Airline Hub and Local Development: The Case of Recife Airport in Brazil

Beatriz de Oliveira Gonçalves[1] and Raul da Mota Silveira Neto[2]

[1,2]Universidade Federal de Pernambuco (PIMES/UFPE)

Contributing authors: beatriz.goncalves@ufpe.br; raul.silveirant@ufpe.br;

Abstract

Airports may generate positive effects on regional economic development by attracting firms through better business opportunities, encouraging local investments, and leading to increased employment. Recent studies have shown that the expansion of air services is associated with growth in employment and income, but few studies analyze these effects in developing regions. The primary objective of this research is to assess the economic impacts of the implementation of an airline hub by Azul Linhas Aéreas in Recife in 2016. Using the synthetic control method and data from 2006 to 2023, it was found that the implementation of the airport hub in Recife had significant effects on the proportion of employees in the formal Travel sector and on the number of registered tour guides in the capital. The implementation of Azul's hub is associated with increases of approximately 48% and 82%, respectively, compared to the pre-intervention averages. Although no significant results were observed for the overall economy, the findings suggest that the intervention had meaningful impacts on the tourism sector in the municipality where it was introduced.

Keywords: Airport. Hub. Employment.

JEL Classification: R11, R41, R42

Area: Infrastructure, transportation, energy, mobility, and communication

Resumo

Aeroportos podem gerar efeitos positivos sobre o desenvolvimento econômico regional ao atrair firmas através de melhores oportunidades de negócios, incentivando investimentos locais e promovendo um aumento do emprego. Estudos recentes têm demonstrado que a expansão dos serviços aéreos está associada a um crescimento do emprego e da renda, mas poucos estudos analisam estes efeitos em regiões em desenvolvimento. O principal objetivo desta pesquisa é avaliar os impactos econômicos da implementação de um hub aéreo da Azul Linhas Aéreas no Recife em 2016. Utilizando o método de controle sintético e dados referentes ao período de 2006 a 2023, constatou-se que a implementação do hub aéreo no Recife gerou efeitos significativos sobre a proporção de empregados no setor formal de Viagens e sobre o número de guias turísticos registrados na capital. A implementação do hub da Azul está associada a aumentos de aproximadamente 48% e 82%, respectivamente, em comparação com as médias anteriores à intervenção. Embora não tenham sido observados resultados significativos para a economia como um todo, os resultados sugerem que a intervenção teve impactos expressivos sobre o setor de turismo no município onde foi implementada.

Palavras-chave: Aeroporto. Hub. Emprego.

Classificação JEL: R11, R41, R42

Área: Infra-estrutura, transporte, energia, mobilidade e comunicação

1 Introduction

In 2016, the airline Azul Linhas Aéreas established a hub at Gilberto Freyre International Airport, located in Recife, the capital of the state of Pernambuco. Since its inception, this operational base has enabled greater connectivity among cities in Brazil's Northeast by increasing the number of available flights. According to data from the Agência Nacional de Aviação Civil [National Civil Aviation Agency] (ANAC), the total number of Azul flights in Recife increased from 16,157 in 2015 to 42,397 in 2019, more than doubling in just four years. In 2023, the airline operated a total of 51,307 flights in Recife.

This initiative aims to enhance the city's connections with the rest of the country, potentially boosting local economic activity by attracting companies, offering better business opportunities, encouraging investment in the region, and generating increased employment (Blonigen and Cristea, 2015; Brueckner, 2003; McGraw, 2020). Such an expectation seems to make sense considering the Brazilian context. According to the Instituto de Pesquisa Econômica Aplicada [Institute for Applied Economic Research] (IPEA, 2010), Brazil has significant potential for developing air transport due to factors such as its continental-scale territory and the high geographic and social mobility of its population. If airport infrastructure does influence local economic indicators in Brazil, the establishment and expansion of air services could be considered important instruments of urban economic development for the country.

Despite the impressive numbers of the new hub in Recife airport, there is no evaluation of its economic impact on the city or region. More broadly, studies linking urban economic development and air services in Brazil remain extremely scarce, despite the importance of air transportation to the country. Given this gap in the literature, the primary objective of this research is to assess the economic impacts of implementing airport hubs in specific regions, focusing on Azul Linhas Aéreas' hub, launched in Recife in 2016. We analyze both general and sector-specific effects on employment and income in the city of Recife. According to the authors' knowledge, the investigation is the first study on the impacts of air hubs in Brazil within the economic literature.

Obtaining unbiased estimates of these effects, however, is a challenging task, as the relationship between airports and economic development may present evident problems of reverse causality and omitted variables. Recent studies using advanced identification strategies have shown that the expansion of air services caused employment and income growth (Blonigen and Cristea, 2015; Sheard, 2014, 2019; McGraw, 2020). Most of these analyses consider airports of various sizes in the United States, but the effects on economic development may differ when focusing only on airport hubs. A hub is an airport that serves as a primary connection point within an airline's network, increasing passenger traffic and the number of flights at the location.

To conduct the analysis, we use the Synthetic Control method. This approach allows for the estimation of what would have happened to the treated unit in the absence of the intervention by constructing a weighted combination of untreated units, providing a better comparison for the region exposed to the intervention. This identification strategy extends the traditional difference-in-differences method by allowing the effects of unobserved variables on the outcome to vary over time, and is suitable for settings with only one treated unit (Abadie et al, 2010). We use a panel dataset constructed from multiple data sources, including the Continuous National Household Sample Survey (PNADC), the Annual Social Information Report (RAIS), several datasets from ANAC, and records of tourism service providers from the Ministry of Tourism. The dataset covers the period from 2006 to 2023.

The results indicate that the implementation of the airport hub in Recife had significant effects on the proportion of employees in the formal Travel sector[1] and on the number of registered tour guides in the capital. The implementation of Azul's hub is associated with increases of approximately 48% and 82%, respectively, compared to the pre-intervention averages. However, no significant effects were found on more aggregated economic variables, such as GDP per capita and employment in the services sector. Therefore, the findings suggest that the airline hub had significant impacts, albeit limited to the tourism sector within the municipality.

[1]The Travel sector, as defined in this paper, corresponds to Division 79 of the National Classification of Economic Activities (CNAE), which comprises economic activities related to travel agencies, tour operators and reservation services. A more detailed description of this sector is presented in the Results section.

2 Local Background

In Brazil, three major airlines dominate the market: Azul, GOL, and LATAM. In 2023, these three companies accounted for 88.9% of all flights operated in the country, according to data from ANAC. Since the beginning of the analyzed series in 2006, these airlines have collectively held the majority of the Brazilian air travel market. Since 2014, Azul, GOL, and LATAM each have a larger market share than the sum of all other airlines combined.

The need for domestic and international connectivity requires Azul, GOL, and LATAM to designate certain airports as primary connection centers, known as hubs. The selection of these hubs is based on business decisions made by the airlines themselves, with no official records from ANAC. However, this information was obtained through direct contact with the press offices of each airline.

LATAM Airlines has two hubs in Brazil: São Paulo - Guarulhos International Airport and Brasília International Airport, in the Federal District. According to the company's press office, both hubs began operations in 2012 (LATAM Press, 2025). GOL Linhas Aéreas did not respond to email inquiries regarding its hubs in Brazil. However, the air network provided on the company's website leads to the assumption that its primary hubs are in São Paulo, Rio de Janeiro, Brasília, and Salvador. In August 2022, GOL announced the establishment of a hub at Salvador International Airport, stating that it would progressively increase its flight offerings (GOL Informa, 2022). Additionally, in 2018, GOL signed an agreement with the State Government of Ceará to establish a hub at Fortaleza International Airport (Governo do Estado do Ceará, 2018). However, this hub did not develop as planned (Diário do Nordeste, 2023), and the expected increase in flights did not materialize significantly in the following years.

Azul Linhas Aéreas Brasileiras operates three hubs in Brazil: Viracopos International Airport in Campinas, São Paulo; Belo Horizonte International Airport in Confins, a neighboring city of the capital of Minas Gerais; and Recife International Airport in Pernambuco. According to Azul's press office, the Campinas hub was established in December 2008, and the Belo Horizonte hub in August 2009. The Recife hub was established in February 2016 (Azul Press, 2025).

The decision to elevate Recife's airport to hub status was made by Azul to "expand interregional connections and links to other parts of the country from Recife, enabling greater connectivity between northeastern capitals" (Prefeitura do Recife, 2016). With the formalization of the agreement between Azul and the Recife City Hall, the municipal economy was expected to be stimulated, generating more jobs and income for the city, particularly in the tourism sector. A reduction in airfare prices was also expected, with a higher number of direct and cheaper flights. According to then-president of Azul Linhas Aéreas, Antonoaldo Neves, the company planned a long-term partnership, aiming to double the number of its flights within four to five years (Prefeitura do Recife, 2016).

This increase occurred as expected, as shown in Table 1. Changes in the number of flights in Recife can also be observed by comparing the total number of flights per year and metropolitan region, as illustrated in Figure 1. This study analyzes whether the establishment of the Recife airport hub, and the resulting sharp increase in total flights in the region, led to significant economic changes in the city.

Table 1: Number and variation of Azul flights in Recife

Year	Number of flights	Variation (%)
2009	1,344	
2010	2,428	80.65
2011	5,510	126.94
2012	7,289	32.29
2013	9,728	33.46
2014	14,713	51.24
2015	16,157	9.81
2016	22,959	42.10
2017	30,032	30.81
2018	34,556	15.06
2019	42,397	22.69
2020	25,332	-40.25
2021	45,386	79.16
2022	47,585	4.85
2023	51,307	7.82

Source: Elaborated by the authors using data from ANAC.
Note: The data include both arriving and departing flights.

