Public Service Obligations (PSOs) in Air Transport – a Benchmarking approach

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Abstract

In recent years, the use of Public Service Obligations (PSOs) in air transport has substantially increased. In remote regions, where air transport services are not profitable, the application of this program is crucial for the economic and social development of these regions. However, there is a great diversity in the provision of PSO services between different regions in Europe. Thus, in order to improve the contracts established between airlines and public authorities, it is essential to assess the performances of the air carriers in operation. The present work uses Data Envelopment Analysis (DEA) to assess the performances of PSO routes within the European Union and to compare the performances of the operating airlines, both when operating under this subsidy program and when operating their regular flights. First, DEA was applied to the annual data of several European airlines, and then applied to the data of their PSO routes, so that a comparison can be made between the performance obtained on regular flights and flights under the PSO regime. The results indicated which airlines had the best performances and which had the lowest scores, as well as the regions of Europe where the airlines tend to have better and worse performances. The Nordic countries and the United Kingdom were the regions where air carriers obtained the worst results, these being the main cases where the administering authorities may consider revising their contracts, in order to improve their operation.

Keywords: Air Transport, Public Service Obligations, Data Envelopment Analysis, Benchmarking, Efficiency.

1. Introduction

Air transport services are a key factor in the transport system in remote regions, allowing a more efficient use of human and natural resources (Bråthen, 2011). Over the past few decades, in order to favour the opening of new air routes or to increase its current traffic, different strategies and/or subsidy programmes have been adopted by governments around the world (Bråthen and Halpern, 2012). As these strategies have a significant impact on national and regional economies, it becomes essential to evaluate the performance of airlines and airports where it has been applied. This benchmarking exercise can then be used to drive public policies and adapt such strategies to specific contexts.

Within the European Union (EU), in order to promote the economic development of remote regions, Public Service Obligations (PSOs) have started to be implemented. In EU air services, a PSO is a contract under which a government authority proposes to subsidise an airline to perform a service on certain routes. This is necessary for some regions, where scheduled airline services are not profitable, but for the economic and social development of these regions, transportation must be carried out. Currently, there are over 170 PSO routes in operation throughout Europe, distributed by over 40 airlines (European Commission, 2019).

Several factors condition the operation of an airline on a PSO route. Minimum service levels, limits on fare and cost of travel are examples of factors that influence the level of subsidy required to operate a route, and which often constitute barriers to entry for some airlines (Williams and Pagliari, 2004). It is up to regional or national governments to decide upon which routes should be protected by PSO regime and have an associated subsidy, and those that do not. However, within the European Union, government bodies appear to have different priorities and notions (and preferences) regarding that decision. This suggests that there are major inconsistencies in the approach and commitment to the provision of social air services, which leads to a certain degree of diversity in the application of PSOs. Thus, for administering authorities and airlines to be more aware of the decisions taken regarding PSOs in the next years, it is essential to evaluate the performance of the airlines operating PSO routes. This research aims to evaluate and benchmark the performance of airlines when operating PSO routes and identify determinants that can explain higher or lower performances. In addition to the PSO routes, airlines were also evaluated taking into account their operations outside this regime, to understand whether they obtain similar performances when operating or not under this subsidy program.

2. Review of previous literature

This section provides a brief review of the previous literature: i) on airline performance measurement and ii) on PSOs in air transport.

Airline Performance measurement

Merkert and Hensher (2011) found that airline management that aims to reduce cost should focus less on stage length and fleet age and more on the other variables, such as airline size, aircraft size and number of different aircraft families in the fleet. Psaraki and Kalakou (2011) showed that Greek airports that served more aircraft and passenger movements during the period 2004–2007 were more efficient than those that served fewer movements. Kuljanin et al. (2019) concluded that the increase in efficiency in European airlines is mainly due to the adoption of new technologies, with low-cost carriers being the most efficient when compared to other selected airlines.

PSOs in air transport

Merkert and Williams (2013) found that in the early stage of PSO contracts the operators obtain better results than when they are near the end. Moreover, the authors showed that operators with a greater number of PSO contracts tend to be more efficient than those with few or only one PSO contract. A large number of studies focused on particular countries/markets. Calzada and Fageda (2012) analysed the effects of price discounts and PSOs applied to Spanish routes. Overall, this study suggests that price discounts for island residents help ensure the profitability of routes regulated by PSOs. A similar study was, later on, carried out by these authors (Calzada and Fageda, 2013), in this case, applied to the five largest European domestic airline markets (France, Germany, Italy, Spain and UK). The results showed that the use of PSOs reduced the competitive level and had different effects on the number of frequencies, depending on the regulation of each country (open or restricted routes).

