# THE IMPACT OF LOGISTICS AND INTERMODALITY ON AIRPORT EFFICIENCY

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***Abstract***

The operational performance of an airport is determined by the efficient management of passenger and cargo flows. This paper aims to analyse the impact of various logistics factors on the efficiency of major airports in Europe.

Using Data Envelopment Analysis (DEA), a comparative analysis has been estimated for the 21 largest European airports over the 2009-2014 period. At a second stage, this research analysed the effects that the *Logistics* and *Intermodality* have on airport efficiency.

The impact of logistics on overall airport efficiency is estimated at 0.15% for every 1% increase in Logistic Performance (LPI), *ceteris paribus*. The results show that airports that have a direct link to a High-Speed Rail (HSR) network were, on average, 23 per cent more efficient over the period. Moreover, the higher the percentage of Gates with fingers-bridges, the higher the levels of overall technical efficiency, pure technical efficiency, and scale efficiency.

**Keywords:** airports; efficiency; logistics; Intermodal; Europe; DEA;

## Introduction

As the global economy is becoming more and more connected, so must the transportation, intermodality and the logistics systems. Thus, the transport industry is an increasingly contributing factor to the economy. According to the statistical office of the European Union (Eurostat, 2016), the contributions of transport – in gross value added- to the EU (28 countries) economy is estimated in €664bn (9% of total) employing around 11 million people.

Air transportation is a strategically important sector that makes a vital contribution to the EU's overall economy (EU Commission, 2018). The aviation market was gradually liberalised through three successive packages of measures adopted at EU level. Since 2004 the European airspace is subject to joint management (Eurocontrol 2016). Thus, in 2016, 10.2 million flights flew over European airspace, with an average of 27,844 daily flights which implies a somewhat complex air traffic control management.

The connectivity of an airport is defined as how "central" this airport is on those networks. Main European airports aspire to become leading players in the global trade system. In the Intermodal system, hubs are one of the critical elements that function as an interchanging of passengers and goods between different modes (Van Dam et al. 2007).

The Single European Sky has caused a significant increase in the number of intracommunity domestic routes (874 in 1992, 3,522 in 2015). Globally EU's trade with the rest of the world represents 25% of all global air traffic (LEAHY 2015). According to the Airport Industry Connectivity Report (2017), 5 EU airports rank among the 10 top global hubs in 2016. Furthermore, regarding cargo traffic, Frankfurt continues to be the airport offering the best hub connectivity in the world.

Logistics *is the process of planning, implementing and controlling procedures for efficient and effective transportation and storage of goods, services, and related information from point of origin to point of consumption* (Li, 2014). The expansion of traditional infrastructures such as highways, terminals, and airports was essential for the development of modern logistics (Hesse and Rodrigue, 2004). However, the complexity of international logistics systems has risen in recent years, as a result of the massive developments in information and communication technologies. An example of this is the hub and spoke system. Today, international transportation is organized in complex networks formed by hubs and spokes.

In an increasingly competitive environment, it is therefore essential to find the critical determinants of Air transport efficiency. There is no doubt that logistic and intermodality are essential components of transportation development. Nevertheless, there have been few studies on the impact of this phenomenon on transport efficiency ( Lai et al., 2004, Min & Jong Joo, 2006, Fugate et al., 2010, Coto-Millán et al., 2015). Given these shortcomings, this paper seeks to contribute to the already-rich debate on this topic by evaluating the impact of logistics and intermodality on the efficiency of the large European airports. With this goal in mind, a sample of data from 2009 to 2014 corresponding to 21 major European hubs has been studied.

We seek to contribute to the studies on airport efficiency in two respects. First, we present evidence of a positive relationship between the national logistics system and the efficiency in airports within 14 countries of the European Union. Second, we highlight the importance of intermodality to achieve airport efficiency.