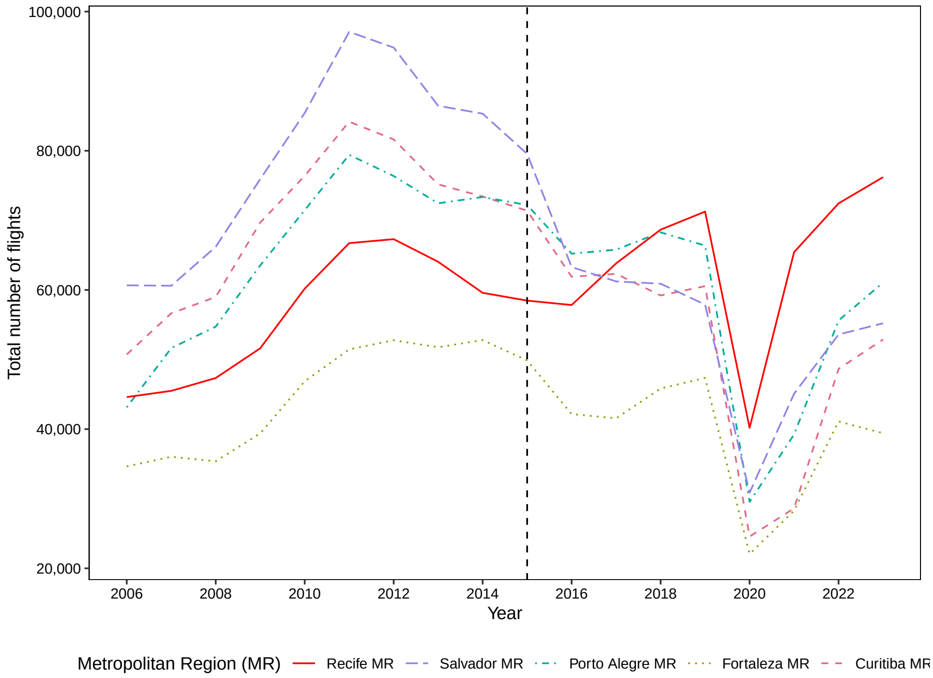

Fig. 1: Total number of flights by metropolitan region (MR) and year

Notes: The annual data refers to the total values for each complete year. Therefore, the 2016 data already include the effects of the changes after the hub implementation. For that reason, the vertical line, which indicates the year of the intervention, is positioned over 2015 in the figures, allowing for the visualization of the hub's impact. The figure displays only the treated unit, the Recife Metropolitan Region, and the four donor pool units with the highest number of flights, for the sake of illustration. The remaining control units follow a similar pattern.

3 Empirical Strategy and Data

3.1 Econometric approach

Airports, and especially hubs, are not randomly established in cities. There is a financial interest on the part of firms, considering that their allocation in a certain region will bring the greatest possible economic return. Consequently, estimating the effects of hubs on local economic indicators is not straightforward, as such estimations may be subject to endogeneity issues, particularly due to reverse causality. Therefore, a robust identification strategy must account for the possibility of endogeneity and adequately address this issue. In this study, we chose the Synthetic Control Method (SCM), as it can construct an appropriate counterfactual for the locality benefiting from the introduction of the airport hub, thereby estimating what the outcomes would have been for the treated unit in the absence of the intervention.

Athey and Imbens (2017) described the synthetic control method as the most important innovation in policy evaluation literature in the fifteen years preceding their publication. This identification strategy allows for the estimation of the treatment effect on the treated unit by generating a counterfactual with observable characteristics similar to those of the treated unit in the pre-treatment period. This counterfactual is constructed from a weighted combination of units that did not receive the treatment, providing a more suitable comparison for the unit exposed to the intervention (Abadie et al, 2010). The synthetic control method was originally proposed to estimate the effects of interventions implemented at an aggregate level that impact a small number of large units (such as cities, regions, or countries) on some aggregate variable of interest (Abadie, 2021).

This model extends the traditional difference-in-differences approach by allowing the effects of unobservable variables on the outcome to vary over time (Abadie et al, 2010). Unlike the difference-in-differences method, synthetic control moves away from using a single control unit or a simple average of control units, instead employing a weighted average of the control group that more closely resembles the treated unit than any single control (Athey and Imbens, 2017). Moreover, the synthetic control methodology formalizes the selection of comparison units through a data-driven procedure, avoiding reliance on informal statements of affinity between treated units and the set of control units (Abadie, 2021).

Beyond these reasons, the use of the synthetic control method is particularly interesting for several factors. First, it makes the difference between the treated unit and the combination of control units transparent. Second, it does not require access to post-treatment outcomes while computing the synthetic control, providing greater protection against specification searches and undesirable manipulations. Third, the method explicitly reveals the contribution of each comparison unit to the counterfactual of interest (Abadie, 2021).

According to Abadie et al (2010), the model is obtained from panel data for $J+1$ regions over a period of T years, with only one region exposed to the intervention of interest (in this study, the introduction of an airport hub in the locality). Thus, J regions serve as potential controls. Let Y_{it}^N be the outcome of the variable of interest (employment, GDP, among others) that would be observed for region i in period t in the absence of the intervention, for units $i = 1, ..., J+1$, and time periods $t = 1, ..., T$. Let T_0 be the number of pre-intervention periods, with $1 \leq T_0 < T$. Let Y_{it}^I be the outcome that would be observed for unit i in period t if this unit were exposed to the intervention in periods $T_0 + 1$ to T. Also, let $\alpha_{it} = Y_{it}^I - Y_{it}^N$ be the effect of the intervention for unit i in period t, and D_{it} an indicator that takes the value of one if unit i is exposed to the intervention in period t, and zero otherwise. Then, the observed outcome for unit i in period t is:

$$Y_{it} = Y_{it}^N + \alpha_{it} D_{it} \tag{1}$$

For $t > T_0$,

$$\alpha_{1t} = Y_{1t}^I - Y_{1t}^N = Y_{1t} - Y_{1t}^N \tag{2}$$

α_{1t} represents the effect of the intervention for unit 1, the only treated unit, for the post-treatment periods, which is precisely what is sought to be estimated. Since Y_{1t}^I is observable, it is only necessary to find Y_{1t}^N to estimate α_{1t}.

Abadie et al (2010) define Y_{it}^N is given by a factor model such that:

$$Y_{it}^N = \delta_t + \boldsymbol{\theta_t Z_i} + \boldsymbol{\lambda_t \mu_i} + \varepsilon_{it} \tag{3}$$

where δ_t is an unknown factor that is common and constant across units, $\boldsymbol{Z_i}$ is a vector of observable covariates (not affected by the intervention), $\boldsymbol{\theta_t}$ is a vector of unknown parameters, $\boldsymbol{\lambda_t}$ is a vector of unobserved common factors, $\boldsymbol{\mu_i}$ is a vector of unknown factor loadings, and the term ε_{it} represents unobserved transitory shocks at the regional level with zero mean.

Consider a weight vector $\boldsymbol{W} = (w_2, ..., w_{J+1})'$ such that $w_j \geq 0 \quad \text{for} \quad j = 2, ..., J+1 \quad \text{and} \quad w_2 + ... + w_{J+1} = 1$. Each specific value of the vector $\boldsymbol{W}$ represents a potential synthetic control, that is, a particular weighted average of the available control regions. The outcome variable for each synthetic control indexed by $\boldsymbol{W}$ is:

$$\sum_{j=2}^{J+1} w_j Y_{jt} = \delta_t + \boldsymbol{\theta_t} \sum_{j=2}^{J+1} w_j \boldsymbol{Z_j} + \boldsymbol{\lambda_t} \sum_{j=2}^{J+1} w_j \boldsymbol{\mu_j} + \sum_{j=2}^{J+1} w_j \varepsilon_{jt} \tag{4}$$

The objective, under the appropriate conditions, is to find a weight vector $\boldsymbol{W^*}$ such that $Y_{1t}^N = \sum_{j=2}^{J+1} w_j^* Y_{jt}$. Thus,

$$\hat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \quad \text{for } t \in \{T_0+1, ..., T\} \tag{5}$$

can be used as an estimator of α_{1t}. A synthetic control satisfying $\sum_{j=2}^{J+1} w_j^* \boldsymbol{Z_j} = \boldsymbol{Z_1}$ and $\sum_{j=2}^{J+1} w_j^* \boldsymbol{\mu_j} = \boldsymbol{\mu_1}$ provides an unbiased estimator of Y_{1t}^N.

The weight vector $\boldsymbol{W^*}$ is chosen to minimize the distance between $\boldsymbol{X_1}$ and $\boldsymbol{X_0 W}$, subject to $w_j \geq 0$ for $j = 2, ..., J+1$ and $w_2 + ... + w_{J+1} = 1$, where $\boldsymbol{X_1}$ represents the pre-intervention characteristics vector for the treated region, and $\boldsymbol{X_0}$ represents the same vector for the control regions. The discrepancy between $\boldsymbol{X_1}$ and $\boldsymbol{X_0 W}$ is measured using:

$$\|\boldsymbol{X_1} - \boldsymbol{X_0 W}\|\boldsymbol{V} = \sqrt{(\boldsymbol{X_1} - \boldsymbol{X_0 W})' \boldsymbol{V} (\boldsymbol{X_1} - \boldsymbol{X_0 W})} \tag{6}$$

where $\boldsymbol{V}$ is a symmetric and positive semidefinite matrix, although other choices are also possible. An optimal choice of $\boldsymbol{V}$ assigns weights to linear combinations of the variables in $\boldsymbol{X_0}$ and $\boldsymbol{X_1}$ to minimize the mean squared error (MSE) of the synthetic control estimator. That is, $\boldsymbol{V}$ is chosen such that the MSE of the outcome variable prediction is minimized for the pre-intervention periods (Abadie et al, 2010).