Santana (2009) analysed a set of European and US regional air carriers to conclude that PSOs have increased the cost of regional airlines in Europe, but not in the US. Boonekamp *et al.* (2018) showed that PSO regimes stimulate the passenger traffic.

From the reviewed literature, it seems that there are a variety of studies that evaluate the performance of airlines or airports. However, studies on the efficiency of airlines operating PSO routes are very limited, and most of them are focused on economic variables, such as subsidies, price discounts or fares and their relationship with management strategies, providing little information about the relative efficiency of the analysed airlines. This research intends to evaluate the relative efficiency of airlines and their PSO routes, with more focus on traffic indicators and less on economic variables, using as a sample the airlines operating on PSO routes.

3. Methods and model specification

This research aims to benchmark the efficiency of European airlines and their PSO routes. Data Envelopment Analysis (DEA) was the method chosen, as it is the most commonly used tool in performance measurement studies in air transport. It is used to estimate production frontiers and evaluate the relative efficiency of different Decision Making Units (DMUs). Each DMU represents an entity under evaluation.

DEA calculates a production frontier by linear programming, using the DMUs of a sample.

There are several models and approaches for DEA. One of the most popular, *the CCR model*, was introduced by Charnes, Cooper and Rhodes (1978). This model adopts a constant return to scale, a.k.a. *CRS model*, by assuming that all observed DMUs are operating at the optimal scale. According to this model, the relative efficiency of any DMU is defined as the maximum ratio of weighted outputs to weighted inputs. The weights are not pre-assigned, but rather found by solving an optimization model.

According to Banker, Charnes and Cooper (1984), a key limitation of CRS model is its assumption that all observed DMUs are operating at the optimal scale. In the PSO air transport sector, imperfect competition, budget restrictions or other regulatory constraints in PSO contracts often result in firms operating at an inefficient scale (Merkert and Williams, 2013). The *BCC model* (Banker, Charnes and Cooper), a.k.a. *VRS model*, for assuming a variable return to scale, evaluates the efficiency of a DMU, by solving the following linear programming problem (Coelli *et al.*, 2005):

$$\begin{aligned} & min_{\theta,\lambda}\ \theta \\ & s.t. \quad -y_i + Y\lambda \geq 0 \\ & \qquad \theta x_i - X\lambda \geq 0 \\ & \qquad I1\lambda = 1 \\ & \qquad \lambda \geq 0 \end{aligned} \tag{1}$$

Where λ is a I × 1 vector of constants which represents the weights for the inputs and outputs. X and Y are the input and output matrices, and θ is a scalar that measures the distance between the observations x_i and y_i and the frontier. In other words, it represents the efficiency score for the i^{th} DMU. A value of $\theta = 1$ indicates a point on the determined frontier and hence a technically efficient DMU. The convexity constraint $I1\lambda = 1$, where *I*1 is a I×1 vector of ones, ensures that an inefficient DMU is only benchmarked against DMUs of a similar size, i.e. the scale effect is taken into account. For this reason, the efficiency obtained for each DMU through the VRS model, is often referred to as pure technical efficiency (PTE).

4. Application

DEA was applied into two phases: i) applied to annual airline data, and ii) to PSO routes data.

Data

In the first phase, all data was collected from the annual reports of each airline. Table 1 shows the 11 selected airlines, and the respective years from which data were obtained (2013–2019).

Table 1 - Sample of the airlines and years analysed

Airline/Group	13	14	15	16	17	18	19
Croatia Airlines	●	●	●	●	●	●	-
Ryanair	●	●	●	●	●	●	●
Air France – KLM (Group)	●	●	●	●	●	●	●
Lufthansa (Group)	●	●	●	●	●	●	●
Aegean (Group)	●	●	●	●	●	●	-
Alitalia SAI S.p.A	-	-	-	●	●	●	-
SATA Internacional	●	●	●	●	●	●	-
SATA Air Açores	●	●	●	●	●	●	-
Eastern Airways	●	●	●	●	●	●	-
Loganair	●	●	●	●	●	●	-
Flybe	●	●	●	●	●	●	-

Only three airlines/group of airlines had reports for the year 2019 available: Ryanair, Air France–KLM and Lufthansa. Alitalia only had available reports for the previous three years (between 2016 and 2018).

The variables used were: **Full-time equivalents (FTE),** for the employed staff; **Available seat kilometres (ASK),** a measure of the offered capacity of each operator; **Number of flights; Revenue passenger kilometres (RPK),** that shows the number of kilometres travelled by paying passengers; **Fleet size,** representing the number of aircrafts owned by each airline; **Number of passengers; Passenger load factor (PLF),** representing occupancy rate of the aircraft and calculated by dividing RPK by ASK.