This research applies the double bootstrap method (Simar and Wilson, 2007) to investigate how the external environment affect the efficiency levels. In the first stage, efficiency scores were estimated for European airports (2009-2014 period). Next, the efficiency rated were regressed on some relevant exogenous variables (the logistics system quality and the airport intermodality) not included in the DEA analysis.

The rest of the document is structured as follows: The second section reviews the literature on the most common topics investigated in airports. In the third section, we propose a theoretical model. The fourth section describes the data used in the study and the main results. Finally, section five sets out the main conclusions of the study.

## Literature review

During the past two decades, there has been a great deal of research on airport efficiency. Gillen & Lall (1997) pioneered the use of Data Envelopment Analysis techniques to study efficiency in the airport sector. Using an output-oriented specification, the authors evaluated the efficiency of 21 USA airports over the 1989-1992 period and found that size positively affects efficiency. On the same vein Martín & Román, (2001) used a DEA approach to evaluate the efficiency of 37 Spanish airports. Based on 1997 data, the authors found a group of airports whose performance was clearly poor, and therefore extracted some policy recommendations.

The question of whether size matters regarding efficiency or not has also been addressed by Sarkis (2000). Using data envelopment analysis, the author evaluates the operational capabilities of forty-four U.S. airports. Results suggest that operation managers should assess and benchmark their performances with airports with similar characteristics. Most later research found a positive relationship between size and efficiency (Pels et al., 2001, Tapiador et al., 2008, Pestana et al., 2008, Perelman and Serebrisky, 2010). The exceptions are the work of Abbot et al. (2002), who estimate the productivity of 12 Australian airports. Using data envelopment analysis and a Malmquist total factor productivity index, the authors found no relationship between the size and efficiency of airports.

Based on the available research, there is no consensus on the role of cargo in airport performance. Coto-Millán et al. (2016) found a positive impact of the proportion of cargo traffic in total traffic on the technical and scale efficiency of the Spanish airport infrastructure. The authors argued that handling cargo is capital intensive and therefore more productive than handling passengers are. Oum, Adler, & Yu, (2006) found a weak positive relationship between the proportion of cargo traffic and variable factor productivity (VFP). On the contrary, Tovar & Martín-Cejas, (2009) found an adverse effect on efficiency when the proportion of cargo that circulates through terminals increases.

Most studies have defined airports as a multi-product business. Gillen & Lall (1997) argued that airports offer two different classes of services: terminal services and movements. Martín & Román, (2001) measured output using three variables: number of passengers, air traffic movements, and the number of tonnes of cargo. Further work have provided an overview of the input and output variables used in airport efficiency studies (Pels et al., 2001, Adler & Berechman, 2001, Abrate & Erbetta, 2010, Tovar & Martín-Cejas, 2010, Liebert & Niemeier, 2013). Some typical outputs include: number of passengers, work load units, cargo tonnes, aircraft movements, operational revenues, aeronautical revenues, and non-aeronautical revenues. Common inputs include proxies of labor and capital, number of employees, number of gates, number of check-in desks, surface area, operating costs, Non-operating costs, number of runways, number of baggage collection belts and number of public parking places.

There has been some interest in the efficiency of the large European airports. Using different partial ratios, Doganis et al. (1995) compared the relative performance of a group of European airports with the average performance of 25 airports in the sample. Adler & Berechman (2001) used DEA to analyse the quality and performance of 25 European airports from the airlines' viewpoint. Pels et al. (2001) estimated the efficiency of 34 European airports using a stochastic production frontier model and then compared it with technical efficiency scores derived from a DEA analysis. The author finds a positive relationship between size and efficiency.

There have been other topics of interest in the study of European airports performance. Using a sample of 57 European airports, Malighetti et al. (2009) studied the relationship between airport efficiency and two factors: airport's centrality in the EU network and the intensity of competition from alternative airports in the same catchment area. Authors find a positive correlation between efficiency and centrality in the European system.