Abadie et al (2010) explain that, in practice, it may not always be possible to obtain a weighted combination of untreated units that satisfies the equations above. Therefore, in each application, the analyst must assess whether the characteristics of the treated unit are sufficiently matched by the synthetic control. In some cases, the fit may be inadequate, in which case the use of a synthetic control is not recommended.

Furthermore, Abadie et al (2010) argue that even when a synthetic control provides a good fit for the treated units, interpolation biases may be substantial if the model is not valid for the entire set of regions in a given sample. To mitigate these biases, the donor pool — the group of possible contributing units — can be restricted to regions with characteristics similar to those of the unit exposed to the intervention of interest, reducing biases arising from interpolation across regions with significantly different characteristics.

An important observation is that the traditional difference-in-differences model can be obtained by imposing that $\boldsymbol{\lambda_t}$ in equation (3) remains constant for all periods t, so that it is eliminated through temporal differencing. In contrast, the synthetic control model allows the effects of unobservable characteristics on the outcome variable to vary over time (Abadie et al, 2010).

3.2 Inference and bias correction

To assess the significance of the estimates generated by the synthetic control method, Abadie et al (2010) propose different inference methods. The authors explain that large-sample inferential techniques are not suitable for comparative case studies when the number of units in the comparison group is small. Therefore, the recommended approach is to use inference techniques similar to permutation tests, which do not require a large number of comparison units in the donor pool.

Permutation tests, or placebo studies, allow for the evaluation of the synthetic control method's ability to replicate the trajectory of the treated unit in the absence of treatment by applying the same method to a control unit. According to Abadie et al (2010), the distribution of a test statistic is computed under random permutations of the assignment of sample units to the treatment and control groups. The synthetic control method is then applied to each possible control unit in the sample, allowing an assessment of whether the estimated effect for the affected region is large relative to the estimated effect for a randomly chosen region. The treatment effect on the treated unit is considered significant when its magnitude is extreme relative to the permutation distribution (Abadie, 2021).

According to Athey and Imbens (2017), in a placebo analysis, the primary specification is replicated by replacing the outcome variable with a pseudo-outcome that is not affected by the treatment. In this case, the true value of the estimand for this pseudo-outcome is zero, and the goal of the supplementary analysis is to assess whether the adjustment methods used in the primary analysis yield estimates close to zero when applied to the pseudo-outcome.

Abadie (2021) explains that even if a synthetic control successfully reproduces the trajectory of the outcome variable for the treated unit before the intervention, this may not hold for all units in the donor pool. Therefore, the proposed test statistic measures the ratio between post-intervention fit and pre-intervention fit, defined as the root mean squared prediction error (RMSPE) of the synthetic control estimator.

For $0 \leq t_1 \leq t_2 \leq T$ and $j = \{1, ..., J + 1\}$, let

$$R_j(t_1, t_2) = \left(\frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} (Y_{jt} - \hat{Y}_{jt}^N)^2 \right)^{1/2} \tag{7}$$

where $\hat{Y}_{jt}^N$ represents the outcome in period t produced by a synthetic control when unit j is considered treated, and all other J units are used to construct the donor pool. According to Abadie (2021), this is the root mean squared prediction error (RMSPE) of the synthetic control estimator for unit j over the time periods $t_1, ..., t_2$. The ratio between post-intervention RMSPE and pre-intervention RMSPE for unit j is

$$r_j = \frac{R_j(T_0 + 1, T)}{R_j(1, T_0)} \tag{8}$$

That is, r_j measures the quality of the fit of a synthetic control for unit j in the post-treatment period relative to the fit in the pre-treatment period. The permutation distribution of r_j is used by Abadie et al (2010) for inference.

A p-value for the inferential procedure based on the permutation distribution of r_j is given by

$$p = \frac{1}{J+1} \sum_{j=1}^{J+1} I_+(r_j - r_1) \tag{9}$$

where $I_+(\cdot)$ is an indicator function that returns one if the argument is non-negative and zero otherwise. Abadie (2021) argues that, although p-values are often used to summarize the results of testing procedures, the permutation distribution of the test statistics, r_j, or of the placebo differences, $Y_{jt} - \hat{Y}_{jt}^N$, are easy to visualize and provide additional information (for example, on the magnitude of the differences between the estimated treatment effect in the treated unit and the placebo differences in the donor group).

Finally, Abadie (2021) argues that, in some scenarios, the predictor values for treated units may not be accurately reproduced by a synthetic control. Alternatively, they may be accurately reproduced only by combinations of units that exhibit large discrepancies in the predictor values relative to the treated unit. In such cases, there may be concerns about potential biases introduced by the discrepancies between the predictor values of the treated units and those of the respective synthetic controls.

Therefore, it is important to perform bias corrections in the estimations. The modifications to the synthetic control estimator proposed by Abadie and L'Hour (2021) and Ben-Michael et al (2021) use regression adjustments to attenuate the bias of synthetic control estimators in scenarios where the counterfactual is constructed using untreated units whose predictor values do not accurately reproduce the predictor values of the treated unit.

For $t = T_0 + 1, \ldots, T$, let $\hat{\mu}_{0t}$ be a sample regression function (parametric or nonparametric) estimated by regressing the outcomes of the untreated units $Y_{I+1,t}, \ldots, Y_{I+J,t}$ on the predictor values for the untreated units $X_{I+1}, \ldots, X_{I+J}$. The bias-corrected synthetic control estimator for unit i is

$$\hat{\tau}_{it} = \left(Y_{it} - \sum_{j=I+1}^{I+J} w_{ij}^* Y_{jt} \right) - \sum_{j=I+1}^{I+J} w_{ij}^* \left(\hat{\mu}_{0t}(X_i) - \hat{\mu}_{0t}(X_j) \right) \tag{10}$$

The first term on the right-hand side of equation 10 is the original synthetic control estimator. The second term, according to Abadie (2021), uses a regression adjustment to correct for discrepancies between the predictor values for the treated unit and the predictor values for the units contributing to the synthetic control.

Alternatively, the estimator in equation 10 can be expressed as

$$\hat{\tau}_{it} = (Y_{it} - \hat{\mu}_{0t}(X_i)) - \sum_{j=I+1}^{I+J} w_{ij}^* \left(Y_{jt} - \hat{\mu}_{0t}(X_j) \right). \tag{11}$$

Equation 11 provides an interpretation of the bias-corrected synthetic control estimator as a synthetic control estimator applied to the residuals of the regression. In the Robustness section of this study, analyses are conducted to ensure the significance of the results after the correction for potential biases.

3.3 Spatial unit of analysis and sample

As mentioned earlier, the analysis will be conducted at the level of capital city[2]. PNADC provides estimates for 27 capital cities, but the analysis was restricted to those belonging to the main metropolitan regions, totaling 20 cities. Furthermore, to estimate the effect of an airport hub in a specific location using the synthetic control method, it is necessary to exclude regions that also implemented hubs during or prior to the analysis period. Thus, São Paulo, Rio de Janeiro, Minas Gerais, and the Federal District were excluded, as their hubs were implemented in or before 2012, making them unsuitable as control units. Fortaleza, in Ceará, was not excluded from the donor pool since, as discussed in the Local Background section, its hub was not effectively implemented.

Additionally, the donor pool was restricted to units with characteristics similar to the treated unit (Abadie, 2021). Therefore, the regions of Amazonas, Amapá, and Mato Grosso were removed due to significant demographic and socioeconomic differences from Pernambuco. Units that could be influenced by the intervention in the treated unit, such as geographically close regions, were also excluded to prevent biased estimates of the counterfactual outcome (Abadie, 2021). As a result, the states of Paraíba and Alagoas were removed.[3] Thus, the sample covers Recife and 12 other capital cities for the period from 2006 to 2023.

The variables of interest are the total number of flights and paid passengers, GDP *per capita*, the proportion of formal employees in specific sectors, real income in these sectors, and the total number of registered tour guides. Each variable will be analyzed separately to achieve the best pre-intervention fit for each.

Predictor variables used to construct synthetic regions include the proportion of formal employees under the CLT regime[4], the proportion of formal employees with completed secondary or higher education, the total number of flights itself, the proportion of residents of brown and black colors/races, the average habitual monthly earnings from all jobs, the unemployment rate, the proportion of residents aged 25 to 54, and lagged observations of the variable of interest. The first four variables are calculated as averages from 2006 to 2015, while the others use the period from 2012 to 2015 — the last year before the intervention in Recife (PE) — for their averages. The variable of interest, however, uses data starting from 2011.

Using the method described in Section 3.1 and the predictor variables, synthetic locations were constructed to reflect the variables of interest in the treated unit before the implementation of the Recife airport hub. The hub's effect on the dependent variables is estimated as the difference between the actual and synthetic regions in the post-implementation years. Robustness tests and placebo studies are also conducted to confirm the statistical significance of the estimated effects, following the methodology proposed by Abadie et al (2010).

