



Reconsidering airport economic impact assessments: A bottom-up comparative analysis of Belgian airports

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ABSTRACT

This study analyses and compares the economic impact of Belgium's five commercial airports on their region and country. The airports represent different types, including Belgium's main airport, Brussels Airport and four regional airports: a low-cost regional airport (Brussels South Charleroi Airport), a specialised cargo regional airport (Liège Airport), and two small regional airports (Antwerp Airport and Ostend-Bruges Airport). The economic impact is measured through input-output analysis, which assesses added value and employment on a direct, indirect, and induced level. To improve accuracy, we employ a bottom-up approach that links company-level employment and added value data to the input-output framework via NACE classifications. Additionally, a Monte Carlo sensitivity analysis is introduced to strengthen the robustness of our findings.

Our results demonstrate significant differences in the airports' economic contributions based on airport size and operational focus, with Liège Airport's cargo specialisation generating a particularly strong regional impact. These findings lead to a broader discussion on airport subsidies based on the economic impact. Beyond the Belgian context, our bottom-up approach provides a replicable framework for more precise airport impact assessments.

1. Introduction

Airports serve as pivotal nodes in the global transportation network, fostering the rapid movement of people and goods. For instance, 973 million passengers and 13.1 million tonnes of freight and mail were transported by air in the EU in 2023 (Eurostat, 2023). By facilitating those flights, airports not only generate direct employment and added value via airport-related activities – such as airlines, ground services and airport retail operations – but also stimulate employment and added value via indirect linkages in sectors such as logistics and tourism (Graham, 2018). Moreover, the presence of an airport can significantly boost regional accessibility and connectivity, attracting business investments and stimulating local development (Halpern and Bråthen, 2010). In many cases, this increased economic activity mutually reinforces the demand for air transport, meaning that regions with higher levels of economic activity tend to generate increased air travel demand, which in turn further supports the growth of airport operations (Marazzo et al., 2010; Van De Vijver et al., 2014; Zhang and Graham, 2020).

In recent decades, numerous studies have examined the economic

impact of airports on their surrounding regions and national economies (e.g., Blonigen and Cristea, 2015; Brueckner, 2003; Button et al., 2010; Green, 2007; Sheard, 2017). However, to the best of our knowledge, no previous research, besides the inconclusive research of Allroggen and Malina (2014), has compared the economic impacts of different types of airports. This comparative perspective could be of interest in understanding the heterogeneous effects of airport operations and informing strategic decision-making by airport operators and policymakers.

Various methodologies have been applied to analyse this relationship between an airport and its economic impact. Econometric models are often employed when large and general datasets are available, allowing for the determination of relationships between variables through rigorous statistical analysis. However, while such models can capture broad trends, they may not adequately reflect the nuanced, context-specific effects that vary among different types of airports (Dimitriou et al., 2011; Graham, 2018; Rittgasszer, 2011; Torio et al., 2024). Computable general equilibrium (CGE) models are considered more comprehensive for capturing complex economic dynamics, yet their practical application is limited by high data requirements, intricate modelling procedures, and a lack of standardisation (Allan, 2015;

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Partridge and Rickman, 2010; Yu, 2018). These limitations can make it difficult to trace the pathways of changes and differences, rendering CGE models less practical for this comparative study (Loveridge, 2004; Yu, 2018). In contrast, the input-output (IO) approach has been widely adopted in airport economic impact studies due to its greater flexibility and transparent representation of inter-sectoral linkages, providing the ability to discover differences between airports in more detail (Dimitriou et al., 2011; Graham, 2018; Rittgasszer, 2011; Torio et al., 2024). Nevertheless, traditional top-down IO analyses can obscure the specific contributions of airports by aggregating data at the sectoral level.

Our study addresses this gap by making three key contributions. First, we conduct a comparative analysis of five Belgian airports to highlight relative differences in the economic impact between Belgian airports. Given the diversity of Belgian airports and the availability of harmonised economic data, Belgium represents a suitable setting for this analysis. More specifically, the airports each fulfil distinct roles: Brussels Airport is the primary international airport; Brussels South Charleroi Airport focuses on low-cost passengers; Liège Airport specialises in cargo operations; and the small regional airports, including Antwerp and Ostend-Bruges, offer general aviation services as well as leisure traffic and small cargo volumes (Pauwels et al., 2024). Second, we improve measurement accuracy by adopting a bottom-up approach that gathers firm-level employment and added value data of airport-related companies, which are then linked to the IO table via NACE codes.¹ This method ensures a more consistent and precise allocation of direct effects within the broader IO framework. Finally, we incorporate a Monte Carlo sensitivity analysis to assess the uncertainty in our results. These contributions not only refine the measurement of economic impacts but also provide a replicable framework for comparing airports' economic impacts in a specific country, thereby informing the discussions on airport subsidies.

The subsequent sections are organised as follows. First, the literature on the economic impact of airports, the analytical frameworks employed in their assessment and the relation to airport subsidies is reviewed. Next, we describe our methodological approach in detail, including the integration of company-level data within the IO framework and the implementation of the Monte Carlo sensitivity analysis. Finally, the findings and their implications on economic development and airport subsidies in Belgium are discussed.

2. Literature review

The literature review is organised into three strands. First, we examine the relationship between airport activity and regional economic development. Second, we discuss the methodological approaches – particularly IO analysis – used to capture airports' direct, indirect and induced effects alongside the supply-side effects. Third, the role of airport subsidies in shaping air transport activity and regional growth is reviewed.

2.1. An airport's economic impact on the surroundings

Early empirical work on airports' economic impact relied on econometric models to investigate the relationship between air transport and economic growth, and it was predominantly conducted in the United States. For instance, Irwin and Kasarda (1991) provided one of the first examinations by linking the structure of airline networks to employment growth across 104 metropolitan areas. Building on these

insights, Brueckner (2003) developed a general framework to assess the impact of air transport activities on regional economic performance according to an econometric approach, which was further extended by, for example, Green (2007) who investigated the effect of passenger boardings and originations per capita on population and employment growth in the largest metropolitan areas of the US; by Mellander and Holgersson (2012) who examined the relationship between the presence and size of an airport and regional development; by Button and Yuan (2013) who analysed the impact of air freight transport on employment and income; by Bilotkach (2015) who explored the effects of traffic volume and the number of destinations served with non-stop flights on key indicators of regional economic development such as the level of employment, number of business establishments, and average wages; by Blonigen and Cristea (2015) who estimated the effects of airline traffic on the local population, income, and employment growth; and by Sheard (2017) who analysed the airport size in relation to local employment (both high- and low-skilled), number of firms, population size and GDP.

The positive relationship between air transport activity – in both passenger numbers and air freight – and regional economic growth observed in the US was further confirmed by Marazzo et al. (2010), who examined the relationship between air transport demand (measured in passenger-kilometre: PAX) and economic growth (GDP) in Brazil, and by Percoco (2010) who assessed the impact of airports on Italian provinces in terms of total passengers and flights. More recently, Ceulemans et al. (2024) used the connectivity of European airports to measure their impact on regional development in terms of employment.

Furthermore, subsequent research has increasingly focused on the economic contributions of regional airports. For example, Button et al. (2010) explored the economic contributions of smaller airports in Virginia and concluded that an increase in passenger traffic could significantly boost per capita income in a given region. Pot and Koster (2022) also examined smaller airports in Europe and found that, in contrast to major hubs, the causality primarily runs from economic growth to air accessibility. Additionally, Baker et al. (2015) and Mukkala and Tervo (2013) investigated the effect of air transportation on regional development in peripheral regions, concluding that “air transportation is even more than a facilitator in remote regions; rather, regional growth causes airport activity, and increased air activity further boosts regional development”.

These contrasting findings regarding the economic impact of regional airports may suggest potential differences in the type of airport and their accompanying economic effects. Accordingly, Allroggen and Malina (2014) cautioned that the output effects of air transport are not uniform across all airports and are influenced by capital appropriation and traffic characteristics. However, while they attribute some variations to differences in traffic patterns, these patterns are not directly captured in their model. They thus suggest incorporating information about traffic characteristics in future research. Building on this extensive body of research, our study aims to address the gap in comparative economic impact studies by focusing on the differences between various types of Belgian airports. While our methodological approach differs from that of Allroggen and Malina (2014), we incorporate their recommendation to account for traffic characteristics by explicitly distinguishing between passenger and cargo traffic. This distinction helps contextualise the observed heterogeneity in airport output effects.

2.2. An input-output analysis to investigate the economic impact

While previous research, including econometric models, provides valuable insights into the broad trends, it often overlooks localised interdependencies and the distinct characteristics of different airports (Rittgasszer, 2011). In contrast, the IO approach has gained prominence due to its ability to capture the intersectoral linkages that underpin airport-related indirect and induced economic effects (Dimitriou et al., 2011; Graham, 2018; Rittgasszer, 2011; Torio et al., 2024).

¹ NACE is the acronym (from the French ‘Nomenclature statistique des Activités économiques dans la Communauté Européenne’ - Statistical classification of economic activities in the European Community) used to designate various statistical classifications of economic activities developed since 1970 by the European Union. In Belgian IO tables, the sectors (64 in total) are based on NACE-BEL codes, which is the Belgian version of the NACE classification.