Table 2 presents a summary of the main descriptive statistics of the variables used in this first phase. In the second phase, the PSO routes were analysed. The data used are for each route and only the year 2018 was analysed, as it is the one available on the PSO inventory table (European Commission, 2019).

The variables used were: **Minimum number of annual seats required by the PSO,** representing the minimum number of seats that must be made available annually by the airline, as imposed by the PSO; **Actual annual seats offered on the PSO route,** i.e. the number of annual seats offered by the respective airline on the route in question; **Amount of annual compensation,** which represents the monetary value that is given to each airline to operate the route for which it was designated; **PSO passengers in 2018; Frequencies,** which represents the number of weekly flights imposed by the PSO on each route; **Passenger load factor (PLF),** representing the annual occupancy rate on PSO routes.

Table 3 presents a summary of the descriptive statistics of the variables (inputs and outputs) in the analyses carried out on PSO routes.

Airlines Analyses

The first analysis performed on airline data was based on the Merkert and Williams (2013). The authors used two inputs (the FTE and ASK) and two outputs (the number of flights and RPK). In this analysis, the same inputs and outputs were used. These variables allowed the analysis of 6 of the 11 airlines shown in Table 1, between 2013 and 2019, totalling 39 observations. The airlines/groups analysed were Croatia Airlines, Ryanair, Air France–KLM, Lufthansa, Aegean and Flybe. The remainder ones were not considered at this stage as their reports do not provide information on all variables.

The second analysis was carried out using the inputs FTE and Fleet size and the outputs number of flights and total number of passengers. Using these variables, it was possible to include three more airlines in addition to those used in the previous analysis, namely Alitalia, SATA Internacional and SATA Air Açores, totalling 54 observations.

In the third analysis only one input (number of flights) and two outputs (number of passengers and PLF) were used. The number of flights is usually used as an output, but in this case, it was used as an input, since this analysis aimed to determine which airlines made the best use of their flights, based on the number of passengers and PLF reached. The variables used made it possible to analyse all the airlines shown in Table 1, totalling 66 observations.

Table 2 - Descriptive statistics of variables used in Airlines Analyses

	N	Mean	SD	Min.	Max.
Inputs					
FTE	54	30384.67	46536.79	592	137784
ASK (10^6)	51	103140.69	128368.86	237	359567
Fleet	54	228.98	255.55	6	763
Outputs					
RPK (10^6)	51	87188.20	107894.13	155	296511
Passengers (10^3)	66	37390.14	49767.94	357	145190
PLF (%)	66	74.79	10.90	51	96
Flights	66	299149.58	372195.60	5597	1177315

Table 3 - Descriptive statistics of variables used in PSOs Analyses

	N	Mean	SD	Min.	Max.
Inputs					
Minimum number of annual seats required by the PSO	76	121499.38	186847.50	1860	851006
Amount of annual compensation (€) (10^3)	76	1801.98	2244.42	0	14100.88
Required Frequencies	130	13.34	16.46	1	95
Outputs					
Actual annual seats offered on the PSO route	76	182679.68	291716.52	3828	1308413
PSO passengers in 2018	130	92027.68	177563.12	35	948464
PLF	130	0.63	0.24	0.0206	1.0221

There is no systematic approach for the selection of inputs and outputs, as they are largely dependent on data availability (Iyer and Jain, 2019). In the aforementioned analysis, the variables selected as inputs were the resources used by the airlines, while the outputs were what they managed to produce.

PSOs Analyses

In the first analysis performed on PSO routes, two inputs and two outputs were used. Inputs were defined based on what was initially imposed by the PSO, also taking into account what was offered to each airline. Thus, the inputs used were: i) the minimum number of annual seats required by the PSO and ii) the amount of annual compensation. Outputs were what the airline was able to offer and the results it was able to achieve: i) the annual seats offered on the PSO route and ii) the number of passengers in 2018. In this context, the performances of 76 routes were analysed.

The second analysis follows from what was done at the third analysis of *Airlines Analyses*, where the number of flights was used as input, and the number of passengers and PLF were used as outputs, taking into account the annual data of airlines. Thus, in this analysis the same input and output variables were used, but only with data referring to PSO networks in 2018. In this analysis, 130 routes were covered.

Regarding the analyses performed on PSO routes, the first one is more focused on evaluating the efficiency of the contracts established by the administering authorities with the operating airlines, while the second analysis focuses more on evaluating the performance of the airlines on the operated routes.

Table 4 presents a summary of all the analyses carried out, both for the annual data of the airlines and for the PSOs routes, indicating for each one the inputs and outputs used.