3.4 Data

Data were obtained from the Continuous National Household Sample Survey (PNADC), conducted by the Instituto Brasileiro de Geografia e Estatística [Brazilian Institute of Geography and Statistics] (IBGE). This dataset provided information on income and employment (both formal and informal), aggregated and by sector, education level, and other population characteristics. PNADC was permanently implemented nationwide in 2012. As of the publication date of this study, the most recent data available from IBGE pertain to the year 2023. Therefore, the annual panel data from PNADC used in this study cover capital cities from 2012 to 2023.

Data from the Annual Social Information Report (RAIS), provided by the Ministry of Labor and Employment, were gathered regarding formal employment relationships in Brazil. The RAIS data span from 2006 — ten years before the Recife hub was implemented — until 2023, the most recent available year. RAIS data used as predictors include the percentage of formal employment contracts under the Consolidation of Labor Laws (CLT) and the proportion of employees with a high school or

[2] The analysis presented in this article was also conducted at the metropolitan region level, and the results are similar to those found for the capital city. These additional findings are available from the authors upon request.

[3] One potential concern is the influence of the Recife Hub on other capitals in the Northeast. Additional results were obtained excluding these capitals, and the main findings remain the same. These results may be made available upon request.

[4] A more detailed description of this variable is presented in the Data section.

college degree. Another RAIS variable analyzed was the percentage of formal employees in specific sectors, though this was used as a dependent variable. With RAIS data, the analysis period could be extended to obtain a more accurate estimation of the airport hub's effects in Recife after its implementation in 2016.

Additionally, Gross Domestic Product (GDP) data for municipalities were obtained from IBGE. However, the latest available data in this series refer to 2021. The collected dataset also includes information on GDP *per capita*. Data on flights and Brazilian airports were obtained from ANAC. The microdata contain detailed annual information, including the number of flights departing from or arriving at a given airport, the airline operating the flight, the number of paying passengers, the volume of paid cargo, and other relevant details.

Finally, data on tourism service providers in Brazil were obtained from the Ministry of Tourism. These data pertain to the registry of individuals and companies operating in the tourism sector, including mandatory registration for tour guides, a category analyzed in this study. It is important to note that, according to the Ministry of Tourism, reports released before 2016 serve only as references and do not attest to the formal registration of service providers. This is because, before 2016, registrations in the Cadastur system were not fully digital, and information validation relied on manual processes, which made ensuring registration regularity difficult (Ministério do Turismo, 2024, 2025).

4 Results

4.1 Flights and passengers

The main objective of the analysis is to measure the impact of the implementation of the airport hub in Recife on the local economy, both in aggregate and by sector. However, it is important to verify whether there was indeed a significant increase in the number of flights compared to the control units and, if so, whether this increase in flights resulted in a higher flow of paid passengers at Recife International Airport.

Figures 2 and 4 display, respectively, the number of flights and the number of paid passengers who embarked or disembarked in Recife, also considering its synthetic version, between 2006 and 2023. Tables 2 and 4 compare the pre-intervention characteristics for the treated region, its synthetic version, and the simple average of the control units. It is evident that the synthetic unit approximates the treated unit much more closely than the simple average of the controls in both tables. Tables 3 and 5 present the weights used in each region for constructing Synthetic Recife.

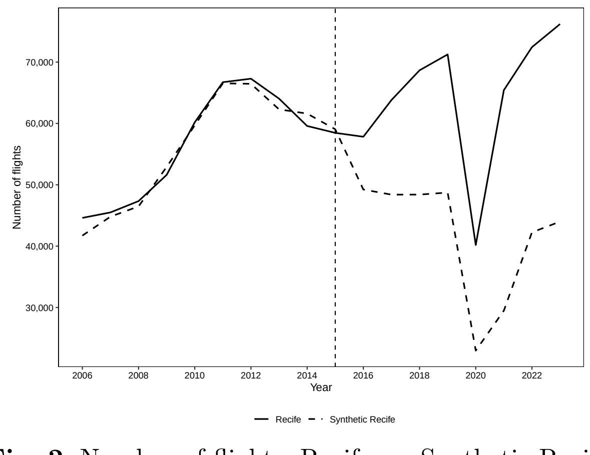

Fig. 2: Number of flights: Recife vs. Synthetic Recife

Panels on the left of Figures 3 and 5 show the results for the placebo tests. The gray lines show, respectively, the difference in the number of flights and paid passengers between each unit in the control group and its respective synthetic version. The black lines represent the estimated difference for Recife. As shown, the estimated difference for the treated unit after the implementation of the hub is substantially higher compared to the distribution of differences for the cities in the control group. The results of the synthetic control analysis indicate that, in the post-treatment period, Recife registered, on average, 22,793 additional flights per year and an increase of 2,187,245 passengers annually compared to its synthetic counterpart. The observed differences represent relative increases of 40.31% and 39.59% over pre-intervention levels, respectively.

The right side of Figures 3 and 5 displays the distributions of the ratios between the mean squared prediction errors (MSPE) for the post/pre-implementation period of the airport hub in Recife for the treated region and the other units tested in the placebo tests. Notably, the Recife region stands out, with the post-implementation MSPE being 300 times greater than the pre-implementation MSPE for the number of flights, and approximately 240 times greater when considering paid passengers. This test verifies that, if the intervention had been randomly assigned in the data, the probability of obtaining a post/pre-implementation MSPE ratio as large as Recife's would be $1/13 = 0.077$, lower than the conventional 10% significance level used in statistical tests. Given the sample size, the p-value of 0.077 represents the lowest achievable and most statistically significant result for the analyzed outcomes.

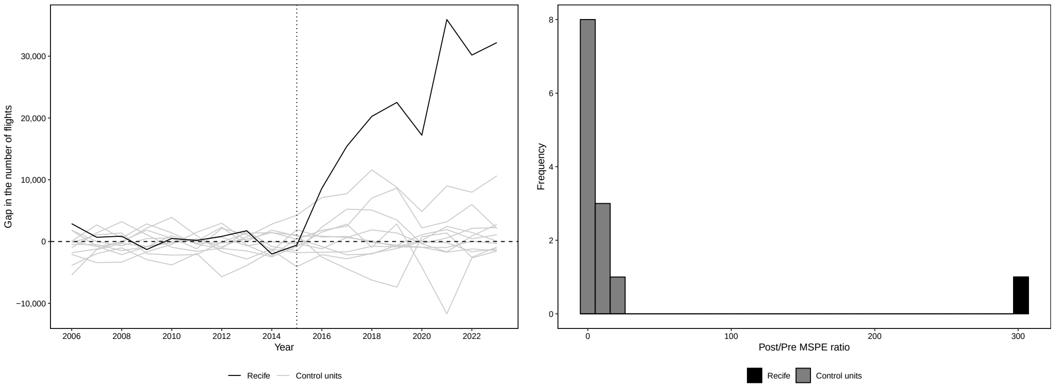

Fig. 3: Flights gaps (left) and post-/pre-hub MSPE ratio for flights (right): Recife and 12 control units

Table 2: Predictors of flights

Variables	Treated	Synthetic	Sample Mean
Formal Employees CLT (%)	74.02	73.98	69.81
High School Completed (%)	43.17	45.08	43.31
Bachelor's Degree Completed (%)	20.55	22.61	23.13
Total Number of Flights	63,225	63,193	41,842
Brown-Skinned Workers (%)	52	44	46
Black-Skinned Workers (%)	06	09	09
Real Monthly Salary (R$)	3,997.90	3,598.47	3,571.59
Unemployment Rate (%)	08	08	08
Population Aged 25 to 54 (%)	45	46	46

Table 3: Municipality weights in the Synthetic Recife: flights

Weights	Municipality
0.00	Belém (PA)
0.18	São Luís (MA)
0.34	Teresina (PI)
0.00	Fortaleza (CE)
0.24	Natal (RN)
0.00	Aracaju (SE)
0.00	Salvador (BA)
0.00	Vitória (ES)
0.16	Curitiba (PR)
0.00	Florianópolis (SC)
0.00	Porto Alegre (RS)
0.08	Goiânia (GO)

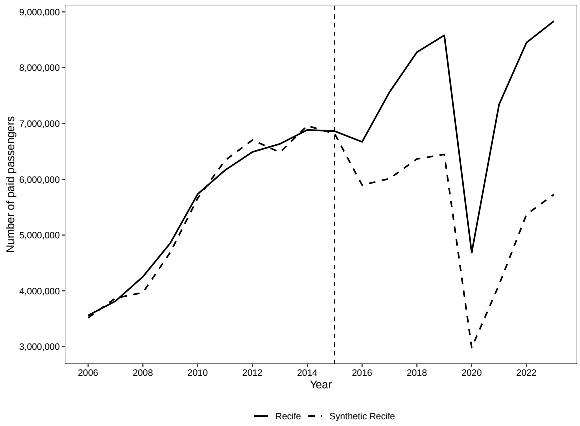

Fig. 4: Number of paid passengers: Recife vs. Synthetic Recife

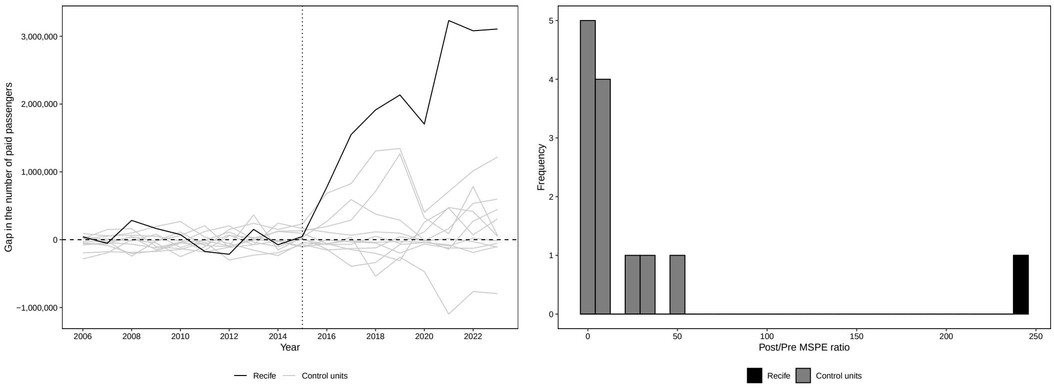

Fig. 5: Paid passengers gaps (left) and post-/pre-hub MSPE ratio for paid passengers (right): Recife and 12 control units