The economic impact of an airport, as captured by IO analysis, can be divided into two categories: the demand-side and supply-side effects. Demand-side effects include the direct, indirect and induced effects. Although there is little debate regarding the definitions of indirect and induced effects, studies differ in how they conceptualise direct effects. Generally, direct effects are defined as the employment and added value generated by the airport's (construction and) operation. However, the geographical origin of those direct effects and the affiliation of companies with the airport operation can vary. For instance, studies by Beifert (2016), Kupfer and Lagneaux (2009), Malina et al. (2007) and Vennix (2017) consider only on-site generated effects, while Baker et al. (2015), Bogdański (2014), Červinka and Tykva (2012), Graham (2018), Percoco (2010), and Zuidberg and Veldhuis (2012) argue that such effects may also extend to surrounding areas; Graham (2018) even suggests a 20-min drive time as a threshold. Additionally, Rittgasszer (2011) and York Aviation (2004) emphasise that employment and income should be predominantly associated with airport operations.

Indirect effects stem from the supply chain, encompassing the employment and added value generated by suppliers of goods and services to support the direct activities within the economy of the study area (Baker et al., 2015; Beifert, 2016; Bogdański, 2014; Červinka and Tykva, 2012; Graham, 2018; Malina et al., 2007; Percoco, 2010; York

Aviation, 2004; Zuidberg and Veldhuis, 2012). This definition often specifies that these effects are confined to the study area, whether regional or national. These indirect effects are sometimes referred to as backward flows within the aviation value chain (Graham, 2018).

Induced effects refer to the additional employment and added value generated by the spending of incomes by employees of the direct and indirect sectors (Baker et al., 2015; Beifert, 2016; Bogdański, 2014; Červinka and Tykva, 2012; Graham, 2018; Malina et al., 2007; Percoco, 2010; York Aviation, 2004; Zuidberg and Veldhuis, 2012). The magnitude of these effects depends on the defined geographical perimeter (regional or national) and are sometimes termed forward linkages within the aviation value chain (Graham, 2018).

Supply-side effects, or catalytic effects, are defined as “the comprehensive economic advantages arising from an airport's ability to stimulate various sectors of the economy, such as trade, investments, productivity, and tourism” by InterVISTAS for ACI Europe (2015). Although quantitative estimation of these effects is emerging (Baker et al., 2015), most studies, such as those by Halpern and Bråthen (2010) and Galeote and Mestanza (2021), have approached catalytic effects qualitatively. According to Forsyth et al. (2021), demand and supply-side effects should be estimated separately, but several studies (e. g., Baker et al., 2015; Bogdański, 2014; Rittgasszer, 2011; York Aviation,

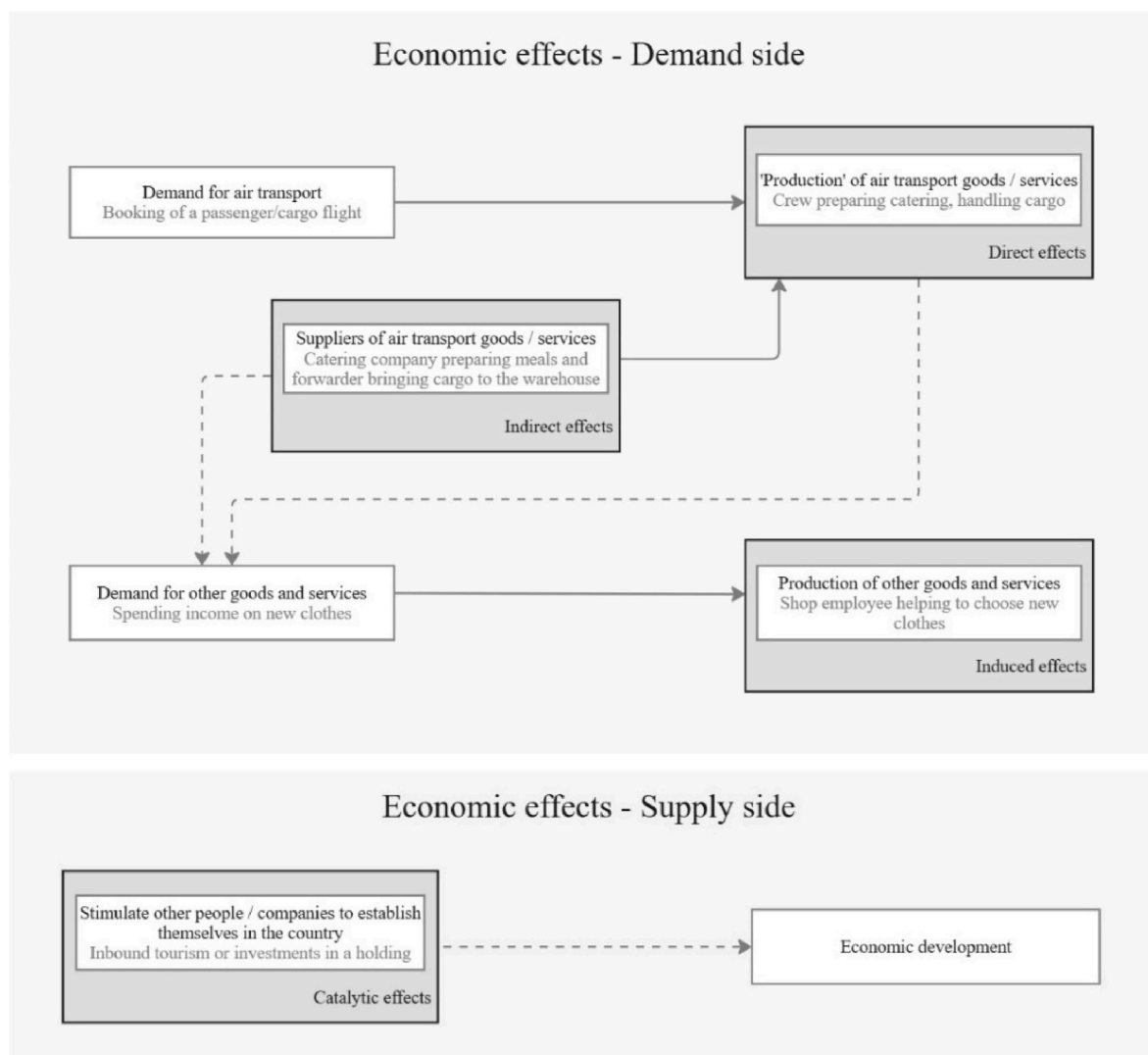


Fig. 1. Economic effects from the demand and supply side (own composition based on literature review).

2004; Zuidberg and Veldhuis, 2012) have grouped them together without clear clarification. In other studies, the catalytic effects are described as ‘other effects’ (Červinka and Tykva, 2012), ‘qualitative effects’ (Galeote and Mestanza, 2021), ‘spillover effects’ (Pot and Koster, 2022; Zhang and Graham, 2020) and ‘supply side effects’ (Beifert, 2016; Graham, 2018; Mikkala and Tervo, 2013). Fig. 1 presents a comprehensive overview of these economic effects, emphasising both the demand- and supply-side effects.

Conventional IO studies in the airport literature, however, have typically concentrated on single airports and point estimates (Dimitriou et al., 2011; Hagemann et al., 2017, 2017; Hakfoort et al., 2001; Huderek-Grapska, 2013; Hujer and Kokot, 2000; Malina et al., 2007; Torio et al., 2024). Two exceptions are the research of Nataraja and Robert (2019), which includes a direct effect analysis of the five busiest airports worldwide, and Kupfer and Lagneaux (2009), which studied the direct and indirect effects of Belgian airports. However, while these studies have provided valuable insights into airport economic impacts, they adopted a descriptive approach and point estimates and did not incorporate direct comparisons between airports. Moreover, the estimation of direct effects in these studies is based on a top-down approach and is limited to on-site activity, neglecting airport-related firms located outside the immediate airport boundary. Notably, no prior research has directly linked bottom-up firm-level data to the broader IO framework through NACE codes, thereby limiting the precision of the direct-to-indirect effect linkage. Building on this foundation, our study advances the literature by systematically comparing five Belgian airports, integrating bottom-up firm-level data through NACE codes to improve the precision of direct effect estimations, and incorporating a Monte Carlo sensitivity analysis to assess result robustness.

2.3. The relationship between airport subsidies and economic impact

The relationship between airport subsidies and their effect on air transport activity – and, in turn, regional development – has been the subject of increasing academic interest. Thomas and Jha (2024) underscored the need for airport subsidies to sustain regional airport operations in India. In relation, Wu et al. (2020) highlighted that government subsidies are often aimed at ensuring air connectivity in remote and smaller regions, though their broader economic, social, and environmental impacts remain underexplored. Wu et al. (2023) further demonstrated that subsidies for regional airports in New Zealand increased scheduled flight capacities and regional air transport activity, subsequently boosting employment and economic growth. Chow et al. (2021) also emphasised that subsidies for small and medium-sized airports can effectively support aviation and tourism development in ethnic minority areas and remote or economically disadvantaged regions with inconvenient land transportation. Moreover, Miller et al. (2016) suggest that subsidies for small airports may be welfare-enhancing if they improve service levels and generate positive economic outcomes.

While these subsidies can enhance the economic contribution of airports, their effectiveness varies depending on the airport’s operational context and regional economic structure. Wu and Qi (2021) found that small and medium-sized Chinese airports with efficient subsidy utilisation adopt distinctive management practices and align their development strategies with regional economic needs. In contrast, poorly managed airports may fail to generate significant returns despite receiving government support (Wu and Qi, 2021). In line with Wu and Qi (2021), Kanafani and Abbas (1987) argued that the economic impact of an airport is highly contingent on the type and volume of traffic it handles and the strategy it employs, necessitating caution in subsidy allocation. Forsyth (2007) further noted that the net effect of subsidies might be negligible or even negative if the benefits merely result in the redistribution of existing economic activity rather than generating new economic growth.