Randrianarisoa et al. (2015) analysed the effect of corruption on the efficiency of 47 European airports for the period 2003-2009. Using a combination of multilateral index number methods and robust cluster random effects models, the authors found substantial evidence that corruption impacts negatively on the airport levels of efficiency.

Despite a significant amount of literature on airport efficiency, to the best knowledge of the authors, there have been no studies regarding the extent to which logistics and intermodality affect airport efficiency. This study is, according to our understanding, therefore the first to analyse this effect.

**Methodology and data used**

**DEA Methodology**

Farrell (1957) suggested a deterministic method of measuring the technical efficiency of a firm in an industry by estimating a frontier production function. Based on Farrell's work (Farrell 1957), Charnes, Cooper, & Rhodes, (1978) shape the deterministic non-parametric methodological technique of Data Envelopment Analysis (DEA) to measure the relative performance of a set of similar organisational units (DMUs) which, in this paper, correspond to airports. In the regional airport context, Merkert et al. (2012) have shown that DEA models are appropriate and useful for performance measurement with multiple inputs and outputs.

DEA methodology can be used to derive both technical and scale efficiency, and to determine the nature of returns to scale. Furthermore, it can be used for measuring the relative performance of organisational units where there is a presence of multiple inputs and outputs. A firm is technically inefficient if production occurs within this production set. The inefficiency of a DMU is measured by the distance from the point representing its observed input and output values to the production frontier. A description of the DEA methodology is explained in Mantri (2008).

DEA can be output or input oriented. On the one hand, a model is input-oriented when the measure of efficiency is the distance between observed and minimum possible input for given outputs, and on the other side, it is output-oriented when trying to determine the maximum possible outputs with given levels of inputs.

Thus, for the jth airport out of n airports, the input-oriented technical efficiency under constant return to scale (CRS) is obtained by solving the following linear programming problem:

$$\min_{\theta_j^{CRS}\lambda} \theta_j^{CRS} \; subject\, to: \; \theta X_j \geq X\lambda; \; Y_j \leq Y\lambda; \; \lambda \geq 0 \qquad (1)$$

Where X and Y are the input and output vectors, respectively, $\varphi_j^{CVS} = 1/\theta_j^{CVS}$ is the technical efficiency ($TE$) of airport j under CRS and $\lambda$ is an n x 1 vector of weights. The non-negative weights $\lambda$ measures the contribution of the efficient airports selected to define a point of reference for the inefficient jth airport. In general, $0 \leq \varphi_j^{CRS} \leq 1$, where $\varphi_j^{CRS} = 1$ if the airport is producing on the production frontier and hence, technically efficient. When $\varphi_j^{CRS} < 1$, the airport is technically inefficient. In the case of variable returns to scale, one can find technical efficiency $\varphi_j^{VRS}$ by adding the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ to (1) (Banker et al., 1984).

Because the distances are the technical efficiency scores from CRS-DEA and VRS-DEA models, scale efficiency (*SE*) can be easily obtained by the ratio of technical efficiency scores of CRS-DEA and VRS-DEA specifications (Coelli 2005)

We apply the smoothing homogeneous bootstrap approach with 2000 iterations to overcome the potential problem of biased results in our second-stage regressions (for a more in-depth discussion see (Simar & Wilson, 2000 and Simar & Wilson, 2008).

**Simar-Wilson bootstrapping regression analysis**

In the second stage, the efficiency values estimated in stage one are regressed on some relevant exogenous variables not included in the DEA analysis. According to Liebert & Niemeier (2013) an advantage of second-stage approaches is that explanatory variables are not included in the first-stage of the analysis and, therefore, do not affect the discriminatory power of the first-stage procedures.