5. Results

Airlines Analysis 1

The first analysis presented similar efficiency scores for all airlines. Ryanair, Croatia Airlines and Flybe were those that achieved the best performance, with VRS efficiency scores equal to 1 in most of the years studied. Figure 1 shows a boxplot graph, which represents for each airline: the minimum, first quartile, median (or second quartile), third quartile and maximum values of the pure technical efficiencies obtained in the analysed years. In this way, the boxplot provides a graphical representation of the ordered set of efficiencies into four equal parts, so each part represents 1/4 of the sample. The graph shows that Aegean seems to have lower efficiencies than the others, however, in all cases, the average VRS efficiency scores was greater than 0.9, which means that, as aforementioned, this analysis showed very similar results for all the airlines concerned.

Table 4 - Summary of all the analyses performed

	Airlines Analyses			**PSOs Analyses**	
	Airlines Analysis 1	Airlines Analysis 2	Airlines Analysis 3	PSOs Analysis 1	PSOs Analysis 2
Inputs	- FTE - ASK	- FTE - Fleet Size	- Number of flights	- Minimum number of annual seats required by the PSO - Amount of annual compensation	- Frequencies
Outputs	- Number of flights - RPK	- Number of flights - Number of passengers	- Number of passengers - PLF	- Annual seats offered on the PSO route - Number of PSO passengers	- Number of PSO passengers - PLF

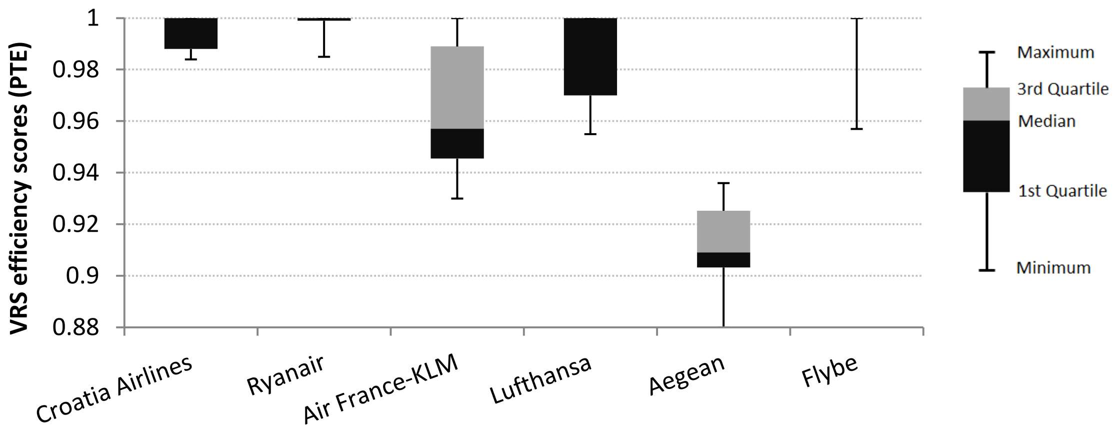

Figure 1 - Boxplot graph - PTE from Airlines Analysis 1

Airlines Analysis 2

In the second analysis, the results showed lower efficiencies for Air France–KLM, Alitalia and Flybe. Other airlines showed VRS efficiency scores very close or, in some cases, equal to 1, as observed in the boxplot of Figure 2 comparing the pure technical efficiencies obtained by each airline.

Airlines Analysis 3

The objective of the third analysis was to identify the airlines that managed to attract the largest number of passengers, based on the number of flights that each carried out. Figure 3 shows the range of the pure technical efficiencies obtained. Ryanair and SATA Internacional were the airlines with the best technical efficiencies. On the other hand, the British airlines Eastern Airways, Loganair and Flybe were the ones with the worst technical efficiencies. Eastern Airways and Loganair were the airlines that registered the lowest occupancy rates (PLF) in the years analysed, resulting in low efficiency scores. Ryanair, on the other hand, was the airline that registered the highest PLFs, and therefore, was one of the airlines with the highest efficiencies. SATA Air Açores showed low efficiency scores, contrary to what happened with SATA Internacional. It means that flights that were carried out by the SATA group outside the Azores archipelago attracted a greater number of passengers than those that were carried out internally. With fewer flights, SATA Internacional reached a higher number of passengers.