Table 4: Predictors of paid passengers

Variables	Treated	Synthetic	Sample Mean
Formal Employees CLT (%)	74.02	74.99	69.81
High School Completed (%)	43.17	47.30	43.31
Bachelor's Degree Completed (%)	20.55	20.54	23.13
Total Number of Flights	56,537	56,487	36,478
Total Number of Passengers	6,606,566	6,659,610	4,084,156
Brown-Skinned Workers (%)	52	52	46
Black-Skinned Workers (%)	06	15	09
Real Monthly Salary (R$)	3,997.90	3,559.47	3,571.59
Unemployment Rate (%)	08	09	08
Population Aged 25 to 54 (%)	45	47	46

Table 5: Municipality weights in the Synthetic Recife: paid passengers

Weights	Municipality
0.00	Belém (PA)
0.03	São Luís (MA)
0.00	Teresina (PI)
0.00	Fortaleza (CE)
0.35	Natal (RN)
0.00	Aracaju (SE)
0.00	Salvador (BA)
0.05	Vitória (ES)
0.39	Curitiba (PR)
0.00	Florianópolis (SC)
0.00	Porto Alegre (RS)
0.17	Goiânia (GO)

4.2 Aggregate economic variables

Having established that there was a significant increase in the number of flights and passengers at Recife International Airport starting in 2016 caused by the hub, the next step is to analyze whether this change had significant impacts on Recife's economy.

The first variable analyzed was the GDP *per capita* at constant prices. Figure 6 shows that the variable had a good fit in the pre-intervention period. However, Figure 7 shows that the implementation of the airport hub did not have a significant effect on Recife's GDP *per capita*, with a placebo MSPE test p-value of 0.769. Table 6 presents the pre-intervention characteristics of the treated region, its synthetic version, and the simple average of the control units. Table 7 displays the weights assigned to each region in the construction of Synthetic Recife.

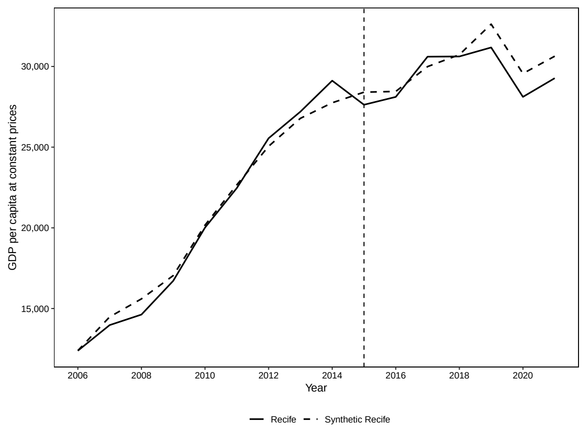

Fig. 6: GDP *per capita*: Recife vs. Synthetic Recife

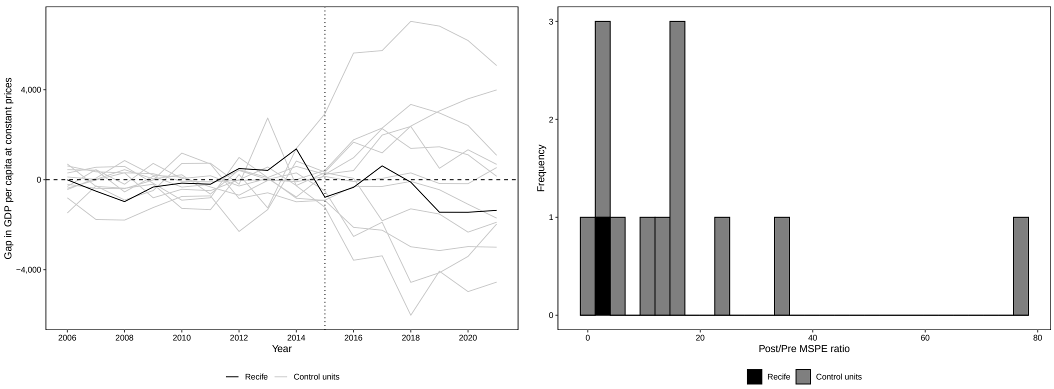

Fig. 7: GDP *per capita* gaps (left) and post-/pre-hub MSPE ratio for GDP *per capita* (right): Recife and 12 control units

Table 6: Predictors of GDP *per capita*

Variables	Treated	Synthetic	Sample Mean
Formal Employees CLT (%)	74.02	72.96	69.81
High School Completed (%)	43.17	44.21	43.31
Bachelor's Degree Completed (%)	20.55	22.77	23.13
Total Number of Flights	56,537	53,567	36,478
GDP *per capita* (R$)	26,392.88	26,132.31	27,430.84
Brown-Skinned Workers (%)	52	44	46
Black-Skinned Workers (%)	06	06	09
Real Monthly Salary (R$)	3,997.90	3,411.38	3,571.59
Unemployment Rate (%)	08	08	08
Population Aged 25 to 54 (%)	45	46	46

Table 7: Municipality weights in the Synthetic Recife: GDP *per capita*

Weights	Municipality
0.00	Belém (PA)
0.31	São Luís (MA)
0.38	Teresina (PI)
0.00	Fortaleza (CE)
0.23	Natal (RN)
0.00	Aracaju (SE)
0.00	Salvador (BA)
0.02	Vitória (ES)
0.05	Curitiba (PR)
0.00	Florianópolis (SC)
0.00	Porto Alegre (RS)
0.00	Goiânia (GO)

4.3 Directly related activities: Travel and tourism

Although no significant effects were identified at the aggregate level, the airport hub was found to have meaningful impacts on specific sectors, particularly the ”Travel Agencies, Tour Operators and Reservation Services” sector described in RAIS.

This sector represented in the RAIS database is associated with Division 79 of the National Classification of Economic Activities (CNAE), which is the official system adopted by Brazil for the production of statistics based on economic activity (IBGE, 2007). Division 79 specifically comprises classes of economic activities related to travel agencies, tour operators, reservation services and other travel-related services not elsewhere classified. Throughout this paper, the sector described will be referred to as the ”Travel sector” for the sake of clarity and simplification.

As shown in Figure 8, the percentage of employees in the formal sector of Travel Agencies, Tour Operators, and Reservation Services in Recife substantially increased after the implementation of the airport hub in Recife. Appendix A presents the comparison between the units and the weights used for the synthetic control for all tourism-related results, shown in Tables A1 and A2, respectively.

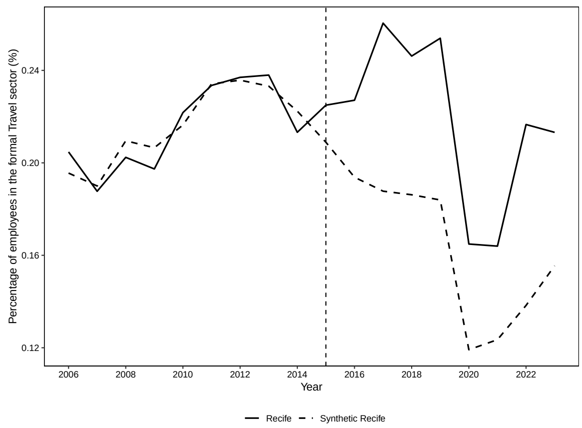

Fig. 8: Proportion of employees in the formal Travel sector: Recife vs. Synthetic Recife

The average annual difference between Recife and its synthetic counterpart is approximately 0.06 percentage point in the proportion of employees in the formal Travel sector. In relative terms, this gap represents an increase of about 26.51% compared to the average level observed prior to the implementation of the hub. Based on the placebo tests and MSPE predictions shown in Figure 9, the result for the percentage of employees in the Travel sector is statistically significant, with a p-value of 0.077.