2.4. Conclusions of the literature review

In summary, while the existing literature provides robust evidence that air transport positively influences economic development, it lacks comparative analyses that distinguish between different airport types within a single country. Moreover, conventional IO studies have not fully leveraged firm-level data to enhance measurement accuracy, nor have they integrated techniques such as Monte Carlo sensitivity analysis to assess robustness. This paper contributes to filling these gaps by providing a comparative overview of the economic impact of Belgian airports, linking detailed bottom-up direct effects via NACE codes to the IO framework and enhancing robustness through Monte Carlo analysis. This approach not only contributes to the academic literature by refining the measurement of airport economic effects but also provides a replicable framework for comparing airports’ economic impacts in a specific country, thereby informing the discussions on airport subsidies.

3. Methodology and data collection

This study employs a comparative case study design to assess the variations in the economic impact of Belgian airports. The analysis focuses on five airports, comparing their contributions in terms of employment and added value. An IO analysis is conducted to quantify these effects, providing a structured approach to measuring airport activities’ direct, indirect, and induced effects.

The section is structured as follows. First, the IO analysis is introduced, detailing how direct, indirect and induced effects are calculated. Then, a Monte Carlo analysis is incorporated to analyse the robustness of the results. Finally, the case study selection is explained, along with the specific data collection methods used to obtain company-level employment and financial data.

3.1. Input-output analysis

The IO model, originated by Wassily Leontief in 1973, provides insights into the interdependencies between different sectors of the economy (Coppens and Degreef, 2005; Goyal and Llop, 2024; Rey, 2000). Central to this model is the IO table (represented in Table 1), which captures the flow of goods and services within the economy by detailing sectoral transactions in a structured matrix format. Both the rows and columns represent the n sectors of the economy. The rows record the output of a given sector, showing how its production is distributed among all sectors and final consumers, including households, government, investments or exports (f). The columns, in contrast, represent the input structure of a sector, detailing the resources required for production, including intermediate goods, imports (m) and added value (va).

where:

- n = number of sectors in the economy
- x_{ij} = output of sector i delivered to sector j /input of sector j delivered by sector i
- m = import
- va = value added
- f = final demand of sector i

Table 1

The basics of an IO table (based on Kupfer and Lagneaux, 2009).

	1	2	...	n	f	x
1	x_{11}	x_{12}	...	x_{1n}	f_1	x_1
2	x_{21}	x_{22}	...	x_{2n}	f_2	x_2
...	...	...	...	...	...	...
n	x_{n1}	x_{n2}	...	x_{nn}	f_n	x_n
m	m_1	m_2	...	m_n	m_f	
va	va_1	va_2	...	va_n		
x	x_1	x_2	...	x_n		

- x_i = total output or the sum of the intermediate usage and the final consumption

IO models demonstrate advantages compared to computable general equilibrium models in terms of sector-specific modelling and straightforwardness, having led to extensive applications in academia and practice (Allan, 2015; Goyal and Llop, 2024; Loveridge, 2004; Partridge and Rickman, 2010). Despite these advantages, the IO model is not without limitations. One key assumption is that economic relationships between sectors remain constant, which oversimplifies dynamic changes in the economy, such as technological advances or shifts in industry practices. Moreover, the absence of an airport does not necessarily lead to a complete redundancy of economic resources, meaning that some alternative usage of those resources might reduce the total impact attributed to the airport. Considering the induced impact, while the model improves upon traditional analyses by treating consumption demand as endogenous, it does not fully account for changes in income distribution and consumption patterns, which could alter the overall economic outcomes. These limitations suggest that while IO models offer valuable insights, their results should be interpreted with an understanding of these constraints. However, given that this study is a comparative analysis, the focus on relative differences between cases helps mitigate some of these concerns, allowing for more meaningful conclusions despite the model's inherent limitations. Additionally, a bottom-up approach based on company-level NACE classifications and a Monte Carlo analysis are introduced to improve accuracy and assess the robustness of our results.

The bottom-up approach starts with estimating direct effects, including the employment and added value generated by businesses that have a direct functional relationship with airport activities. Fig. 2 provides an overview of the relevant companies. The left circle represents the companies included in the economic impact assessment of the air transport cluster, while the right circle shows the businesses considered in evaluating the economic impact of an airport. More specifically, to determine the direct impact of an airport, it is necessary to include all companies within the air transport cluster inside the airport zone (e.g., airlines or baggage handlers) and all other airport-related activities (e.g., restaurant concessions or airport hotels). In contrast, firms falling outside categories B and C are not considered part of an airport's direct economic effects. For instance, businesses that are not airport-related but are located in the airport zone (e.g., IT consultancy firms that do not provide services to the airport) or businesses that are air transport-related but operate outside the airport zone (e.g., space- and aircraft maintenance companies unrelated to the specific airport under study) are not part of an airport's direct economic effects.

More practically, the VAT listing of the airport is collected as a

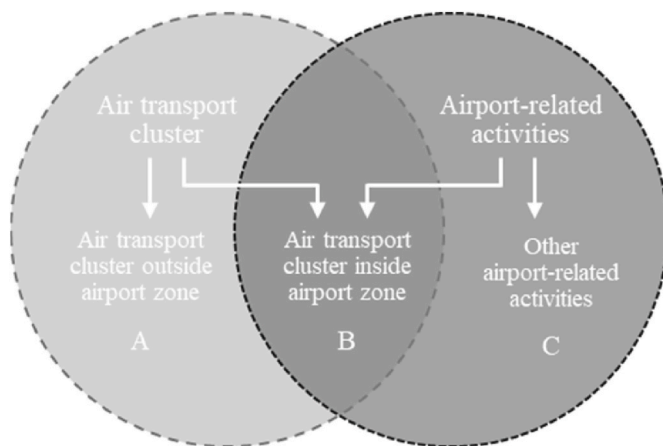


Fig. 2. Direct impact of air transport cluster and airport (own composition based on Kupfer and Lagneaux, 2009).

starting point for companies directly related to the airport.² To, therefore, clearly distinguish between businesses inside and outside the airport zone, the airport area is delineated based on the official airport boundaries and the surrounding municipal administrative divisions. Moreover, companies are categorised according to whether their activities are related to the airport by examining their NACE codes. These codes reflect the inherent nature of each company's activities and are also used in the national IO table to reflect the sectors.

Once the company list is finalised and validated, the number of full-time equivalents (FTE) and added value can be retrieved. More specifically, the FTE data of each company can be obtained from the National Social Security Office, which records yearly employment figures per establishment based on official company declarations. The added value of each company is the difference between the value of a company's output (or products and services) and the cost of the inputs (like raw materials and external services), and it can be calculated based on individual annual accounts.³ The collected FTE and added value figures are summed up, respectively, to receive the direct economic impact.

Because our primary interest lies in understanding the direct, indirect (supplier-driven) and induced (income-driven) effects of airport operations, the portion of each sector's activity attributable to the airport is isolated within the IO table.⁴ This is necessary because the n sectors in the IO table (Table 1) do not include a dedicated airport sector. However, accuracy and consistency are ensured by using NACE codes in both the identification of companies for the direct effects and the classification system used in the IO table. To achieve this, we derive a splitting proportion p_i for each sector i via a metric (added value or FTE as obtained from our direct effect analysis), defined as:

$$p_i = \frac{\text{Airport related metric in sector } i}{\text{Total metric in sector } i}$$

Based on these splitting proportions p_i , we construct a transformation matrix A (of dimensions $n \times (n+1)$) to partition each sector into two components: a non-airport portion with weight $1 - p_i$ and an airport portion with a weight p_i . With sectors 1, 2, ..., n and splitting proportions $p_1, p_2, \dots, p_n$, the transformation matrix is given by:

$$A = \begin{pmatrix} 1 - p_1 & 0 & \dots & 0 & p_1 \\ 0 & 1 - p_2 & \dots & 0 & p_2 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & 1 - p_n & p_n \end{pmatrix}$$

If X denotes the original $n \times n$ IO table, where the element x_{ij} represents the output from sector i delivered to sector j . We extend this table

² The VAT (Value Added Tax) listing of the airport refers to a comprehensive record – typically comprising invoices and receipts for tax compliance – that is maintained by the airport's administration to track business activities associated with the airport.

³ In accounting terms, the added value can be estimated either by aggregating the staff costs (62), depreciation and value adjustments (630), provisions for liabilities and charges (635/8), other operating expenses (640/8) and operating profit or loss (9901) and then subtracting operating costs capitalised as restructuring expenses (649) and operating subsidies if they are not product-related (740) or by subtracting the intermediate consumption including purchases of goods (600/8), services and other goods (61), changes in stocks of purchased goods (609) and operating subsidies if they are not product-related (740) from the output including turnover (70), changes in stocks of produced goods (71), capitalised own account production assets (72), contributions, gifts, legacies and grants (73) and operating income (74). The aggregations based on a cost and production approach give equal results and are further described in the guidelines of the European System of National and Regional Accounts and the National Bank of Belgium (Eurostat, 2013; National Accounts Institute, 2024; Vennix, 2017). The numbers referenced are derived from the Minimum Chart of Accounts, which can be accessed at: https://www.cbn-cnc.be/nl/node/2250?language_content_entity=en.

⁴ The choice of the right IO table is based on the objectives of the study. The rationale behind our choice is explained in Appendix A.

into a new $(n+1) \times (n+1)$ IO table X' by applying the following transformation matrix:

$$X' = A^T X A$$

In the extended table X' , the first n rows and columns represent the non-airport portions of each sector and the $(n+1)$ th row and column constitute the newly created airport sector, aggregating all the airport-related activities. By performing this transformation, we integrate the direct effects (quantified at the firm level using NACE codes) into the macro-level IO framework. This allows us to accurately track not only the direct economic contributions of airport-related activities but also the subsequent indirect and induced effects throughout the economy.