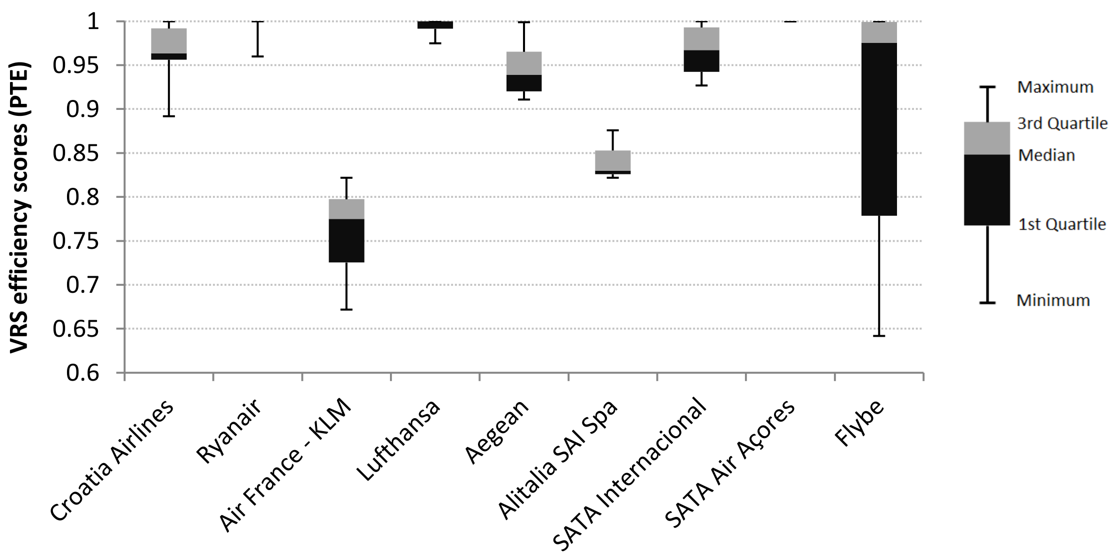

Figure 2 - Boxplot graph - PTE from Airlines Analysis 2

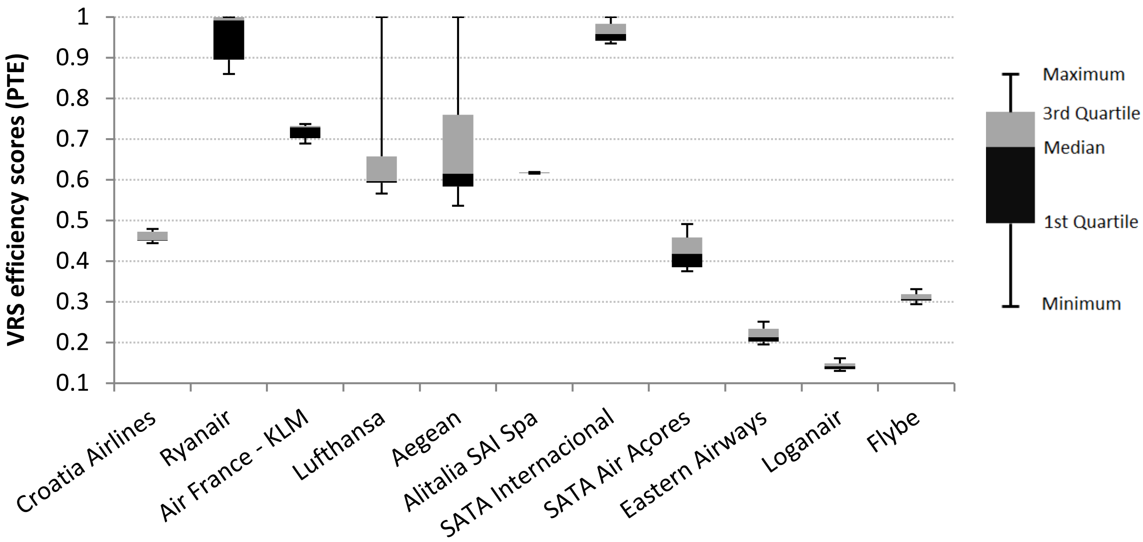

Figure 3 - Boxplot graph - PTE from Airlines Analysis 3

PSOs Analysis 1

In this analysis, 13 routes achieved maximum efficiency (PTE = 1). Table 5 shows the airports that form these routes, as well as the airlines operating and the member states responsible for the administration of that route. These routes are those whose airlines have managed to make better use of the inputs to produce the outputs. It is observed that the airlines most represented, among all routes that showed maximum efficiency, are Croatia Airlines and SATA Air Açores. Figure 4 shows the efficiencies obtained by the PSO routes, distributed by the respective member states. The member states whose routes obtained the worst efficiency scores were Finland, Ireland, Sweden and the UK. To become efficient, or to obtain better performances, these are the countries where the administering authorities should review their contracts, to assess the extent to which it is possible to reduce the annual financial compensation, or the minimum number of seats required. In some cases, on inefficient routes, the compensation offered or the number of seats required is too large for the number of passengers that are transported.