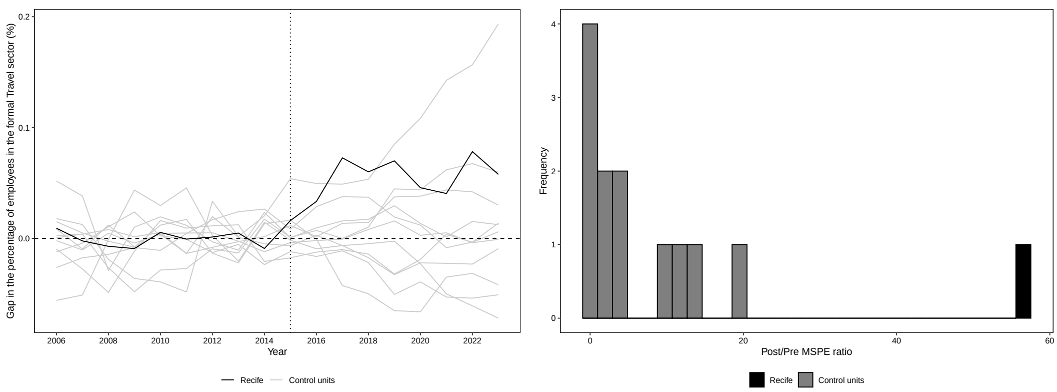

Fig. 9: Proportion of employees in the formal Travel sector gaps (left) and post-/pre-hub MSPE ratio (right): Recife and 12 control units

The results described above corroborate the findings regarding the number of tour guides registered in the Ministry of Tourism. Taking the number of guides as the dependent variable, it is observed that the implementation of the airline hub in Recife is associated with a considerable increase in the number of registered tour guides in the city. Figure 10 shows the difference between the actual region and its synthetic counterpart. Following the intervention, Recife exhibited an average annual increase of approximately 95 registered tour guides compared to its synthetic control. This corresponds to an increase of approximately 64.08% relative to the pre-intervention average. The results are also statistically significant, with a p-value of 0.077, as shown in Figure 11.

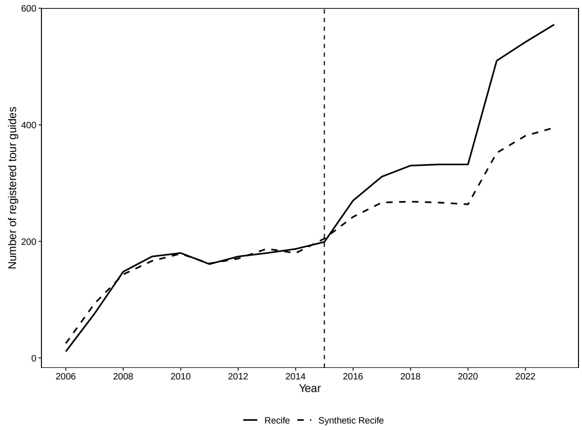

Fig. 10: Number of tour guides: Recife vs. Synthetic Recife

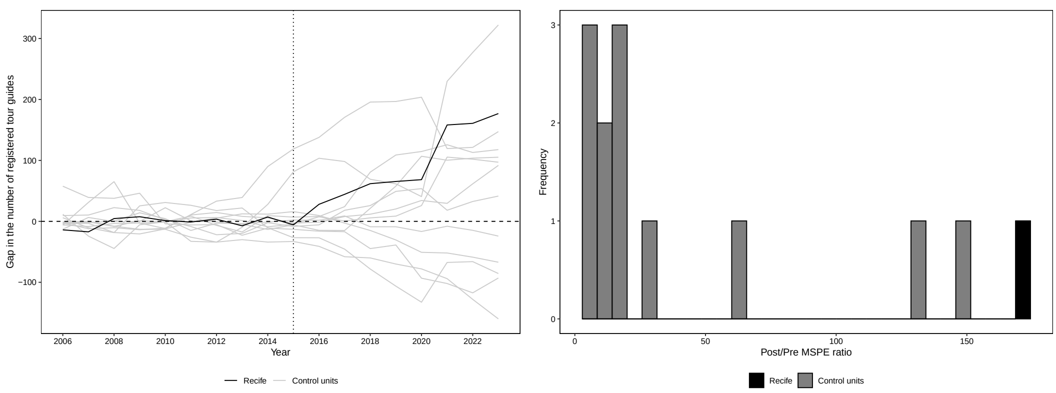

Fig. 11: Number of tour guides gaps (left) and post-/pre-hub MSPE ratio for tour guides (right): Recife and 12 control units

Thus, it is concluded that, although the implementation of Azul's airline hub at Recife International Airport did not generate significant effects on the local economy as a whole, the hub had positive and significant effects on the sector of Travel Agencies and Tour Operators, including employees registered as tour guides in the city. However, in other tourism-related sectors, no adjustment or significant effects were found for employment in activities related to Accommodation and Food Services.

Real earnings in tourism-related sectors were also analyzed, but none of the income results were found to be statistically significant. The trajectories of real and synthetic earnings are shown in the left side of Figures 12, 13 and 14. The right side of these figures displays the MSPE tests for the Travel, Accommodation, and Food Services sectors. Their respective p-values are 0.231, 0.615, and 0.538.

This result on wages is not unexpected, since this economic segment is not characterized by a highly qualified workforce, a situation that allows for employment adjustments without wage increases.

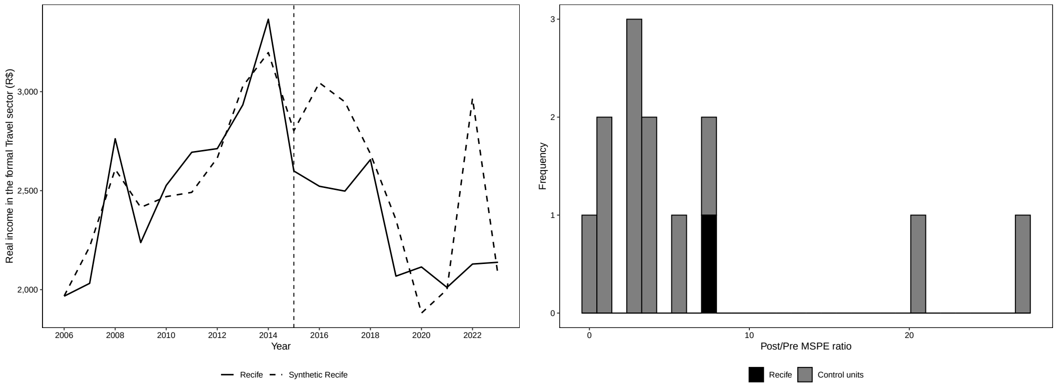

Fig. 12: Real income in the formal Travel sector for Recife and its Synthetic Control (left) and post-/pre-hub MSPE ratio for Recife and 12 control units (right)

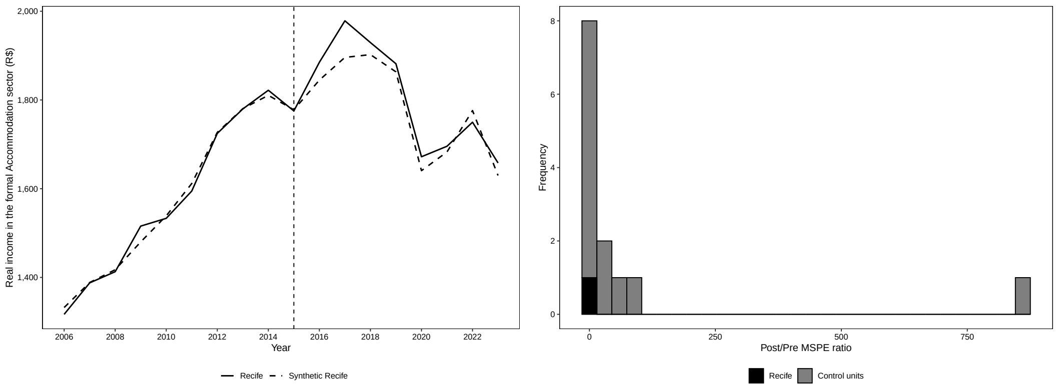

Fig. 13: Real income in the formal Accommodation sector for Recife and its Synthetic Control (left) and post-/pre-hub MSPE ratio for Recife and 12 control units (right)

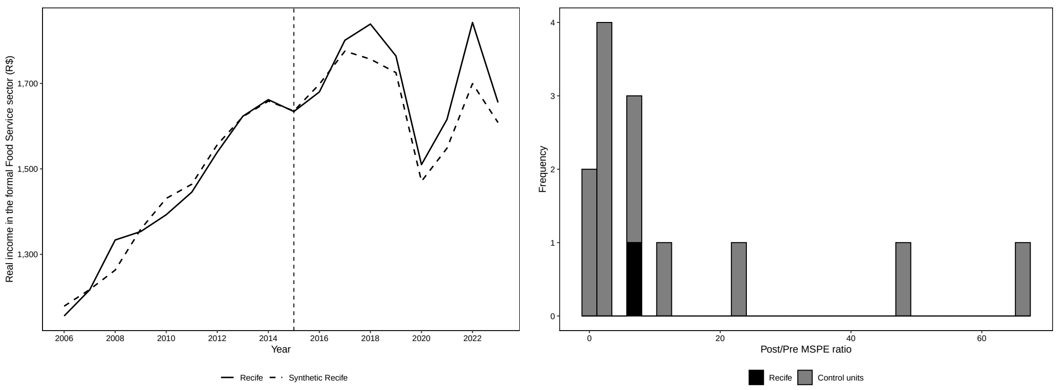

Fig. 14: Real income in the formal Food Service sector for Recife and its Synthetic Control (left) and post-/pre-hub MSPE ratio for Recife and 12 control units (right)

4.4 Robustness checks

As explained by Abadie (2021), certain diagnostic checks can be used to assess the credibility of synthetic control counterfactuals, as well as robustness exercises to evaluate the sensitivity of results to changes in study design. Therefore, in this section, additional tests are conducted to demonstrate that the significant results found through the main specification are not sensitive to some of the choices made in its design, ensuring the credibility of synthetic controls. The robustness analyses will be based on the estimation of the synthetic control with bias correction. The goal here is to assess whether the result remains significant after removing potential biases.