As a second step, the technical coefficients are calculated.⁵ The technical coefficient, b_{ij} , captures the input structure of a sector by quantifying the proportion of intermediate inputs from sector i used in the production process of sector j . It is defined as:

$$b_{ij} = \frac{x_{ij}}{x_j}$$

Where x_{ij} represents the output from sector i delivered to sector j , and x_j is the total output of sector j . Consequently, the total output of sector i can be expressed as the intermediate and final consumption:

$$x_i = \sum_{j=1}^n b_{ij} \cdot x_j + f_i$$

Once the technical coefficients are determined, the Leontief multiplier (l_{ij}) can be calculated. This multiplier quantifies the total effect on the national output resulting from a one-unit increase in the final demand for a particular industry. The necessity for employing a multiplier, rather than solely considering the direct effect of a change in final demand, stems from the economy's inherent 'ripple effect'. For instance, an increase in final demand for the air transport industry – such as an increase in demand for airline tickets – not only elevates the direct output of that sector (e.g., more flights) but also induces supplementary demand in related industries. As the air transport sector expands, it requires additional inputs from its supply chain, such as food and beverages from wholesalers for in-flight catering services, which in turn boosts the output of these sectors. Consequently, the initial increase in final demand triggers a series of interrelated increases across the economy, a phenomenon that is effectively captured by the Leontief multiplier.

In the final stage, the overall impact on employment (measured in full-time equivalents) and added value is computed when both intermediate usage and final demand are reduced to zero. It is important to note that because our analysis assesses the impact of the entire airport sector, we employ the change in the total output Δx_j (intermediate usage and final demand) rather than a change in final demand Δf_j , as is common in other IO analyses. Therefore, a correction factor is applied by dividing each element in the Leontief inverse matrix by the on-diagonal element of the Leontief inverse matrix. This translates the output-to-final demand multiplier (l_{ij}) into an output-to-output multiplier (l_{ij}^*) (Cai and Leung, 2004; Miller and Blair, 2009; Oosterhaven and Stelder, 2002). Specifically, the change in direct and indirect full-time equivalents can be estimated using the formula below.⁶ Because only the indirect effect is calculated, the number of direct full-time equivalents should be subtracted from the result.

⁵ The technical coefficients are based on the input structure of the IO table. However, if the same IO table and the same data are used, the degrees of dependency method, using the output structure, should give equal results (Aviato, 2020; Coppens and Degreef, 2005).

⁶ The formula is the same for calculating the added value but then the e_i is changed into VA_i .

$$\Delta e_i^{(\infty)} = \sum_i \frac{e_i}{x_i} \cdot l_{ij}^* \cdot \Delta x_j$$

where:

- e_i is the number of full-time equivalents in sector i ,
- x_i equals the output of sector i ,
- $l_{ij} = (1 - b_{ij})^{-1}$ denotes the output-to-final demand Leontief multiplier,
- $l_{ij}^* = l_{ij} / l_{jj}$ is viewed as the total output-to-output Leontief multiplier,
- Δx_j is the change in total output for sector j comprising both final and intermediate demand.

Finally, the induced effects are estimated by quantifying the additional employment and added value generated by re-spending incomes from the direct and indirect effects. In this context, the induced effects represent the multiplier effect resulting from household consumption expenditures. For example, when an airport ground handler uses his income to purchase goods such as a car, a portion of that expenditure is subsequently re-spent in other sectors, thereby further amplifying the economic impact.

To capture these induced effects, the IO model is extended to include the household sector. Specifically, an additional row – representing the compensation of employees (i.e. labour income per unit of output) – and an additional column – referring to the final consumption expenditure by households – are incorporated into the IO table (D'Hernoncourt et al., 2011; Huderek-Glapska, 2020; Miyazawa, 2012; Pischner and Stäglin, 1976; Schumann, 1975). Notably, household consumption is measured in terms of total household income rather than total expenditure to avoid overestimating induced effects due to consumption financed by 'unearned' income (e.g., pensions or capital gains).

3.2. Monte Carlo sensitivity analysis

To further enhance the robustness of our IO estimates, we incorporate a Monte Carlo sensitivity analysis into our methodology. For this analysis, probability distributions were assigned to each uncertain input. We then conducted 10,000 Monte Carlo iterations, generating distributions for our estimated direct, indirect and induced effects. The reported results include rounded means, along with the 2.5th and 97.5th percentiles, providing confidence intervals that reflect the robustness of our findings.⁷ The Monte Carlo analysis incorporates several specific assumptions:

First, missing values in the social security employment data were approximated using sector-specific averages. These averages were derived from employment data of organisations within the airport cluster and NACE-BEL sector or, when necessary, from the overall averages for that NACE-BEL sector. For the former, Monte Carlo draws were generated according to the formula:

$$\bar{x} + t_{n-2} \cdot \frac{s}{\sqrt{n}}$$

where, $\bar{x}$ denotes the mean used for imputation, t_{n-2} is a random draw from a t -distribution with $n - 2$ degrees of freedom, s is the standard deviation associated with $\bar{x}$ and n is the number of observations underlying the mean $\bar{x}$ estimate. In cases where the standard deviation and sample size for the NACE-BEL averages were unavailable, we assumed that the NACE-BEL average follows a normal distribution with a standard deviation equal to the mean divided by 19 – approximately corresponding to a 10 % deviation from the mean at the 95 % confidence

⁷ The FTE have been rounded to the nearest hundred and the added value has been rounded to the nearest 10 million. The confidence intervals have been rounded down for the lower bound and up for the upper bound.

Table 2

General information on Belgium's commercial airports with controlled airspace (own composition).

Airport	Nature of activities	WLUs 2019	Ownership structure
BRU	International, hub, multifunctional	31,000,000	BAISA (75 %) and SFPIM (25 %)
LGG	Cargo	9,200,000	NEB Participations S.A. (50.4 %), Aéroports de Paris Management S.A. (25.5 %) and SOWAER (24.1 %)
CRL	Low-cost passengers	8,200,000	Belgian Airport S.A. (48.32 %), SOWAER (35.87 %), Sambrinvest S.A. (13.68 %), IGRETEC (1.66 %) and SABCA S.A. (0.48 %)
OST	Leisure, general aviation, cargo	700,000	LOM-LEM structure (with commercial ownership by Egis)
ANR	Leisure, general aviation	300,000	LOM-LEM structure (with commercial ownership by Egis)

interval.

Second, as the National Bank of Belgium does not report FTE at the NACE-BEL sector level – a measure for incorporating an additional airport-related sector into the IO table – the total employment hours on the NACE-BEL sector level were converted into FTE by dividing by the assumed weekly working hours. Specifically, we assumed that employees work either 40, 38 or 37.6 h per week, each with an equal probability, consistent with a uniform distribution.

Third, missing values for added value were approximated using the following procedure: If the number of FTE working for an organisation was available, the imputed added value was calculated by multiplying the number of FTE by the average added value per FTE for the corresponding NACE-BEL sector. This sector-specific average was assumed to follow a normal distribution with a standard deviation equal to the mean divided by 19. When the number of FTE was also unavailable, both the FTE and the corresponding added value were approximated simultaneously using the same assumptions.

3.3. Case study

Belgium was selected as the case study because of its diverse airport types and the availability of harmonised economic data. The country encompasses five commercial airports with controlled airspace and distinct operational focuses. For example, Brussels Airport (BRU), located approximately 12 km northeast of the capital, is the primary international hub, having transported around 26 million passengers and 500 thousand tons of cargo in 2019 (Skeyes, 2023; Brussels Airport, 2019). In contrast, the two (regional) airports in Wallonia demonstrate different strategic focuses, such as Brussels South Charleroi (CRL), primarily serving low-cost carriers and Liège Airport (LGG), which specialises in cargo operations. In Flanders, smaller regional airports like Ostend-Bruges (OST) and Antwerp (ANR) primarily cater to leisure flights and general aviation, with Ostend-Bruges also having processed approximately 25,000 tons of cargo in 2019. Table 2 provides an overview of these airports, summarising their core activities, passenger and cargo volumes, and ownership structures. Notably, while most airports exhibit a mixed public-private ownership structure, Brussels Airport is predominantly privately owned. This heterogeneity in airport characteristics renders Belgium a suitable context for comparative analysis as it allows for the exploration of how the different operational focuses influence economic impacts in Belgium.

As described in the methodology section, the 2019 VAT listings for BRU, LGG, CRL, OST and ANR served as the primary data source for capturing the direct economic effects of airport operations. The year 2019 was selected because it represents a stable pre-COVID-19 baseline – given that the 2024 annual accounts were not yet available – and because the pandemic significantly disrupted the aviation industry. The data cleaning process consisted of three main steps. To distinguish between businesses located within and outside the airport zone, the airport areas were delineated based on official airport boundaries and the surrounding municipal administrative divisions. For instance, the airport zone for Brussels Airport includes the municipalities of Machelen, Steenokkerzeel, Zaventem, and Kortenberg; for Liège Airport, the zone comprises Awans, Grâce-Hollogne, and Flémalle; for Brussels South Charleroi Airport, it includes Charleroi and Fleurus; for Ostend-Bruges

Airport, it covers Oostende and Middelkerke; and for Antwerp Airport, it encompasses Antwerpen, Borsbeek, and Mortsel. Thereafter, companies were categorised based on whether their activities were directly related to the airport by examining their NACE codes. These codes reflect the inherent nature of each company's operations. They are consistent with those used in the national IO table, ensuring accurate alignment between the firm-level data and the broader economic framework. Finally, the list was supplemented with companies not captured within the VAT listing, including self-employed people and non-profit organisations (NPOs) involved in pilot training at airport-based flight schools, government employees, and certain airlines registering employees abroad.