Simar and Wilson (2007) describe a data generating process under which two-step methods are consistent. Following the Simar and Wilson (2007) approach, the paper assumes and tests the following regression specification:

$$\varphi_j^{VRS} = a + z_j\delta + \varepsilon_j \tag{2}$$

which can be understood as the first-order approximation of the unknown true relationship. In Eq. (2), $a$ is the constant term, $\varepsilon_j$ is the error term, and $z_j$ is a (row) vector of observation-specific variables for $DMU_j$ that we expect is related to the DMU's efficiency score, $\varphi_j^{VRS}$.

Based on a truncated-regression with a double bootstrapping procedure, the Simar and Wilson (2007) approach assume that the distribution of $\varepsilon_j$ is truncated normal with zero mean, unknown variance, and (left) truncation point determined by this very condition.

Eq. (2) is estimated by maximising the corresponding likelihood function concerning $\delta$ parameters and the variance of the error term. Algorithm#2 from Simar and Wilson (2007) is applied. For the sake of brevity, we refer the reader to Simar and Wilson (2007) for the details of the bootstrap procedure.

The explanatory *z-variables* used in our model have been chosen as a result of an extensive review of airport literature. Three environmental variables for each airport are measured in terms of: (1) the Logistic Performance Index (*Logistic)*[1]; (2) the presence of a High Speed Rail (HSR) station in the airport (*Airport Intermodality*); (3) the rate of Gates with fingers-bridges relative to total Gates (*Jet bridge*).

**Data Analysis**

The study sample includes the major 21 airports in Europe. The database is a balanced panel observed over the 2009 to 2014 period. All sample airports operate as hubs. The airports included are Amsterdam, Barcelona, Berlin TXL, Brussels, Budapest, Copenhagen, Dublin, Dusseldorf, Frankfurt, Hamburg, Lisbon, London LGW, London LHR, Madrid, Munich, Paris CDG, Paris ORY, Roma FCO, Stockholm ARN, Vienna, and Zurich.

The selection of output and input variables for the first stage of our investigation was based on a review of airport efficiency literature. Financial, operational and infrastructure characteristics of the European airports have been used to estimate the airport efficiency.

The number of passengers arriving or departing via commercial flights (*Pax*), the amount of cargo shipped (*Cargo*) and the operating revenue (*OpRev*) have been selected as output variables. Selecting the output variables we took into account that the airport industry is a paradigmatic case of joint production (see Yoshida & Fujimoto 2004).

Input data include the number of full-time equivalent employees directly employed by the airport (*Labour)*, number of gates (*Gates*) and the Intermodal Freight Area (*CargoArea*). Other authors (Coelli et al., 1999, Bazargan & Vasigh, 2003, Sarkis, 2000,…) have previously used these input variables. All input and output variables selected have frequently been used in studies on airport efficiency, as shown in the survey conducted by Liebert & Niemeier, (2013).

To undertake this empirical analysis, the airport traffic and technical information were obtained from the information published by each airport operator. The financial data was gathered from the audited financial statements published annually by each airport in their Annual Reports.

[1] The World Bank's Logistics Performance Index (LPI hereinafter) measures the logistic development of countries. The LPI is based on a worldwide survey of ground operators (global freight forwarders and express carriers), providing feedback on the logistics "friendliness" of countries in which they operate and those with which they trade. Performance is evaluated using a 5-point scale and the overall LPI is aggregated as a weighted average of the six areas of logistics performance: Customs, Infrastructure, International Shipments, Logistics Quality, Tracking and Tracing and Timeliness.

The data source is the AMADEUS database manage by Bureau van Dijk. The financial data has been revised and expanded using the corporate website of each entity. All variables expressed in monetary units have been converted to constant 2009 prices using the CPI (Consumer Price Index) from the World Bank database. Table 1 summarises the primary statistics of the sample used in this analysis.