Starting with the number of flights and paid passengers, the results remain statistically significant, with a p-value of 0.077. The annual bias-corrected gaps from the placebo tests are shown on the right side of Figures 15 and 16, while the left side displays the original gaps for comparison. The bias-corrected gaps and p-values by year in the post-treatment period between Recife and its synthetic version are presented in Table B3 in Appendix B.

Given the robust gaps between the observed values for Recife and its synthetic counterpart, the results indicate that the implementation of Azul's hub is associated with an average annual increase of 20,604 flights between 2016 and 2023. Similarly, the number of paid passengers rose by an average of 1,750,248 per year. These effects correspond to relative increases of 36.44% and 31.68%, respectively, compared to the pre-intervention averages.

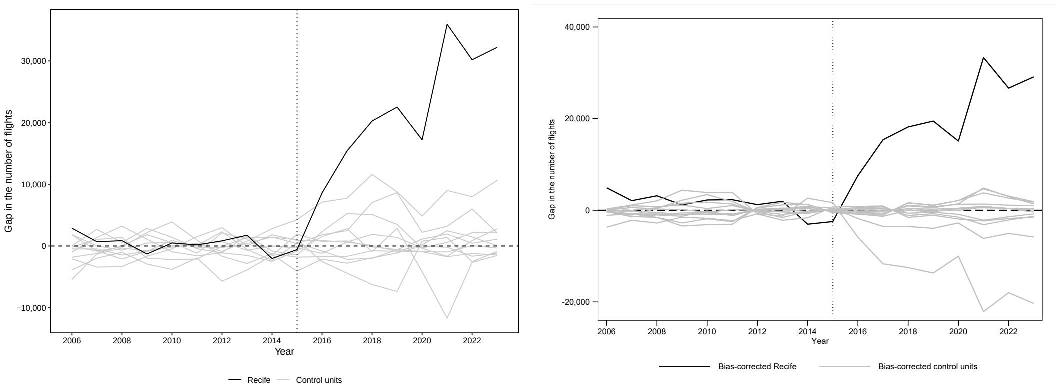

Fig. 15: Gaps (left) and bias-corrected gaps (right) for Recife and control units: Number of flights

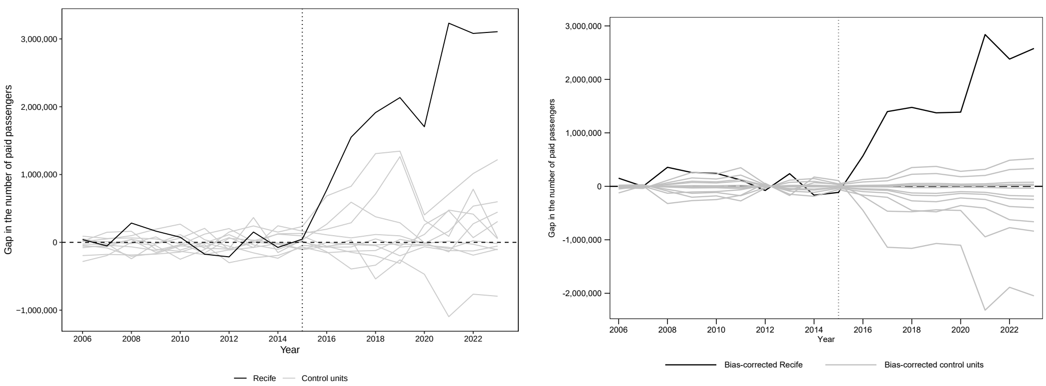

Fig. 16: Gaps (left) and bias-corrected gaps (right) for Recife and control units: Number of paid passengers

Considering the proportion of employees in the formal Travel sector, Figure 17 and Table B3 show that, after bias correction, the results remain robust. Once the bias is eliminated, the effect of the hub on the percentage of employees in the formal Travel sector in Recife remains statistically significant at the 10% level, with a p-value of 0.077 for all years after the hub's implementation.

The findings indicate that the establishment of Azul's hub is associated with an average increase of 0.10 percentage point in the proportion of workers employed in this segment. This effect corresponds to a relative variation of 48.36% compared to the pre-intervention average.

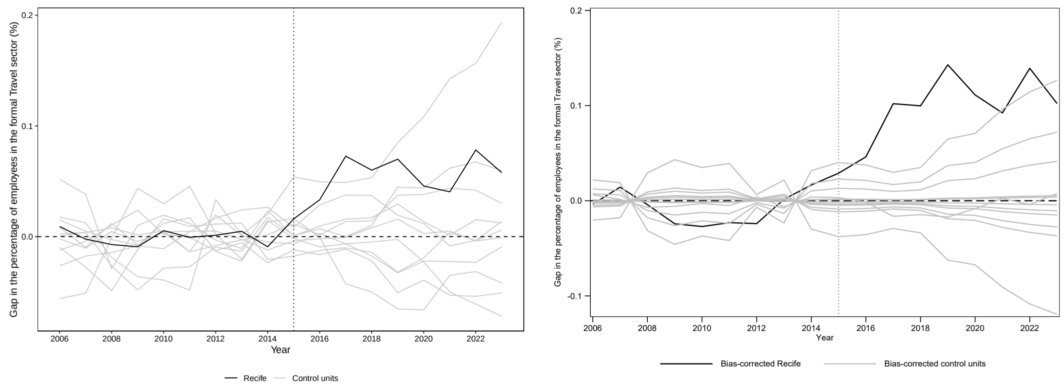

Fig. 17: Gaps (left) and bias-corrected gaps (right) for Recife and control units: Proportion of employees in the formal Travel sector

The results are also statistically significant when analyzing the number of registered tour guides. After bias correction, the hub's effect on the number of guides remains significant for all years following the hub's implementation, with a p-value of 0.077. The results are presented in Figure 18 and Table B3.

Among the variables analyzed, this one exhibits the most significant impact. The implementation of the Azul hub is associated with an average annual increase of 123 registered professionals, representing a relative growth of 82.31% compared to the average number of tour guides in Recife prior to the intervention.

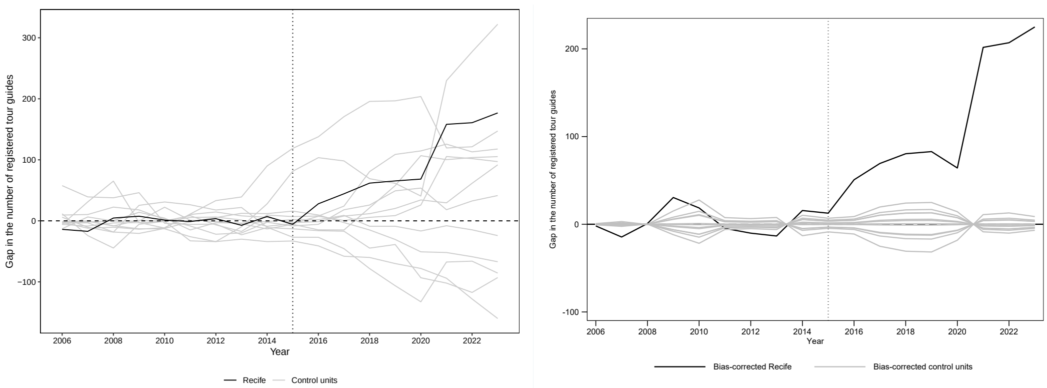

Fig. 18: Gaps (left) and bias-corrected gaps (right) for Recife and control units: Number of registered tour guides

5 Conclusion

This study aimed to assess the economic impacts of implementing airline hubs in specific regions, focusing on the case of Azul Linhas Aéreas' hub, established in the city of Recife in 2016. This company's base of operations enabled greater connectivity among cities in Brazil's Northeast by increasing the number of flights. Despite the evident expansion in the supply of this service, there has been no prior evaluation of the economic impact of this regional hub in the literature. Based on the available information, this study appears to be the first to analyze the economic effects of airport hubs in a developing country such as Brazil. The analysis considered both general and sectoral effects on employment and income.

Using the synthetic control method, significant effects were identified regarding employment in the tourism sector, specifically in the Travel Agencies and Tour Operators segment at the capital city level, as well as in the number of registered tour guides in Recife. The results remained positive and statistically significant after bias correction. The findings indicate that the share of employees in the formal Travel sector increased by approximately 48%, while the number of registered tour guides rose by around 82% compared to the average prior to the hub's implementation.

These findings align with the theories proposed by Rodrigue (2024) and Appold and Kasarda (2013), who argue that the economic impact of air transport is most strongly pronounced near airport hubs, influencing entire sectors within a given region. Although no significant effects on income and employment in other sectors were found after bias correction, the observed impact on the tourism and Travel sector is particularly relevant for the local economy, as it boosts formal employment within this segment of the service sector.

Several reasons may explain these results. First, it is important to recognize that this is a regional hub, with limited scale and impact compared to larger connection centers. Thus, the lack of impact on aggregate economic indicators is probably related to the size of the city (with around 1.5 million inhabitants) and the predominance of other sectors of the economy, such as medical services, IT, education, and commerce and services in general. With such a productive structure and little dependence on tourism, at least in the period analyzed, it is reasonable that the effects end up localized in segments directly involved with travel and tourism. In turn, the lack of effects on wages is consistent with the low level of qualifications in these specific sectors, which can expand employment without increasing wages.