Italy seems to be the country with the most disparate results. The most efficient routes administered by this member state were operated by Alitalia, while the inefficient routes were operated by Danish Air Transport. The routes operated in Italy by the Danish airline were those that obtained the worst efficiency results, among all the routes in this analysis.

Table 5 - PSOs Analysis 1: PSO routes with maximum pure technical efficiency (PTE=1)

Member State	Airport	Airport	Airlines operating
Croatia	Zagreb	Brač	Croatia Airlines
Croatia	Osijek	Dubrovnik	Croatia Airlines
Croatia	Osijek	Split	Croatia Airlines
Cyprus	Larnaca	Brussels	Ryanair
France	Strasbourg	Amsterdam	Air France
Italy	Cagliari	Roma – Fiumicino	Alitalia SAI S.p.A.
Portugal	Ponta Delgada	Flores	SATA Air Açores
Portugal	Ponta Delgada	Pico	SATA Air Açores
Portugal	Ponta Delgada	São Jorge	SATA Air Açores
Portugal	Ponta Delgada	Terceira	SATA Air Açores
Spain	Palma de Mallorca	Ibiza	Air Nostrum, Air Europa
Spain	Gran Canaria	Tenerife South	Binter group
Spain	Gran Canaria	Tenerife North	Binter group, CanaryFly, Air Europa

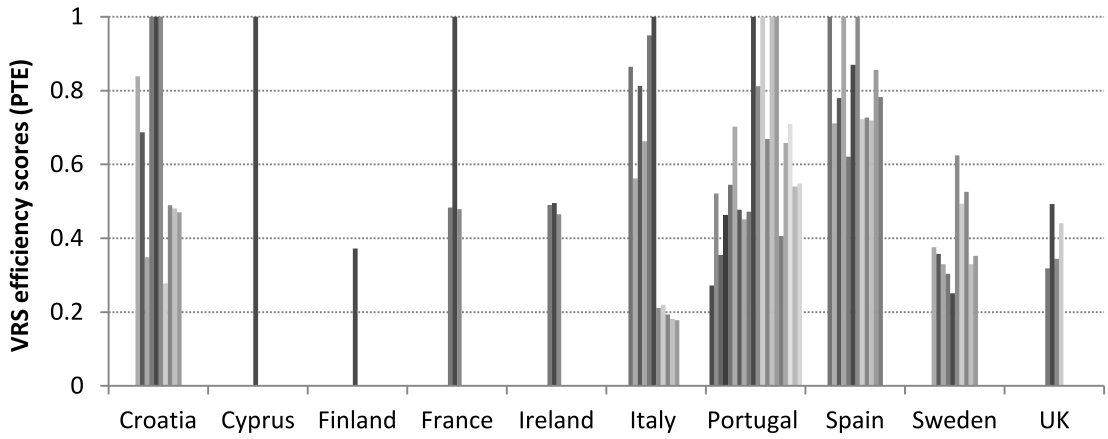

Figure 4 - Member States PTE from PSOs Analysis 1

PSOs Analysis 2

The main objective of the second analysis carried out on the PSO routes was to identify the PSO routes that managed to attract a greater number of passengers based on the number of flights performed on each one. Table 6 shows the eight routes that reached maximum efficiency (PTE = 1). Only one open PSO route achieved maximum efficiency (Bastia – Paris (Orly)). This is somewhat surprising since the open PSO routes are those on which any air carrier can operate as long as it fulfils its requirements, without exclusivity and compensation granted. Thus, these should be the routes that would attract the most passengers, in the sense that they would be the most profitable routes for airlines since they do not require financial compensation to operate. In this analysis, only Croatia Airlines was able to include two routes in the group of the most efficient, routes that had already achieved maximum pure technical efficiency in the previous analysis (PSOs Analysis 1). These were Osijek – Dubrovnik and Osijek – Split. In addition to these routes, others that achieved maximum pure technical efficiencies in both analyses carried out on PSO routes were the route operated by Ryanair, Larnaca – Brussels, and the route operated by Alitalia, Cagliari – Roma – Fiumicino.

Figure 5 shows the efficiencies obtained by the various analysed routes, distributed by the respective member states. The member states whose routes had the worst results were Estonia, Finland, Ireland, Sweden and the UK, with the last four repeating the poor performances obtained in the previous analysis. It leads to the conclusion that the Nordic countries and the region of the UK seem to be the regions where contracts should be reformulated. In this analysis, the routes that obtained the worst efficiency results are those whose management authorities must consider reducing the number of required frequencies, which would lead to a reduction in the associated costs of the operating airlines, and consequently, a reduction in the annual compensation offered.