**Table 1. Summary statistics of inputs and outputs**

| | Variables | Definition and units | Minimum | Maximum | Mean | Standard deviation |
|---|---|---|---|---|---|---|
| Outputs | *Pax* | Number of passengers arriving or departing in thousands | 8,081.07 | 73,405.33 | 30,875.47 | 16,596.02 |
| | *Cargo* | Amount of cargo in thousands of tons | 19.56 | 2,231.35 | 440.35 | 605.54 |
| | *OpRev* | Turnover in millions of Euros | 172.65 | 3,631.71 | 773.72 | 650.54 |
| Inputs | *Labour* | Labour in number of workers | 749.00 | 12,053.00 | 3,098.00 | 2,270.00 |
| | *Gates* | Total number of boarding gates | 17.00 | 224.00 | 110.00 | 61.00 |
| | *CargoArea* | Intermodal Freight Area in square kilometres | 10.00 | 980.00 | 178.81 | 259.23 |

Source: Own elaboration.

Table 2 shows airport ranking by number of passengers and cargo traffic. For example, the cargo traffic of the main hubs such as London LHR, Paris CDG, Frankfurt and Amsterdam airports represents almost 70% of the total airport traffic. Meanwhile, the overall passenger traffic of the four top airports is 36%.

**Table 2. Ranking of airports by passengers number and cargo Traffic (2009-2014).**

| Airports | Passengers (in thousands of) | Passengers (% of total) | Cargo Traffic (Tonnes x 103 ) | Cargo Traffic (% of total) | Logistic (LPI) (Index) |
|---|---|---|---|---|---|
| **LONDON LHR** | 69526.94 | 0.11 | 1436.87 | 0.16 | 3.95 |
| **PARIS CDG** | 60549.59 | 0.09 | 1504.49 | 0.16 | 3.84 |
| **FRANKFURT** | 55917.54 | 0.09 | 2065.05 | 0.22 | 4.09 |
| **AMSTERDAM** | 49476.29 | 0.08 | 1525.29 | 0.16 | 4.06 |
| **MADRID** | 45644.89 | 0.07 | 380.08 | 0.04 | 3.67 |
| **MUNICH** | 36825.02 | 0.06 | 314.25 | 0.03 | 4.09 |
| **ROMA FCO** | 36290.38 | 0.06 | 147.12 | 0.02 | 3.66 |
| **LONDON LGW** | 34178.41 | 0.05 | 95.54 | 0.01 | 3.95 |
| **BARCELONA** | 33097.24 | 0.05 | 97.27 | 0.01 | 3.67 |
| **PARIS ORY** | 26938.31 | 0.04 | 69.22 | 0.01 | 3.84 |
| **ZURICH** | 24029.28 | 0.04 | 309.78 | 0.03 | 3.89 |

| | | | | | |
|---|---|---|---|---|---|
| **COPENHAGUE** | 22720.21 | 0.04 | 164.90 | 0.02 | 3.89 |
| **VIENNA** | 20913.80 | 0.03 | 226.47 | 0.02 | 3.80 |
| **DUSSELDORF** | 20124.70 | 0.03 | 85.06 | 0.01 | 4.09 |
| **DUBLIN** | 19749.84 | 0.03 | 109.43 | 0.01 | 3.76 |
| **STOCKHOLM ARN** | 19143.40 | 0.03 | 82.77 | 0.01 | 3.97 |
| **BRUSSELS** | 18659.32 | 0.03 | 420.51 | 0.05 | 3.98 |
| **BERLIN TXL** | 17397.83 | 0.03 | 29.20 | 0.00 | 4.09 |
| **LISBON** | 15275.92 | 0.02 | 92.69 | 0.01 | 3.45 |
| **HAMBURG** | 13414.99 | 0.02 | 28.67 | 0.00 | 4.09 |
| **BUDAPEST** | 8511.07 | 0.01 | 62.69 | 0.01 | 3.18 |

Source: Own elaboration

## Efficiency analysis

The DEA approach was used to determine the levels of scale efficiency, pure efficiency, and overall technical efficiency[2]. Table 3 reports average scores (2009-2014) for the three types of efficiency, ranking the airports according to overall technical efficiency. The airports reaching the top levels of technical efficiency are Zurich, Vienna, Frankfurt, Berlin TXL, Amsterdam, and London LGW. The results also show that only one airport (Zurich) is on the efficient frontier for the entire period. Furthermore, the average technical efficiency score is relatively high (0.78), indicating that European airports are achieving optimum airport management proportional to their operating scale.