Once the company list was finalised and validated, the number of full-time equivalents (FTE) and the added value for each company were retrieved. FTE data were obtained from the Belgian Social Security agency (RSZ, Rijksdienst voor Sociale Zekerheid),⁸ which records annual employment figures per establishment based on official company declarations. The added value for each company was calculated using individual annual accounts, as provided by the National Bank of Belgium.

To assess indirect and induced effects, we relied on the most recent product-by-product IO table from 2015, provided by the Federal Planning Bureau.⁹ National figures for employment, added value, and output for each sector (for 2019) were extracted from the National Bank of Belgium and Statbel, and additional data on employee compensation and household final consumption (for 2019) were also obtained from Statbel (2023). Table 3 offers an overview of the data sources and the corresponding variables utilised in the analysis.

4. Results

In this section, we present the findings of our economic impact assessment, including the 95 % confidence intervals based on our Monte Carlo simulation. We begin with an overarching summary of the key results, providing a broad perspective on the economic contributions of different airport types, before moving into a more detailed breakdown of the direct, indirect, and induced effects.

Table 4 summarises general information – including the number of passengers and the volume of cargo transported in 2019 – as well as the estimated impacts at the direct, indirect, and induced levels in terms of full-time equivalents and added value for the five airports under study. The results are presented as the rounded means of the 95 % confidence intervals.

4.1. Direct effects

In this subsection, we provide the direct economic effects of the five

⁸ Or ONSS, Office National de Sécurité Sociale, in French.

⁹ Given that the National Bank of Belgium does not provide a 2019 IO table, we used the most recent available IO table from 2015. In mature economies like Belgium, where structural intersectoral linkages are generally stable over short- to medium-term periods, we assume that the four-year gap is unlikely to materially affect our analysis.

Table 3

Data requirements for the IO analysis (own composition).

	Data requirements	Sources
Direct effects	VAT listings of the five airports (2019) Full-time equivalents for each directly related company (2019) Annual accounts of each directly related company (2019)	Individual airport operators Rijksdienst Sociale Zekerheid National Bank of Belgium
Indirect effects	Product-by-product IO table (2015) Employment, added value and output for each sector (2019)	Federal Planning Bureau National Bank of Belgium and Statbel
Induced effects	Compensation of employees and final consumption expenditure by households (2019)	Statbel

Table 4

Direct, indirect and induced effects of the five main airports in Belgium (own composition).

Indicators	BRU	LGG	CRL	OST	ANR
General information					
PAX	26,000,000	200,000	8,200,000	450,000	300,000
Cargo (in tonnes)	500,000	900,000	–	25,000	–
WLU	31,000,000	9,200,000	8,200,000	700,000	300,000
Total demand-side impact					
FTE	52,700	10,400	5600	1300	1100
Added value (in mil)	5400	1190	480	100	70
Direct effects					
Direct FTE	21,800	4600	2400	500	400
Added value (in mil)	2300	470	200	40	30
Indirect effects					
Indirect FTE	17,400	3100	1800	500	400
Added value (in mil)	1620	370	150	30	20
Induced effects					
Induced FTE	13,500	2700	1400	300	300
Added value (in mil)	1480	350	130	30	20

Belgian airports, focusing on their contributions to full-time employment and added value. The analysis presents estimates for each airport, highlighting the range of these effects with 95 % confidence intervals to capture potential variability.

The direct effects of Brussels Airport are estimated at 21,800 FTE with a 95 % confidence interval between [21,000; 22,600] and 2.3 billion euros added value with a 95 % confidence interval between [2.28 billion euros; 2.35 billion euros]. For Liège Airport, they are estimated at 4600 FTE [95 % CI: 4500; 4800] and 470 million euros added value [95 % CI: 460 million euros; 490 million euros]. For Brussels South Charleroi Airport, they are estimated at 2400 FTE [95 % CI: 2300; 2500] and 200 million euros added [95 % CI: 200 million euros; 210 million euros]. For Ostend-Bruges Airport, the direct effects are estimated at 500 FTE [95 % CI: 400; 500] and 40 million euros added value [95 % CI: 30 million euros; 40 million euros]. Finally, for Antwerp Airport, they are estimated at 400 FTE [95 % CI: 300; 400] and 30 million euros added value [95 % CI: 20 million euros; 40 million euros].

An analysis of the contributing sectors reveals that the air transport sector is the most significant contributor, accounting for 17 % of the total direct FTE and 15 % of the total added value. In terms of FTE, this is followed by the cargo handling and storage sector and the courier and postal activities. Concerning added value, the airport operator sector ranks second, followed by the cargo handling and storage sector in third place.¹⁰ When comparing the contributions across different airports, it is

evident that BRU and LGG generate a larger share of FTE and added value from the cargo handling and storage sector, as well as from the courier and postal activities. Conversely, CRL, OST, and ANR exhibit relatively higher contributions from the airport operator and air transport sectors. A more detailed breakdown of the sectoral contributions for each airport is provided in [Appendices B](#) through [F](#).

The cargo-related activities, in particular, appear to have a significant impact. To generate a more detailed examination, all relevant NACE-BEL codes were classified under either passenger or cargo-related activities. Certain classifications, such as NACE code 55 (accommodation; food and beverage service activities) and NACE code 53 (courier and postal activities), were straightforwardly attributed to passenger and cargo operations, respectively. However, others – such as those encompassing air navigation services, airport operators, and security companies – posed more significant challenges in classification. Given that the primary objective of this comparison was to assess the significance of cargo activities, supporting services were consolidated with passenger-related activities, while exclusively cargo-related activities were reported separately. This approach revealed that 31 % of direct full-time equivalents (approximately 9000 FTE) and 29 % of direct added value (approximately 880 million euros) can be attributed solely to cargo operations.

4.2. Indirect effects

In this subsection, we examine the indirect economic effects generated by the activities of suppliers to companies directly associated with the five airports. For Brussels Airport, these indirect effects are estimated at 17,400 FTE with a 95 % confidence interval of [16,800; 18,000] and 1620 million euros added value within a 95 % confidence interval of [1600 million euros; 1650 million euros]. For Liège Airport, indirect effects are estimated at 3100 FTE [95 % CI: 2900; 3200] and 370 million

¹⁰ The air transport sector includes companies with NACE-BEL codes '51100' (passenger air transport) and '51210' (freight air transport). The cargo handling and storage sector covers companies with NACE-BEL code '52100' (warehousing and storage), '52210' (service activities incidental to land transportation), '52249' (cargo handling except sea ports) and '52290' (other transportation support activities). The courier and postal activities sector includes companies with NACE-BEL code '53100' until '53200' (postal and courier activities). Finally, the airport operator sector accounts for companies with NACE-BEL code '52230' (service activities incidental to air transportation).

euros added value [95 % CI: 350 million euros; 390 million euros]. For Brussels South Charleroi Airport, the estimates are 1800 FTE [95 % CI: 1700; 1900] and 150 million euros added value [95 % CI: 140 million euros; 160 million euros]. The indirect effects of Ostend-Bruges Airport are estimated at 500 FTE [95 % CI: 400; 500] and 30 million euros added value [95 % CI: 30 million euros; 40 million euros], while for Antwerp Airport, the figures are 400 FTE [95 % CI: 300; 500] and 20 million euros added value [95 % CI: 20 million euros; 30 million euros].

A comprehensive analysis of the NACE-BEL sectors contributing to these indirect effects indicates that legal, accounting and management consultancy activities represent the most significant contributor in terms of FTE. They are followed by employment and interim services; warehousing and transportation support; security, facility and administrative services; and, lastly, accommodation and food services. With regard to indirect added value, the leading contribution originates from warehousing and transportation support activities, followed by legal, accounting and management consultancy services. Employment and interim services rank third, followed by real estate activities and, finally, rental and leasing activities. All airports share this core set of indirect activities; however, there are differences in the relative importance of these sectors across the individual airports. For instance, BRU, LGG and CRL demonstrate a relatively higher reliance on warehousing and transportation support activities, whereas smaller regional airports such as OST and ANR exhibit comparatively larger proportions in service-oriented sectors such as legal, accounting and management consultancy activities, as well as employment and interim services and security, facility and administrative services. Moreover, regional airports like LGG, CRL, OST and ANR generate a relatively higher proportion of indirect added value through rental and leasing activities than BRU.¹¹

4.3. Induced effects

The induced effects, which capture the additional employment and added value generated by the spending of incomes by employees in both the direct and indirect sectors, are estimated as follows. For Brussels Airport, induced effects amount to 13,500 FTE with a 95 % confidence interval of [13,000; 14,000] and 1.48 billion euros added value within a 95 % confidence interval of [1.47 billion euros; 1.51 billion euros]. For Liège Airport, they are approximated at 2700 FTE [95 % CI: 2600; 2900] and 350 million euros added value [95 % CI: 340 million euros; 360 million euros]. Brussels South Charleroi's induced effects are estimated at 1400 FTE [95 % CI: 1400; 1500] and 130 million euros added value [95 % CI: 120 million euros; 140 million euros]. For Ostend-Bruges Airport, the induced effects are estimated at 300 FTE [95 % CI: 300; 400] and 30 million euros added value [95 % CI: 20 million euros; 30 million euros], and for Antwerp Airport, at 300 FTE [95 % CI: 200; 300] and 20 million euros added value [95 % CI: 10 million euros; 30 million euros].