Table 6 - PSOs Analysis 2: PSO routes with maximum pure technical efficiency (PTE=1)

Member State	Airport	Airport	Airlines operating
Croatia	Osijek	Dubrovnik	Croatia Airlines
Croatia	Osijek	Split	Croatia Airlines
Cyprus	Larnaca	Brussels	Ryanair
France	Cayenne	Saül	CAIRE
France	Bastia	Paris (Orly)	Air Corsica – Air France HOP
Greece	Thessaloniki	Kalamata	Olympic Air
Italy	Cagliari	Roma - Fiumicino	Alitalia SAI S.p.A.
Portugal	Funchal	Ponta Delgada	SATA Internacional

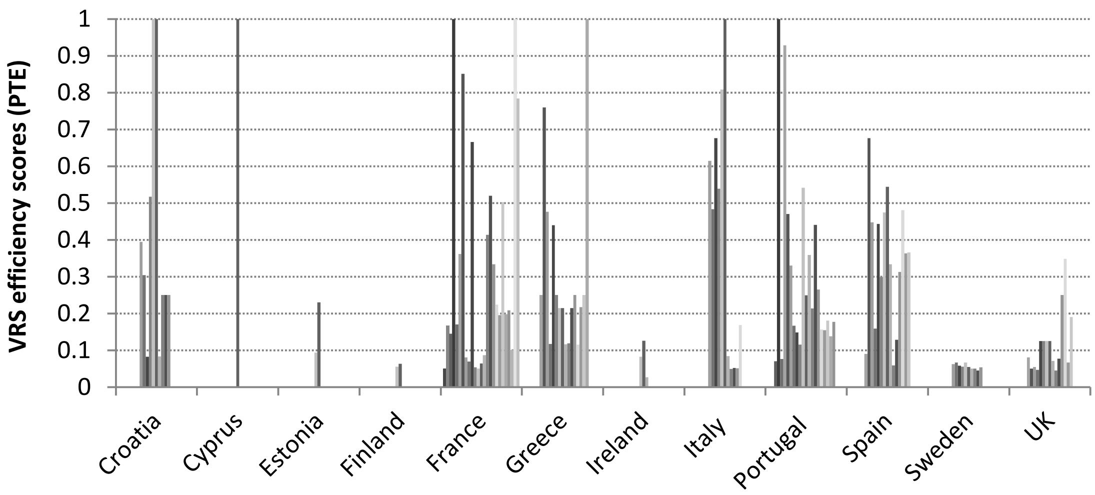

Figure 5 - Member States PTE from PSOs Analysis 2

Airlines Analyses vs. PSOs Analyses

Among all of the airlines and PSO routes used in the analyses, it is important to highlight those that obtained efficiencies equal to 1. The airlines or PSO routes that achieved maximum efficiencies are the DMUs that act as peers for the inefficient ones. The airline that most often acted as a peer was Ryanair, having been a reference in all analyses, both those performed using its annual data, and those performed with data from the PSO routes. Another airline that behaved as a peer in most analyses was Croatia Airlines, having achieved maximum efficiencies in several years on Airlines Analyses 1 and 2, and in three routes on PSOs Analyses. It is also relevant to compare the performance of airlines in Airlines Analysis 3 and PSOs Analysis 2, where the same inputs (number of flights) and the same outputs (number of passengers and PLF) were used. In addition to Ryanair, which obtained good efficiency scores in all analyses, Alitalia and SATA Internacional also achieved good efficiencies both on PSO routes and on their regular flights. SATA Air Açores, on the other hand, returned to present low efficiency scores in the analysis made to its PSO routes, similarly to what had already happened in the analysis made to the regular flights. It means that, both on regular flights and PSO flights, SATA Internacional had a greater capacity to attract passengers than SATA Air Açores. Finally, the poor performance of British airlines – Eastern Airways, Loganair and Flybe – should be highlighted, since they all presented low-efficiency scores, revealing a weak ability to use their inputs to compete with the others in the number of passengers they manage to attract either on their regular flights or on those operated under PSO.

6. Conclusions

This research used DEA to evaluate the performance of European airlines, both when operating their regular flights and when operating PSO routes. First, DEA models were applied to the annual data of each selected airline, during the period 2013–2019. Then, most European PSO routes were analysed to assess their efficiencies and compare their operation with performances obtained outside the PSO context. One of the most relevant findings was the excellent performance obtained by Ryanair in all the analyses carried out, standing out from all the others, both in the analyses carried out on regular flights and those carried out on PSO operations. The results obtained from the analyses carried out on the PSO routes can improve the way the administering authorities deal with their management. Overall, the results indicated that the Nordic countries and the UK region were the ones with the lowest efficiencies. These are the cases in which the contracts between the airlines and the administering authorities may be revised, in order to reformulate the minimum services required or the amount of annual compensation offered.