Regarding sector-specific effects, one hypothesis is that, despite the increase in passenger numbers in Recife, the Accommodation and Food Service sectors already had sufficient capacity and infrastructure to meet additional demand without requiring new hires. This dynamic differed in the Travel Agencies and Tour Operators sector, which needed to fill new job openings to accommodate the increased demand for these services.

In conclusion, although the hub's implementation did not generate significant effects on the economy as a whole, it had positive and meaningful impacts on local tourism, particularly within the formal Travel Agencies, Tour Operators, and Booking Services sector, as well as on the number of registered tour guides in the city. The limited timeframe for analysis requires us to be cautious in drawing definitive conclusions. However, given the characteristics of the Recife airport hub and the local economy, the results suggest that these interventions can contribute to job creation. Nevertheless, these measures should not be regarded as a comprehensive solution for the region's economic development.

Appendix A Predictors and Weights for Tourism-Related Activities

Table A1: Predictors of tourism-related activities for the Synthetic Recife

Variables	Sample Mean	Treated	Synthetic			
			Guides	Emp. Travel	Emp. Accom	Emp. Food
Formal Employees CLT (%)	69.81	74.02	69.91	72.97	75.41	73.98
High School Completed (%)	43.31	43.17	43.09	43.01	47.26	44.31
Bachelor's Degree Completed (%)	23.13	20.55	23.73	22.80	20.65	21.91
Total Number of Flights	36,478	56,537	49,005	42,735	56,044	42,657
Brown-Skinned Workers (%)	46	52	34	42	52	52
Black-Skinned Workers (%)	09	06	08	07	15	06
Real Monthly Salary (R$)	3,571.59	3,997.90	3,953.37	3,931.10	3,572.51	3,100.63
Unemployment Rate (%)	08	08	08	08	09	08
Population Aged 25 to 54 (%)	46	45	45	46	47	45
Total Number of Guides	144	180	181	*	*	*
Prop. Emp. Travel Sector (%)	0.21	0.23	*	0.23	*	*
Prop. Emp. Accom Sector (%)	0.78	0.61	*	*	0.64	*
Prop. Emp. Food Sector (%)	2.83	2.98	*	*	*	2.98

Table A1: Predictors of tourism-related activities for the Synthetic Recife (continued)

Variables	Sample Mean	Treated	Synthetic		
			Income Travel	Income Accom	Income Food
Formal Employees CLT (%)	69.81	74.02	71.26	74.10	75.28
High School Completed (%)	43.31	43.17	47.69	45.12	46.25
Bachelor's Degree Completed (%)	23.13	20.55	21.33	21.01	21.20
Total Number of Flights	36,478	56,537	56,798	41,957	52,121
Brown-Skinned Workers (%)	46	52	49	53	52
Black-Skinned Workers (%)	09	06	21	09	13
Real Monthly Salary (R$)	3,571.59	3,997.90	3,712.94	3,676.42	3,766.22
Unemployment Rate (%)	08	08	10	09	09
Population Aged 25 to 54 (%)	46	45	48	46	47
Real Income Travel Sector (R$)	2,554.87	2,860.93	2,836.78	*	*
Real Income Accommodation Sector (R$)	1,861.56	1,739.29	*	1,741.51	*
Real Income Food Sector (R$)	1,693.70	1,580.84	*	*	1,587.39

Table A2: Municipality weights in the Synthetic Recife: Tourism-related activities

Municipality	Guides	Proportion in the Sector			Income in the Sector		
		Travel	Accom	Food	Travel	Accom	Food
Belém (PA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
São Luís (MA)	0.16	0.00	0.02	0.19	0.00	0.01	0.00
Teresina (PI)	0.18	0.01	0.06	0.03	0.00	0.00	0.05
Fortaleza (CE)	0.00	0.05	0.00	0.15	0.00	0.00	0.00
Natal (RN)	0.01	0.31	0.37	0.52	0.00	0.39	0.39
Aracaju (SE)	0.00	0.00	0.00	0.00	0.16	0.02	0.00
Salvador (BA)	0.00	0.18	0.00	0.04	0.00	0.14	0.00
Vitória (ES)	0.39	0.22	0.00	0.01	0.00	0.03	0.00
Curitiba (PR)	0.00	0.04	0.37	0.06	0.57	0.14	0.29
Florianópolis (SC)	0.19	0.00	0.00	0.00	0.06	0.00	0.00
Porto Alegre (RS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goiânia (GO)	0.07	0.19	0.18	0.00	0.21	0.26	0.27

Appendix B Bias-Corrected Gaps and P-Values

Table B3: Bias-corrected gaps and p-values by year in the post-treatment period between Recife and Synthetic Recife for the number of flights, paid passengers, proportion of employees in the formal Travel sector, and number of guides

Year	Flights		Passengers		Prop. of emp. Travel sector (%)		Guides	
	Gap	P-value	Gap	P-value	Gap	P-value	Gap	P-value
2016	7,557.663	0.0769231	569,003.6	0.0769231	0.0461424	0.0769231	50.71028	0.0769231
2017	15,390.98	0.0769231	1,397,867	0.0769231	0.1020281	0.0769231	69.31232	0.0769231
2018	18,183.59	0.0769231	1,476,646	0.0769231	0.0997531	0.0769231	80.40397	0.0769231
2019	19,471.37	0.0769231	1,374,755	0.0769231	0.1429131	0.0769231	82.83703	0.0769231
2020	15,113.11	0.0769231	1,387,123	0.0769231	0.1112063	0.0769231	64.14569	0.0769231
2021	33,328.89	0.0769231	2,838,547	0.0769231	0.0923558	0.0769231	201.6844	0.0769231
2022	26,664.96	0.0769231	2,379,731	0.0769231	0.1392481	0.0769231	206.9735	0.0769231
2023	29,118.50	0.0769231	2,578,314	0.0769231	0.1021798	0.0769231	224.9722	0.0769231

References

Abadie A (2021) Using synthetic controls: Feasibility, data requirements, and methodological aspects. Journal of economic literature 59(2):391–425

Abadie A, L'Hour J (2021) A penalized synthetic control estimator for disaggregated data. Journal of the American Statistical Association 116(536):1817–1834

Abadie A, Diamond A, Hainmueller J (2010) Synthetic control methods for comparative case studies: Estimating the effect of california's tobacco control program. Journal of the American statistical Association 105(490):493–505

Appold SJ, Kasarda JD (2013) The airport city phenomenon: Evidence from large us airports. Urban Studies 50(6):1239–1259

Athey S, Imbens GW (2017) The state of applied econometrics: Causality and policy evaluation. Journal of Economic perspectives 31(2):3–32

Azul Press (2025) Email about azul hubs. Email sent to the author on Jan 9, 2025

Ben-Michael E, Feller A, Rothstein J (2021) The augmented synthetic control method. Journal of the American Statistical Association 116(536):1789–1803

Blonigen BA, Cristea AD (2015) Air service and urban growth: Evidence from a quasi-natural policy experiment. Journal of Urban Economics 86:128–146

Brueckner JK (2003) Airline traffic and urban economic development. Urban Studies 40(8):1455–1469

Diário do Nordeste (2023) Hub falho e limitado: Gol reduz pela metade voos em fortaleza e abre espaço para concorrentes. URL https://diariodonordeste.verdesmares.com.br/opiniao/colunistas/igor-pires/hub-falho-e-limitado-gol-reduz-pela-metade-voos-em-fortaleza-e-abre-espaco-para-concorrentes-1.3344265

GOL Informa (2022) Gol implanta centro de distribuição de voos na bahia. URL https://www.voegol.com.br/sobre-a-gol/imprensa/gol-implanta-centro-de-distribuicao-de-voos-na-bahia

Governo do Estado do Ceará (2018) Hub aéreo: Início de operações é marco histórico para turismo e economia do ceará. URL https://www.ceara.gov.br/2018/05/03/hub-aereo-inicio-de-operacoes-e-marco-historico-para-turismo-e-economia-do-ceara/

Instituto Brasileiro de Geografia e Estatística (IBGE) (2007) Introdução à classificação nacional de atividades econômicas - cnae 2.0. URL https://cnae.ibge.gov.br/images/concla/documentacao/CNAE20_Introducao.pdf

Instituto de Pesquisa Econômica Aplicada (IPEA) (2010) Panorama e perspectivas para o transporte aéreo no brasil e no mundo. URL https://repositorio.ipea.gov.br/bitstream/11058/4407/1/Comunicados_n54_Panorama_perspectivas.pdf

LATAM Press (2025) Email about latam hubs. Email sent to the author on Jan 9, 2025

McGraw MJ (2020) The role of airports in city employment growth, 1950–2010. Journal of Urban Economics 116:103240

Ministério do Turismo (2024) Portal de dados abertos. URL https://dados.gov.br/dados/conjuntos-dados/cadastur-01

Ministério do Turismo (2025) Email about cadastur. Email sent to the author on Jan 21, 2025

Prefeitura do Recife (2016) Diário oficial do recife. URL https://dome.recife.pe.gov.br/dome/doDia.php?dataEdicao=2016-02-18, n. 18, p. 1, 18 fev. 2016

Rodrigue JP (2024) The geography of transport systems, 6th edn. Routledge

Sheard N (2014) Airports and urban sectoral employment. Journal of Urban Economics 80:133–152

Sheard N (2019) Airport size and urban growth. Economica 86(342):300–335