¹¹ The legal, accounting and management consultancy sector includes companies with NACE-BEL codes '69' (legal and accounting services) and '70' (activities of head offices and management consultancy firms). The employment and interim sector covers companies with NACE-BEL code '78' (employee provision). The warehousing and transportation support sector represents companies with NACE-BEL code '52' (warehousing and transport support activities). The security, facility and administrative sector includes businesses with NACE-BEL code '80' (security and investigation services), '81' (services to buildings; landscape services) and '82' (office administrative, office support and other business support activities). The accommodation and food sector comprises businesses with NACE-BEL code '55' (accommodation) and '56' (food and beverage establishments). The real estate sector includes companies with NACE-BEL code '68' (operation of and trade in real estate). Finally, the rental and leasing sector accounts for companies with NACE-BEL code '77' (rental and lease).

5. Discussion

The results underscore the varying economic contributions of different airport types in Belgium. More specifically, the findings reveal that Brussels Airport exerts the most significant impact on both the regional and national economies, with the total demand-side impact amounting to approximately 52,700 FTE and 5.4 billion euros added value. Moreover, Liège Airport, with its strong focus on cargo operations, has emerged as the second-largest contributor. These results support the well-established notion that airport size is a key determinant of economic impact, as previously documented by, for example, [Melander and Holgersson \(2012\)](#) and [Sheard \(2017\)](#). However, our comparative analysis goes beyond merely confirming that larger airports have a more significant economic contribution in Belgium. We also examine three additional dimensions: (1) the proportion of a NUTS 2 region's GDP attributable to the direct added value of each Belgian airport, (2) the relationship between workload units and the generated added value of Belgian airports, and (3) the relationship between the exploitation/operating subsidies and economic impact of Belgian airports.¹² As we explore these additional dimensions, it is important to note that this study focuses on Belgium as a case study and the demand side of the economic impact. The effects generated on the supply side – such as tourism and investments of businesses related to the presence of the airport – are not considered in this analysis.

Our examination of direct added value as a percentage of the GDP of the NUTS 2 region reveals how each airport's activities compare within its respective region.¹³ As illustrated in [Fig. 3](#), Brussels Airport exhibits the highest relative contribution at approximately 5 %, followed by Liège Airport at 1.6 % and Brussels South Charleroi at 0.7 %. Ostend-Bruges and Antwerp Airport both register negligible proportions. The relatively low share for Antwerp Airport, for instance, reflects not only its smaller airport operations but also the significant economic contributions of other sectors – such as the Port of Antwerp, the second-largest port in Europe – that bolster the overall regional GDP. This observation indicates that the economic contributions of airports must be interpreted in the broader context of regional economic structures.

[Fig. 4](#) includes the relationship between an airport's workload units (WLUs) and the total added value it generates. It demonstrates the significance of both airport size and operational focus of Belgian airports in determining demand-side economic impact. As mentioned, Brussels Airport, with the highest WLU count, generates the highest added value, significantly outperforming the other airports. Liège Airport, with its focus on cargo operations, also contributes substantial added value, although less than Brussels Airport, reflecting its smaller size. Brussels South Charleroi Airport, while having a similar number of WLUs to Liège, generates less added value. The smaller regional airports, Ostend-Bruges and Antwerp, contribute considerably less added value, which aligns with their smaller number of WLUs.

Beyond size, the composition of WLUs appears critical. Liège Airport, an airport primarily dedicated to cargo, demonstrates a substantially higher contribution in terms of added value and FTE compared to Brussels South Charleroi, a low-cost passenger airport, despite both serving a similar volume of WLUs. This disparity may be attributed to the composition of the WLUs; at Liège, 98 % are related to cargo operations, whereas cargo traffic is negligible at Charleroi. Furthermore,

¹² Exploitation subsidies are defined as financial grants provided by public authorities to offset the recurring operating costs of a company.

¹³ We use the direct effects because the delineated impact area of the direct effects is regional, whereas the impact area of the indirect and induced effects is on a national scale ([Toró, 2018](#)).

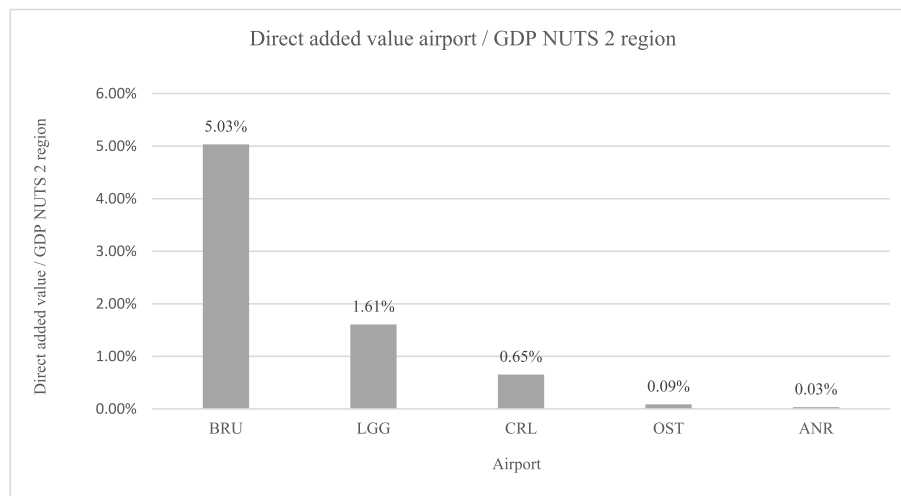


Fig. 3. Direct added value as a percentage of GDP NUTS 2 region in 2019 (own composition).

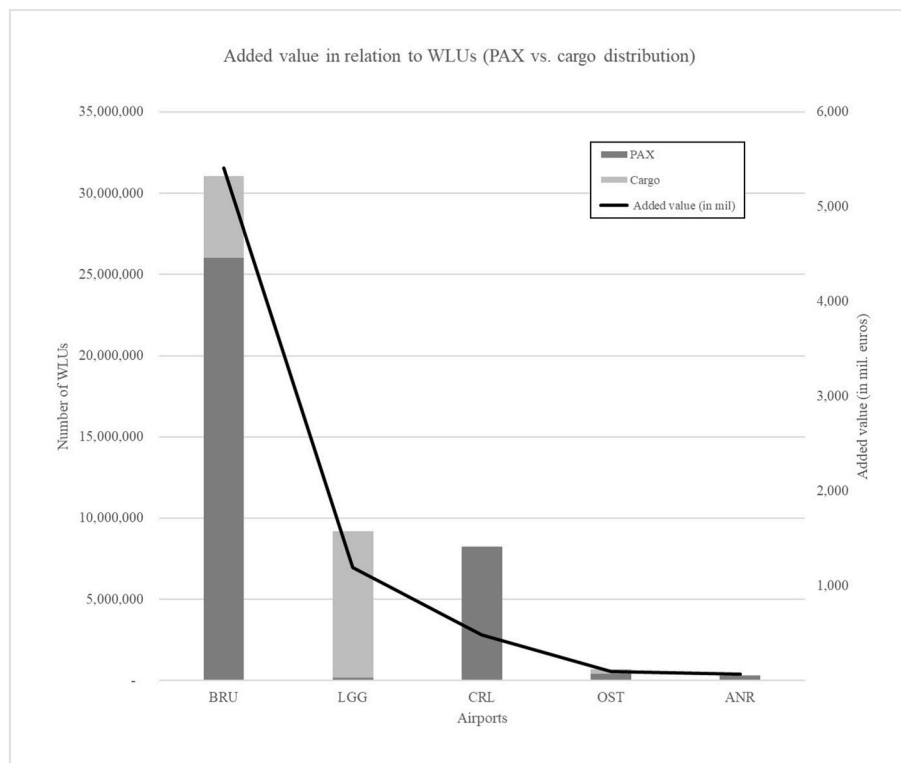


Fig. 4. Total added value in relation to WLUs in 2019 (own composition).

Brussels Airport, which serves both passengers and cargo traffic, generates 27 per cent of its FTE and 23 per cent of its added value solely through cargo activities, despite only 16 per cent of its WLUs being cargo-related.¹⁴ Moreover, a significant proportion of the traffic at Antwerp and Ostend-Bruges Airport comprises general aviation services

¹⁴ To generate this comparison between cargo-related added value and passenger-related added value, the NACE-BEL sector codes were divided into passengers and cargo. As the purpose of this comparison is to reflect on the importance of cargo activities, we opted to merge supporting activities (such as the airport operator and the air traffic control services) and passengers and report the 100 % cargo-related activities separately.

(including private jet services) in addition to regular passenger traffic, which might explain their relatively higher added value despite their low WLU volumes. These observations indicate that, within the Belgian context, not only airport size but also the nature of its operations – whether cargo-focused, low-cost or business passenger – can substantially shape its overall economic contribution to the surrounding region. This is consistent with previous research indicating that differences in air traffic structure can influence an airport's regional economic impact and that there is a positive relationship between airfreight activity and regional development (Allroggen and Malina, 2014; Button and Yuan,

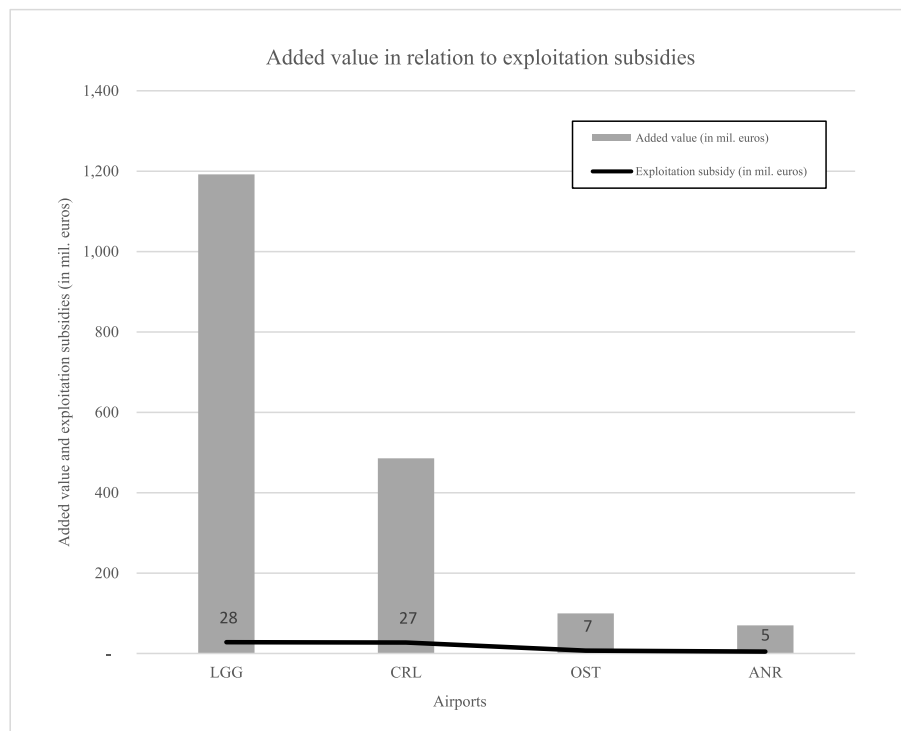


Fig. 5. Total added value in relation to the exploitation subsidies of 2019 (own composition).

