strategic decisions within the aviation sector.

Author Contributions

Conceptualization, L.A.T.; methodology, L.A.T. and M.C.; software, L.A.T. and E.J.S; validation, L.A.T, M.C. and E.J.S.; formal analysis, M.C. and E.J.S.; investigation, L.A.T.; resources, data curation and writing—original draft preparation, L.A.T. and M.C.; writing—review and editing, L.A.T., M.C. and E.J.S.; visualization, L.A.T., M.C. and E.J.S.; supervision, M.C.; project administration, L.A.T.; funding acquisition, M.C. and E.J.S. All authors have read and agreed to the published version of the manuscript.

Funding

This study was supported by the National Council for Scientific and Technological Development (CNPq), Brazil, Research Productivity (PQ), grant number 304919/2022-5.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data can be made available upon request.

Acknowledgments

The authors would like to thank the National Council for Scientific and Technological Development (CNPq), Brazil, for their financial support in this work.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

[1] Fregnani, J.A., Müller, C., Correia, A., 2013. A fuel tankering model applied to a domestic airline network. Journal of Advanced Transportation. 47(4), 386–398. DOI: https://doi.org/10.1002/atr.162

[2] Smith, L.D., Bilir, C., 2023. Modelling Airline Operations at Major Commercial Airports for Strategic Decision Support. Transportation Development Research. 1(1), 6–19. DOI: https://doi.org/10.55121/tdr.v1i1.101

[3] Yoo, H., Lee, J., Moon, I., 2024. An integrated approach for an aircraft routing and fuel tankering problem. Transportmetrica A Transport Science. 1–28. DOI: https://doi.org/10.1080/23249935.2024.2392164

[4] ANAC, 2023. Dados estatísticos. Available from: https://www.gov.br/anac/pt-br (12 Jun 2024).

[5] O'Reilly, P., Sulzbacher, F., Coutinho, D.J., et al., 2022. Aviation Fuel Tankering and Sustainability: The Brazilian Scenario. International Journal of Aviation, Aeronautics, and Aerospace. 10(2), 1. DOI: https://doi.org/10.58940/2374-6793.1786

[6] Tabernier, L., Fernández, E.C., Tautz, A., et al., 2021. Fuel Tankering: Economic Benefits and Environmental Impact for Flights Up to 1500 NM (Full Tankering) and 2500 NM (Partial Tankering). Journal of Aviation Technology and Engineering. 8(2), 37. DOI: https://doi.org/10.3390/aerospace8020037

[7] Deo, V.A., Silvestre, F.J., Morales, M., 2020. The benefits of tankering considering cost index flying and optional refuelling stops. Journal of Air Transport Management. 82, 101726. DOI: https://doi.org/10.1016/j.jairtraman.2019.101726

[8] AitBihiOuali, L., Carbo, J.M., Graham, D.J., 2020. Do changes in air transportation affect productivity? A cross-country panel approach. Regional Science Policy & Practice. 12(3), 493–505. DOI: https://doi.org/10.1111/rsp3.12280

[9] Mokhele, M., 2018. Towards the operationalization of a spatial economic theory for airport-centric developments. Regional Science Policy & Practice. 10(3), 189–201. DOI: https://doi.org/10.1111/rsp3.12127

[10] Caetano, M., Silva, E.J., Vieira, D.J., et al., 2022. Criteria prioritization for investment policies in General Aviation aerodromes. Regional Science Policy & Practice. 14(6), 211–234. DOI: https://doi.org/10.1111/rsp3.12538

[11] Proque, A.L., Betarelli Junior, A.A., Perobelli, F.S., 2022. Fuel tax, cross subsidy and transport: Assessing the effects on income and consumption distribution in Brazil. Research in Transportation Economics. 95, 101204. DOI: https://doi.org/10.1016/j.retrec.2022.101204

[12] Bullerdiek, N., Neuling, U., Kaltschmitt, M., 2021. A GHG reduction obligation for sustainable aviation fuels (SAF) in the EU and in Germany. Journal of Air Transport Management. 92, 102020. DOI: https://doi.org/10.1016/j.jairtraman.2021.102020