**Table 3. Average scores for the efficiency in airports ranked by overall technical efficiency**

| Airports | Technical efficiency (constant returns) | Pure technical efficiency (variable returns) | Scale efficiency |
|---|---|---|---|
| **ZURICH** | 0.99 | 1.00 | 0.99 |
| **VIENNA** | 0.97 | 0.99 | 0.98 |
| **FRANKFURT** | 0.97 | 0.97 | 1.00 |
| **BERLIN TXL** | 0.97 | 1.00 | 0.97 |
| **AMSTERDAM** | 0.95 | 0.95 | 1.00 |
| **LONDON LGW** | 0.93 | 0.96 | 0.97 |
| **DUSSELDORF** | 0.90 | 0.91 | 0.99 |
| **BRUSSELS** | 0.89 | 0.99 | 0.89 |
| **MUNICH** | 0.86 | 0.97 | 0.89 |
| **PARIS CDG** | 0.86 | 0.93 | 0.92 |
| **ROMA FCO** | 0.84 | 0.96 | 0.88 |
| **LONDON LHR** | 0.83 | 0.90 | 0.92 |

[2] To mount the potential problem of biased results in the analysis' second-stage, we use the smoothing homogeneous approach with 2000 iteration.

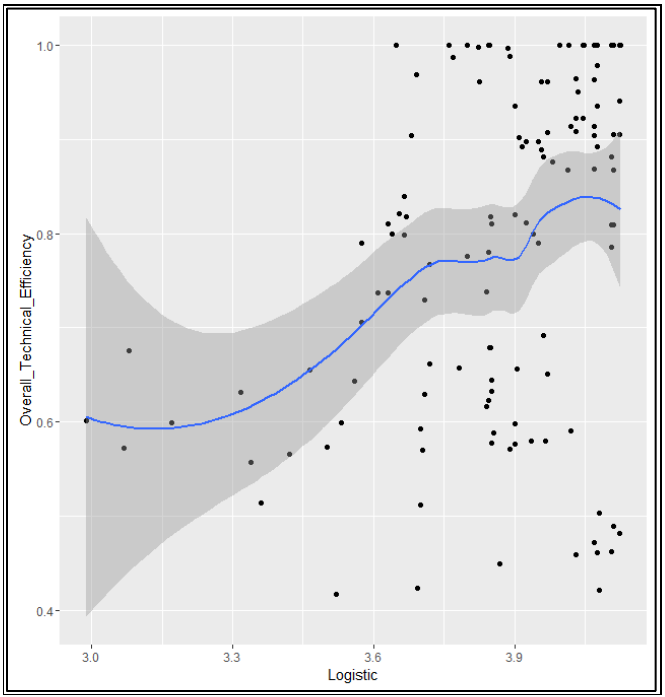
| | | | |
|---|---|---|---|
| **BARCELONA** | 0.73 | 0.80 | 0.92 |
| **MADRID** | 0.70 | 0.77 | 0.91 |
| **PARIS ORLY** | 0.67 | 0.70 | 0.95 |
| **BUDAPEST** | 0.62 | 0.93 | 0.67 |
| **COPENHAGUE** | 0.60 | 0.61 | 0.98 |
| **STOCKHOLM ARN** | 0.58 | 0.59 | 0.98 |
| **LISBON** | 0.58 | 0.73 | 0.79 |
| **DUBLIN** | 0.50 | 0.53 | 0.95 |
| **HAMBURG** | 0.47 | 0.58 | 0.82 |

Source: Own elaboration.