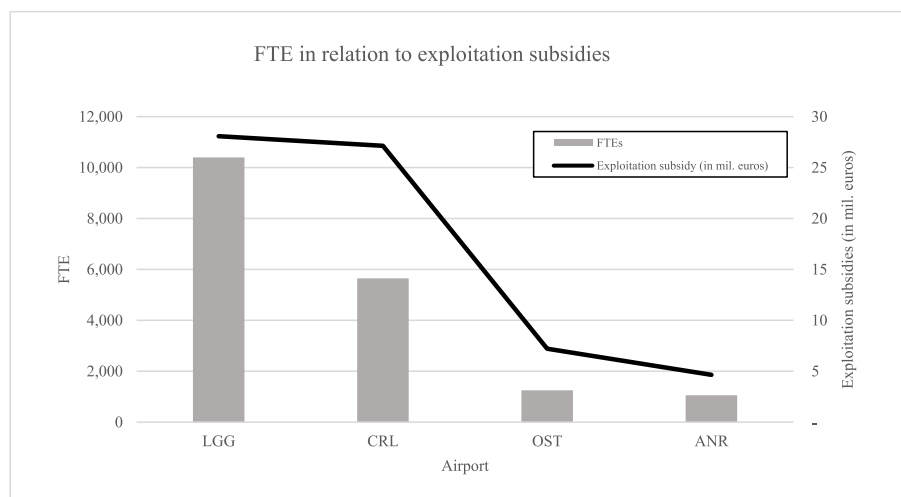


Fig. 6. Total FTE in relation to the exploitation subsidies of 2019 (own composition).

2013).

Finally, our study assesses how effectively exploitation subsidies are translated into demand-side economic impact across Belgian regional airports.¹⁵ Figs. 5 and 6 highlight the relationship between the exploitation subsidies per airport and total added value and FTE, respectively. Liège Airport stands out by converting exploitation subsidies into economic value more effectively than its counterparts, achieving an added value of over 40 million euros per euro of subsidy and generating approximately 370 FTEs per million euros of subsidy. In contrast, Brussels South Charleroi, Ostend-Bruges, and Antwerp airports – primarily passenger- and general aviation-oriented – exhibit lower direct

economic impact per subsidy (both in added value and FTE). More specifically, their respective added value-to-exploitation subsidy ratios are 18, 14 and 15, and their FTE-to-exploitation subsidy (in mil. euros) ratios stand at 210, 170 and 230.

Consequently, the ability to produce higher levels of demand-side economic value relative to exploitation subsidies can vary considerably based on the operational focus of the Belgian airports; therefore, policymakers might consider prioritising support for the cargo-centric airport at Liège. However, Pot and Koster (2022) and Wu and Qi (2021) argue that the justification for state aid to regional airports can extend beyond purely economic metrics – particularly for smaller airports that fulfil important connectivity functions but may not yield equally high economic returns. In some instances, the argument for subsidising these smaller airports is more about maintaining regional infrastructure and services rather than maximising added value or

¹⁵ Brussels Airport is not included in this comparison due to its profitability, making subsidies less relevant to its economic impact.

employment. Nevertheless, Pot and Koster (2022), Mikkala and Tervo (2013) and Baker et al. (2015) also acknowledge that regional heterogeneity exists and that in remote areas, smaller airports may still play a critical role in ensuring accessibility and supporting local economies. Hence, our results indicate that a one-size-fits-all approach to airport subsidies may be suboptimal. Instead, tailoring support based on the Belgian airport's operational focus and economic efficiency could lead to more effective outcomes.

6. Conclusions

This study provides a comparative assessment of the economic impact of five Belgian airports by analysing direct, indirect and induced effects (demand side) in terms of added value and employment using an input-output (IO) framework enhanced by a bottom-up approach and Monte Carlo sensitivity analysis. Three main conclusions can be drawn from this comparative case study analysis:

First, the size of the Belgian airport significantly influences the economic impact from the demand side. Our findings, consistent with Sheard (2017) and Mellander and Holgersson (2012), demonstrate that larger airports – exemplified by Brussels Airport – generate substantially higher direct, indirect, and induced effects and account for a larger share of regional GDP than smaller airports.

Second, our analysis suggests that operational focus may affect economic contributions. For instance, Liège Airport, which is primarily focused on cargo operations, appears to deliver higher economic returns in terms of full-time equivalents and added value compared to Brussels South Charleroi Airport, which predominantly serves low-cost passengers. However, our sample is limited to five Belgian airports, and our findings would benefit from being supported by a larger international subset.

Third, our evaluation of exploitation subsidies indicates significant differences in subsidy efficiency among Belgian regional airports. Liège Airport stands out by converting exploitation subsidies into economic value more effectively than its counterparts. Smaller regional airports may require subsidies primarily to maintain regional infrastructure rather than to drive high levels of demand-side economic impact. Nonetheless, the importance of regional heterogeneity should not be overlooked, as smaller airports can still play a vital role in ensuring accessibility and connectivity (Pot and Koster, 2022; Mikkala and Tervo, 2013; Baker et al., 2015).

In addition to these empirical findings, our study contributes methodologically by refining the traditional IO approach. Specifically, we integrated bottom-up firm-level data via NACE codes into the IO framework – by introducing a new ‘airport’ column – and enhanced the robustness of our estimates through Monte Carlo sensitivity analysis.

Appendix A. Different input-output tables

Because various types of input-output (IO) tables exist, the choice of the table depends on the specific objectives and constraints of the study (Eurostat, 2008; European Union, 2013). First, not all IO tables exclusively capture domestic production; some IO tables reflect total production (domestic and foreign). Such tables require additional assumptions, such as treating domestically and foreign-produced goods as if they are produced under the same technological conditions. Second, IO tables may be constructed either product-by-product or industry-by-industry. According to Eurostat's IO manual (2008), product-by-product tables often provide more homogeneous representations of economic transactions since they trace the flow of products regardless of the industry that produced them. In contrast, industry-by-industry tables capture inter-industry relations, describing how each industry uses different products in the production process (Eurostat, 2008; European Union, 2013). Figure A1 demonstrates the process of transforming supply and use tables into symmetric IO tables according to their specific assumptions.

In this study, we adopt a product-by-product IO table for our airport economic impact assessment. By focusing on products rather than industries, this approach provides a more granular view of how individual goods and services (e.g., those related to airport operations) interact within the production system. Such a level of detail is especially relevant for capturing the specific activities – including those of airlines, ground handling, retail and others – that define an airport's direct and indirect contributions to the economy.

This methodological advancement allows for a more nuanced understanding of how Belgian airport size and operational focus influence economic contributions.

Nevertheless, several limitations must be acknowledged. First, our assessment focuses solely on airports' positive demand-side economic effects, thereby omitting complementary analyses (e.g., environmental impact assessments) and supply-side effects. Moreover, the analysis is based on 2019 data – a peak pre-COVID-19 year – which may lead to an overestimation of impacts. However, since this study is comparative in nature, the relative differences remain informative. Second, the IO impact assessment has inherent limitations, including the assumption that the absence of an airport renders resources redundant and that economic activities within sectors remain constant. Finally, while our model improves upon traditional IO analyses in terms of including bottom-up firm-level data, a direct connection to the IO table via NACE codes and the induced effects by treating consumption demand as endogenous, it does not fully account for potential shifts in income distribution and consumption patterns that could influence the outcomes. Therefore, the results should be interpreted within the contextual understanding.

Future research could expand upon this study by incorporating more airports in countries with other regional characteristics and/or a supply-side perspective. Additionally, longitudinal studies assessing airports' economic impact over multiple years could provide deeper insights into their evolving roles and contributions, particularly in light of changing travel patterns and economic conditions post-2019. Lastly, employing alternative methodologies to assess economic impact could help refine our understanding and address some of the assumptions inherent in this study.

CRedit authorship contribution statement

Jolien Pauwels: Writing – review & editing, Writing – original draft, Investigation. **Sven Buyle:** Writing – review & editing, Validation, Supervision. **Wouter Dewulf:** Writing – review & editing, Validation, Supervision. **Bart Jourquin:** Writing – review & editing, Validation.