[13] ANAC, 2023. Flight and Air Operations Database – Active Scheduled Flight (VAR). 2019–2023. Available from: https://dados.gov.br/dados/conjuntos-dados/dadosabertos-areas-de-atuacao-voos-e-operacoes-aereas-voo-regular-ativo-vra (25 Jan 2024). [in Portuguese]

[14] ABEAR, 2020. Panorama 2019 – The Airline Sector in Data and Analysis. Available from: https://www.abear.com.br/wp-content/uploads/2020/10/Panorama2019.pdf (19 Dec 2024). [in Portuguese]

[15] ANP, 2023. Annual Price Bulletin. Available from: https://www.gov.br/anp/pt-br/assuntos/precos-e-defesa-da-concorrencia/precos/precos-revenda-e-de-distribuicao-combustiveis/serie-historica-do-levantamento-de-precos (15 Jun 2024). [in Portuguese]

[16] EPE, 2023. Fuel Price in Brasil Study Series: Understanding fuel price composition in Brazil. Available from: https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-251/topico-195 (15 Jun 2024).

[17] Alfano, V., Capasso, S., 2024. Fuelling the pandemic: The impact of fuel prices on COVID-19. Case Studies on Transport Policy. 18, 01314. DOI: https://doi.org/10.1016/j.cstp.2024.101314

[18] Raeder, F.T., 2025. Airfares adjustment to fuel price shocks: Evidence from the Brazilian airline market. Journal of Air Transport Management. 125, 102785. DOI: https://doi.org/10.1016/j.jairtraman.2025.102785

[19] Guilloteau, P., Groll, N., Jensen, A.D., et al., 2025. Production of sustainable aviation fuel: Influence of feedstock and plant capacity on fuel price. International Journal of Hydrogen Energy. 157, 150494. DOI: https://doi.org/10.1016/j.ijhydene.2025.150494.

[20] Uy, J.G., Juan, J.L.S., 2024. Multi-objective optimization of airline fuel loading problem considering sustainable aviation fuel and book-and-claim. Journal of Cleaner Production. 482, 144241. DOI: https://doi.org/10.1016/j.jclepro.2024.144241

[21] Teixeira, A.T., Silva, A.C.M., Cavalcante, R.M., et al., 2024. Process simulation and economic evaluation of the Alcohol-to-Jet production of sustainable aviation fuel in the Brazilian context. Energy Conversion and Management. 319, 118947. DOI: https://doi.org/10.1016/j.enconman.2024.118947

[22] Ahire, J.P., Bergman, R., Runge, T., et al., 2024. Techno-economic and environmental impacts assessments of sustainable aviation fuel production from forest residues. Sustainable Energy Fuels, 8, 4602-4616. DOI: https://doi.org/10.1039/D4SE00749B.

[23] Abid, H., Skov, I.R., Mathiesen, B.V., et al., 2025. Standalone and system-level perspectives on hydrogen-based sustainable aviation fuel pathways for Denmark. Energy. 320, 135450. DOI: https://doi.org/10.1016/j.energy.2025.135450.

[24] Oesingmann, K., Grimme, W., Scheelhaase, J., 2024. Hydrogen in aviation: A simulation of demand, price dynamics, and CO2 emission reduction potentials. International Journal of Hydrogen Energy. 64, 633-642. DOI: https://doi.org/10.1016/j.ijhydene.2024.03.241.

[25] Brito, R., Henkes, J.A, 2023. A study on aviation fuels: hydrogen and fuel cells. Brazilian Journal of Civil Aviation & Aeronautical Sciences. 3, (2), 159–182.

[26] Mueller, T., Winter, E., Grote, U., 2025. Decarbonizing the aviation sector: Multiplier effects of power-to-liquid fuel production on the German economy. Sustainable Energy Technologies and Assessments. 82, 104478. DOI: https://doi.org/10.1016/j.seta.2025.104478.