As a continuation of the work carried out, the approach used can be applied to the years following those that were analysed, being of particular interest an evaluation of performances in 2020, an atypical year that, due to the pandemic situation, has forced air carriers to reduce their operations. It would be interesting to assess which airlines have performed better, and consequently better adapted to adversity. In addition to the PSO regime, other subsidy programs around the world are applied, such as EAS and RASS. An assessment of the performance of airlines operating under these regimes similar to the one here made for the PSO routes and subsequent comparison between them would be interesting to understand whether the differences between the contracts applied in the various subsidy programs or the geographic location affects the efficiencies of the operating airlines.

References

Banker, R. D., Charnes, A. and Cooper, W. W. (1984) ‘Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis’.

Boonekamp, T., Zuidberg, J. and Burghouwt, G. (2018) ‘Determinants of air travel demand: The role of low-cost carriers, ethnic links and aviation-dependent employment’, *Transportation Research Part A: Policy and Practice*. Elsevier, 112, pp. 18–28. doi: 10.1016/j.tra.2018.01.004.

Bråthen, S. (2011) ‘Air Transport Services in Remote Regions’, *International Transport Forum Discussion Papers*. doi: 10.1787/5kg9mq3xcrxx-en.

Bråthen, S. and Halpern, N. (2012) ‘Air transport service provision and management strategies to improve the economic benefits for remote regions’, *Research in Transportation Business and Management*. Elsevier Ltd, 4, pp. 3–12. doi: 10.1016/j.rtbm.2012.06.003.

Calzada, J. and Fageda, X. (2012) ‘Discounts and Public Service Obligations in the Airline Market: Lessons from Spain’, *Review of Industrial Organization*, 40(4), pp. 291–312. doi: 10.1007/s11151-011-9331-7.

Calzada, J. and Fageda, X. (2013) ‘Competition and public service obligations in European aviation markets’, *Transportation Research Part A: Policy and Practice*, 70, pp. 104–116. doi: 10.1016/j.tra.2014.10.009.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978) ‘Measuring the efficiency of decision making units’, *European Journal of Operational Research*, 2(6), pp. 429–444. doi: 10.1016/0377-2217(78)90138-8.

Coelli, T. J. *et al.* (2005) *An Introduction to Efficiency and Productivity Analysis*.

European Commission (2019) ‘List of Public Service Obligations’, *Mobility and Transport*. doi: 10.1017/CBO9781107415324.004.

Iyer, K. C. and Jain, S. (2019) ‘Performance measurement of airports using data envelopment analysis: A review of methods and findings’, *Journal of Air Transport Management*, 81. doi: 10.1016/j.jairtraman.2019.101707.

Kuljanin, J. *et al.* (2019) ‘A comparative efficiency and productivity analysis: Implication to airlines located in Central and South-East Europe’, *Journal of Air Transport Management*. Elsevier Ltd, 78, pp. 152–163. doi: 10.1016/j.jairtraman.2019.01.009.

Merkert, R. and Hensher, D. A. (2011) ‘The impact of strategic management and fleet planning on airline efficiency - a random effects tobit model based on dea efficiency scores’, *Transportation Research Part A: Policy and Practice*. Elsevier Ltd, 45(7), pp. 686–695. doi: 10.1016/j.tra.2011.04.015.

Merkert, R. and Williams, G. (2013) ‘Determinants of European PSO airline efficiency – Evidence from a semi-parametric approach’, *Journal of Air Transport Management*. Elsevier Ltd, 29, pp. 11–16. doi: 10.1016/j.jairtraman.2012.12.002.

Psaraki-Kaloupsidi, V. and Kalakou, S. (2011) ‘Assessment of Efficiency of Greek Airports’, *Journal of Airport Management*, 5(2), pp. 1–17.

Santana, I. (2009) ‘Do Public Service Obligations hamper the cost competitiveness of regional airlines?’, *Journal of Air Transport Management*. Elsevier Ltd, 15(6), pp. 344–349. doi: 10.1016/j.jairtraman.2008.12.001.

Williams, G. and Pagliari, R. (2004) ‘A comparative analysis of the application and use of public serviceobligations in air transport within the EU’, *Transport Policy*, 11(1), pp. 55–66. doi: 10.1016/S0967-070X(03)00040-4.