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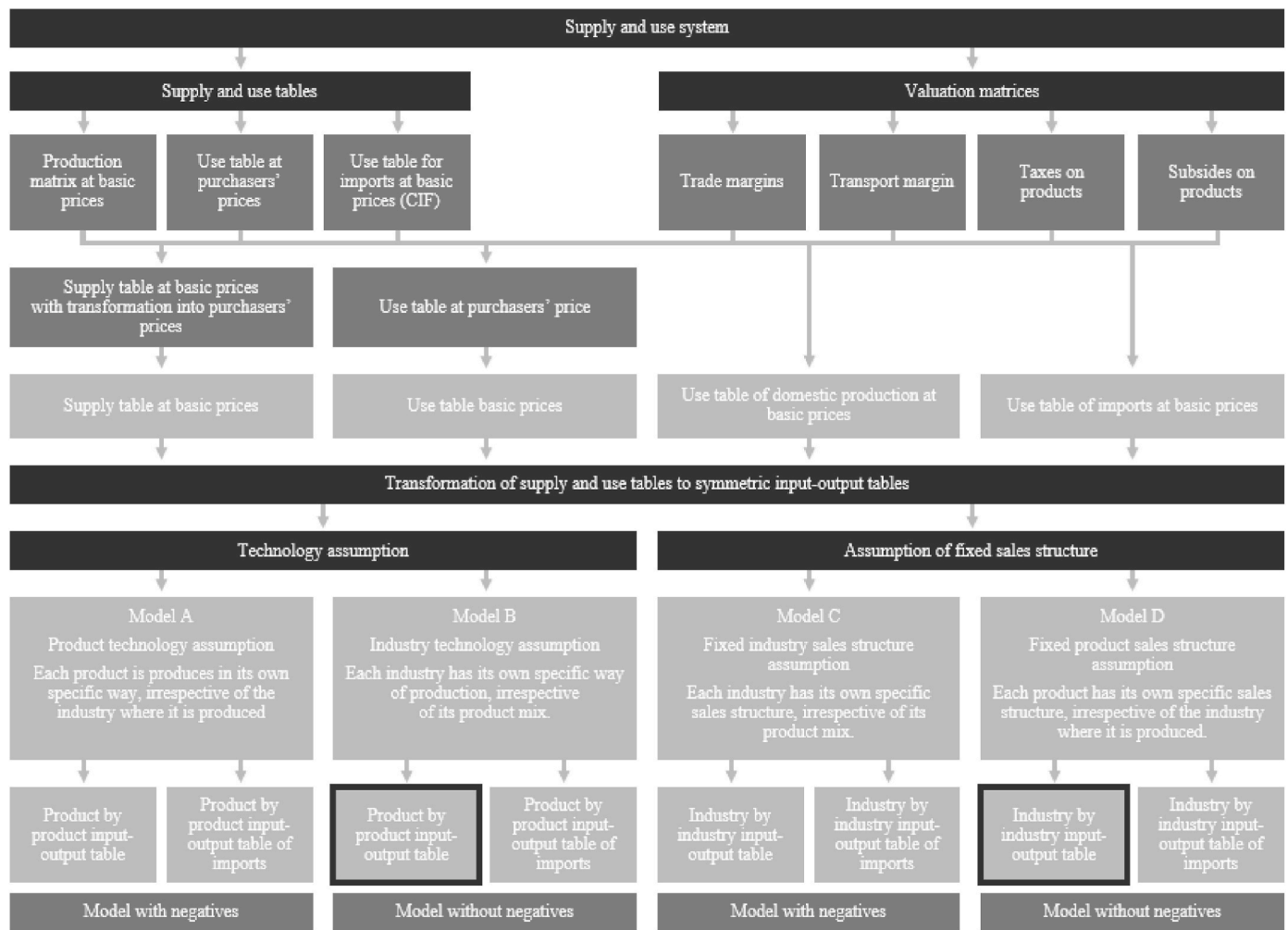


Fig. A1. Framework for constructing different IO tables (Eurostat, 2008).

Appendix B. Direct effects of Brussels Airport (own composition)

FTE 2019 BRU	FTE	%
Air transport cluster	9200	42 %
Air transport	4800	22 %
Travel agencies and tour operators	200	1 %
Airport operator	900	4 %
Airport handling	1700	8 %
Building and repairing of aircraft	800	4 %
Other air transport supporting activities	800	4 %
Other airport-related activities	12,600	58 %
Passenger transport over land	300	2 %
Freight transport over land	400	2 %
Cargo handling and storage	3500	16 %
Courier and post activities	1600	7 %
Security and industrial cleaning	1500	7 %
Trade	500	2 %
Hotels, restaurants and catering	1700	8 %
Other services	1200	6 %
Public authorities	1800	8 %
	21,800	100 %

Within the 95 % confidence interval: [21,000; 22,600].

Added value 2019 BRU	Mil. euros	%
Air transport cluster	1196	52 %
Air transport	440	19 %
Travel agencies and tour operators	7	0 %
Airport operator	426	18 %
Airport handling	106	5 %
Building and repairing of aircraft	68	3 %
Other air transport supporting activities	149	6 %
Other airport-related activities	1107	48 %
Passenger transport over land	16	1 %
Freight transport over land	26	1 %
Cargo handling and storage	277	12 %
Courier and post activities	146	6 %
Security and industrial cleaning	81	4 %
Trade	32	1 %
Hotels, restaurants and catering	82	4 %
Other services	273	12 %
Other industries	11	0 %
Public authorities	163	7 %
	2303	100 %

Within the 95 % confidence interval: [2280 mil. euros; 2350 mil. euros].

Appendix C. Direct effects of Liège Airport (own composition)

FTE 2019 LGG	FTE	%
Air transport cluster	1400	30 %
Air transport	730	16 %
Travel agencies and tour operators	10	0 %
Airport operator	160	3 %
Building and repairing of aircraft	130	3 %
Other air transport supporting activities	400	9 %
Other airport-related activities	3200	70 %
Freight transport over land	30	1 %
Cargo handling and storage	760	16 %
Courier and post activities	1850	40 %
Security and industrial cleaning	220	5 %
Trade	70	2 %
Hotels, restaurants and catering	30	1 %
Other services	20	0 %
Public authorities	210	5 %
	4600	100 %

Within the 95 % confidence interval: [4500; 4800].

Added value 2019 LGG	Mil. euros	%
Air Transport Cluster	190	41 %
Air transport	110	24 %
Airport operator	30	6 %
Building and repairing of aircraft	10	3 %
Other air transport supporting activities	40	8 %
Other airport-related activities	280	59 %
Cargo handling and storage	80	17 %
Courier and post activities	150	32 %
Security and industrial cleaning	10	2 %
Trade	10	2 %
Other services	10	2 %
Public authorities	20	4 %
	470	100 %

Within the 95 % confidence interval: [460 mil. euros; 490 mil. euros].

Appendix D. Direct effects of Brussels South Charleroi Airport (own composition)

FTE 2019 CRL	FTE	%
Air transport cluster	1350	56 %
Air transport	350	15 %
Airport operator	650	27 %
Building and repairing of aircraft	300	12 %
Other air transport supporting activities	50	2 %
Other airport-related activities	1050	44 %
Passenger transport over land	160	7 %
Security and industrial cleaning	270	11 %
Trade	60	3 %
Hotels, restaurants and catering	250	10 %
Other services	30	1 %
Public authorities	280	12 %
	2400	100 %

Within the 95 % confidence interval: [2300; 2500].

Added value 2019 CRL	Mil. euros	%
Air transport cluster	130	64 %
Air transport	40	18 %
Airport operator	50	26 %
Building and repairing of aircraft	30	16 %
Other air transport supporting activities	10	4 %
Other airport-related activities	70	36 %
Passenger transport over land	5	3 %
Security and industrial cleaning	15	8 %
Hotels, restaurants and catering	20	10 %
Other services	5	3 %
Public authorities	25	12 %
	200	100 %

Within the 95 % confidence interval: [200 mil. euros; 210 mil. euros].

Appendix E. Direct effects of Ostend-Bruges Airport (own composition)

FTE 2019 OST	FTE	%
Air transport cluster	310	67 %
Air transport	120	26 %
Airport operator	110	24 %
Airport handling	40	10 %
Other air transport supporting activities	40	10 %
Other airport-related activities	150	33 %
Passenger transport over land	20	4 %
Cargo handling and storage	10	2 %
Trade	20	4 %
Hotels, restaurants and catering	40	9 %
Public authorities	60	13 %
	460	100 %

Within the 95 % confidence interval: [400; 500].

Added value 2019 OST	Mil. euros	%
Air transport cluster	29	77 %
Air transport	16	42 %
Airport operator	5	13 %
Airport handling	2	5 %
Other air transport supporting activities	7	17 %
Other airport-related activities	9	23 %
Passenger transport over land	2	5 %
Hotels, restaurants and catering	2	5 %
Public authorities	5	13 %
	38	100 %

Within the 95 % confidence interval: [30 mil. euros; 40 mil. euros].

Appendix F. Direct effects of Antwerp Airport (own composition)

FTE 2019 ANR	FTE	%
Air transport cluster	260	72 %
Air transport	120	33 %
Airport operator	70	19 %
Airport handling	10	3 %
Other air transport supporting activities	60	17 %
Other airport-related activities	100	28 %
Passenger transport over land	10	3 %
Cargo handling and storage	30	8 %
Other services	30	8 %
Public authorities	30	8 %
	360	100 %

Within the 95 % confidence interval: [300; 400].

Added value 2019 ANR	Mil. euros	%
Air transport cluster	21	72 %
Air transport	9	31 %
Airport operator	3	10 %
Airport handling	1	3 %
Other air transport supporting activities	8	28 %
Other airport-related activities	8	28 %
Cargo handling and storage	2	7 %
Other services	2	7 %
Other industries	1	3 %
Public authorities	3	10 %
	29	100 %

Within the 95 % confidence interval: [20 mil. euros; 40 mil. euros].

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