The results show that Dusseldorf, Hamburg, and Budapest operate at the optimal scale. On the contrary, Madrid, Munich, and Roma FCO operate under decreasing returns to scale. Hence, these airports' operators should seek opportunities to increase their scale.

The findings reported in Table 2 and 3 suggest a positive relation between logistic system quality and technical efficiency. To corroborate these results, Figures 1 shows the relationship between the proportion of logistics levels and the overall technical efficiency.

**Figure 1. Relationship between overall technical efficiency and Logistics levels**




Source: Own elaboration.

## Regression analysis

The growing trend of airport competition is challenging airport managers worldwide to provide the best possible services most efficiently. To achieve this, airports need to be aware of their performance compares to the industry's best practices.

Table 4 displays the estimated numbers of regression models for the 21 airports sample providing scores for overall technical efficiency, pure technical efficiency, and scale efficiency as dependent. The truncated regression with a bootstrap model appears to fit the data well, with positive t-statistics, which are statistically significant, in most cases. Parameters with a positive sign reveal a positive relationship between the corresponding explanatory variable and the dependent variable.

**Table 4. Parameter estimates for the Simar-Wilson regression model**

| Explanatory factors | Overall technical efficiency -constant returns to scale- (z-statistic) | Pure technical efficiency -variable returns to scale- (z-statistic) | Scale efficiency - economies of scale- (z-statistic) |
|---|---|---|---|
| **Logistic (LPI)** | 0.15027** | -0,19331 | 0.35362*** |
| | 1,95 | 1,35 | 4,95 |
| **Airport Intermodality** | 0.27312*** | 0.58595** | 0.05337 |
| | 3,02 | 2,42 | 0,71 |
| **jet bridge** | 0.42768*** | 0,55867*** | 0.47360*** |
| | 3,27 | 2,63 | 3,28 |

Notes: ***, **, and *: Below the 1%, 5% and 10% statistical significance thresholds, respectively. Likelihood ratio chi-square (df = 2)

The results were obtained by an input-oriented model, which assumes that the managers cannot influence the traffic level in the short-term future. Consequently, the focus should be given to increase the efficiency levels by enhancing the intermodality and the logistic quality system. This policy could improve the efficiency of the whole system in the European air infrastructure in the long-term future.

The *logistic* variable is significant to explain the overall technical efficiency and the scale efficiency with a positive coefficient. The *logistic* variable provides feedback from logistic operators, supplemented with quantitative data on the performance of the main components of the logistics chain. The positive sign of the *logistic* variable indicates that airports located in countries that have higher LPI levels are expected to have higher overall technical efficiency, and scale efficiency scores compared to the rest of European airports. The economic impact of national logistics (measured using the LPI) on overall airport efficiency is estimated at 0.15% for every 1% increase in LPI, ceteris paribus.

*Airport Intermodality* variable is significant with a positive coefficient, indicating that airports with direct linkage between the airport and a High-Speed Rail network are expected to have higher overall technical efficiency and pure technical efficiency compared to airports without HSR Station.

Our analysis shows that Intermodal Airports (airports linked to a High-Speed Rail network) were, on average, 23 percent more efficient over the period. These HSR links allow passengers to substitute short-haul flights for trains. Furthermore, direct HSR link allows airports to manage their slot capacities better when facing congestion. Direct rail links also increase airport catchment areas for passengers. However, according to the above results, this type of intermodality still suffers from a lack of physical integration and interoperability among the different airports in Europe.

The *jet bridge* variable is significant to explain the overall technical efficiency, the pure technical efficiency and the scale efficiency with a positive coefficient. Therefore, airports with a higher percentage of Gates with fingers-bridges are expected to perform at a much more efficient level.

The above results are meaningful to policymakers. Supply chains are a complex sequence of coordinated activities. The performance of the supply chains depends on such government interventions as infrastructure, logistics services provision, and cross-border trade facilitation.

Redirect public expenses toward more efficient investment in the innovation of the logistic process could be advisable in the Air transport sector.

There is room for a coordination policy regarding off-airport operations. Better integration of vehicle, ship, rail, and air transport passengers and cargo would be desirable to achieve better airport efficiency. Additionally, airports that are linked to railway networks will have a considerable advantage if participating in an extensive intermodal network. If air traffic is congested in some areas in Europe, it will be advantageous for other airports to redirect traffic demand towards them by rail.

The above results are also meaningful to airport managers. The operational performance of an airport is determined by the efficient management of passenger and cargo flows. Optimising the interface between airport and aircraft on all aspects – personal, physical, informational- will reduce aircraft ground time and also will streamline the use of land resources. Investments in logistics innovations should help the management of security checking, boarding & deplaning, personnel processes and terminal processes. Moreover, the development and improvement of hub management strategies should be supported by logistics innovations.

These findings are in line with those of Coto-Millán et al. (2015) who estimated the contribution of logistics in domestic technical efficiency and found that the economic impact of logistics on technical efficiency was estimated at 0.59% for every 1% increase in LPI, ceteris paribus.

## Conclusions

Using Data Envelopment Analysis, this paper estimates the Efficiency of the major 21 European airports over the 2009-2014 period. Additionally, in stage 2, applying Simar-Wilson bootstrapping regression analysis, we investigated whether the intermodality and the quality of the national logistics system has a significant influence on the technical and scale efficiency of European airports.

This paper contributes to the literature by estimating the contribution of logistics to Airport efficiency. Thus, to the best of our knowledge, this study is the first to document the effect of the national logistics system on Airport productivity.

The results highlight the significant impact that the quality of the national logistics system has on Airport efficiency. We show that with a 1% increase in the Logistic Performance Index, the current airport level of overall technical efficiency would improve by 0.15%, ceteris paribus.

Results highlight the significant impact that the intermodality has on Airport efficiency. Thus, airports with a direct linkage between the airport network and the High-Speed Rail network are expected to have higher overall technical efficiency and pure technical efficiency. The results show that airports that have a direct link to a High-Speed Rail (HSR) network were, on average, 23 percent more efficient over the period.

The easy of access to the Aircraft another essential factor to explain the efficiency level. Thus, airports that offer more facilities (higher rate of Gates with fingers-bridges) to optimize the interface between airport and aircraft are linked to higher efficiency levels.

There are substantive variations in the level of efficiency across Airports in our sample. The results show that only one airport (Zurich) is on the efficient frontier for the entire period. The results also show that the airports of Dusseldorf, Hamburg, and Budapest operate at the optimal scale. However, Madrid, Munich and Rome FCO operate under decreasing returns to scale. Hence, these airports' operators should seek the above opportunities to increase the scale.

The above results are meaningful to policymakers. An efficient and integrated multimodal transport system necessarily requires different modes of transportation being seamlessly linked and efficiently combined. Airports do not have control over access to high-speed rail lines. The efficiency of logistics networks depends on government services, investments, policy and strategic planning. Building infrastructure, developing a regulatory regime for transport services, and designing and implementing efficient customs clearance procedures are the areas where governments play an essential role. Effective investment in the innovation of the logistic process could be advisable in the Air transport sector.

The above results are also meaningful to airport managers. The operational performance of an airport is determined by the efficient management of passenger and cargo flows. Global supply chains require modern logistics services including innovations in intermodal transport and the application of information technology in physical distribution and materials management. Investments in logistics innovations should help the management of security checks, boarding & deplaning, personnel processes and terminal processes. Moreover, the development and improvement of hub management strategies should be supported by logistics innovations.

## AUTHOR CONTRIBUTION

X.L.F and J.G. conceived of the presented idea. X.L.F. and J.G. developed the theory and performed the computations. P.C. verified the analytical methods and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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