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Disentangling the European airlines efficiency puzzle: A network data envelopment analysis approach

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ABSTRACT

In recent years the European airline industry has undergone critical restructuring. It has evolved from a highly regulated market predominantly operated by national airlines to a dynamic, liberalized industry where airline firms compete freely on prices, routes, and frequencies. Although several studies have analyzed performance issues for European airlines using a variety of efficiency measurement methods, virtually none of them has considered two-stage alternatives – not only in this particular European context but in the airline industry in general. We extend the aims of previous contributions by considering a network Data Envelopment Analysis (network DEA) approach which comprises two sub-technologies that can share part of the inputs. Results show that, in general, most of the inefficiencies are generated in the first stage of the analysis. However, when considering different types of carriers several differences emerge – most of the low-cost carriers' inefficiencies are confined to the first stage. Results also show a dynamic component, since performance differed across types of airlines during the decade 2000–2010.

1. Introduction

Interest in measuring the relative performance of airline companies has developed considerably since the open sky deregulation experience of the US airlines in the late 1970s, which motivated most of the research to focus upon the consequences of this experience in the US. Some studies compared the efficiency differences between the deregulated US airlines and the highly regulated European airlines, which have often been criticized on the grounds that they are inherently less efficient than US carriers [27]. During the last two decades however, the European airline industry has undergone critical restructuring and has evolved from a highly regulated market predominantly operated by national airlines to a dynamic, liberalized industry where airline firms compete freely on prices, routes, and frequencies. Liberalization reforms in the European airline industry created a new market environment which deserves a closer look to find out more about the recent performance record of the airlines.

In this study, we focus on efficiency and productivity issues in the European airline industry post-liberalization over the period between 2000 and 2010. During our study period, a number of factors led to episodes of turbulence in international air transport, such as the 9/11 attacks in 2001 and the global financial crisis which began in 2008. We examine the impact of those major events on the performance of European airlines.

The industry provides an interesting case study since full-service carriers coexist alongside the low-cost carriers that entered the liberalized market after the introduction of the reforms. Compared to US deregulation, liberalization in European airline industry was slow and gradual. Starting in 1987, successive reform packages were introduced to remove economic barriers, with the ultimate aim of establishing a fully liberalized Single Aviation Market. Drastic measures in pricing and market access, however, came with the third liberalization package in 1993, and full deregulation only came into force during 1997. The reforms created a competitive environment which is expected to foster growth in productivity and efficiency. European airlines in the new environment are expected to improve their efficiencies in order to remain competitive. Our paper examines this aspect to find out if there has been any efficiency and productivity change over time.

Few studies in the literature have been devoted solely to analyzing the efficiency and productivity of European airlines.

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Our paper seeks to fill this gap by concentrating on the recent evolution of the performance of airline firms in Europe and specifically analyzing the impact of recent major events on the industry. The great majority of studies do not capture this as they mostly use data from the 1980s or 1990s.

More specifically, we attempt to contribute to this literature in two additional ways. First, we use a unique data set which facilitates capturing recent developments in the industry with more precision. We follow [27], as well as [49] and [50], to construct our dataset to include all the relevant input and output variables. We use a number of sources, such as the International Civil Aviation Organization (ICAO), Avmark and Platts to construct our comprehensive dataset.

Second, although there are now a remarkable number of studies measuring different aspects of airline efficiency and productivity, there is still scope for more detailed modeling. As we will see in the literature review section, the previous literature dates back as far as the 1970s, when [12] assessed US airline productivity. More recent empirical contributions have dealt explicitly with airline *efficiency* issues, generally considering frontier methods. Although some studies have used the parametric Stochastic Frontier Analysis (SFA), they are outnumbered by Data Envelopment Analysis (DEA) applications.

DEA efficiency studies in the airline industry have generally treated their reference technologies as "black boxes", where inputs are transformed into outputs, and the transformation process is generally not modeled explicitly. However, as [24] note, in some cases researchers might be interested in adding more structure to the model to better suit the application. Modeling these "black boxes" is the objective of network DEA models. To produce outputs (y), inputs (x) are transformed using the production process (P)—i.e., network DEA models aim at disentangling the "black box" or production process (P), which may be quite intricate. Network DEA is also more general than two-stage network structures and, therefore, is more popular due to its ability to accommodate more complex structures. As a consequence, several varieties have been proposed in the literature (see,for instance [23,25]).

In the particular case of the airline industry, very few studies have considered two-stage DEA models; of these several have considered the case of airport – not airline – efficiency and therefore cannot be strictly regarded as related literature (see, for instance [1,56]). One of the few studies which have explicitly modeled airline performance using a network process is [58], who considers fuel, salaries, and other factors in the first stage resources to maintain the fleet size and load factor. The other is [37], who propose a two-dimensional efficiency decomposition (2DED) of profitability for a production system to account for the demand effect observed in productivity analysis. Although these applications deal with related issues, they differ in both the settings and specific models considered. Regarding the time span, Zhu's study covers the years 2007 and 2008 and Lee and Johnson's 2006 to 2008. In contrast, we focus on a longer and more recent period (2000–2010). The selected sample also differs, since while we analyze the European airline industry, [37] look at US airlines, and [58], a mix of the two.

However, and most importantly, [58] uses the centralized model of [39], whereas [37] consider network DEA as a part of their study, but not a central part. Specifically, their study considers two parts, and network DEA is only used in the first one to identify four components of efficiency (capacity design, demand generation, operations, and demand consumption), whereas the second dimension decomposes the efficiency measures, integrating them into a profitability efficiency framework. In addition, the application to the airline industry is basically an illustration of their model, whereas in our case it is a central part and the model is particularly tuned to illustrate these issues.

Specifically, we define a network DEA comprising two sub-technologies that can share a portion of the inputs. This proposal opens up an avenue that could be completed in the near future by the study of the advantages of re-allocation of specific inputs, perhaps in the line of [19] and [20]. Our work is related to the proposals by [34] and [15]. Although similar, our proposal presents significant variations, however: variable returns to scale as an acceptable technological assumption, shared inputs between the sub-technologies, inclusion of intangible inputs related to customer loyalty and satisfaction, and orientation towards the increase of the final output, and not focusing on averaging the specific efficiency of sub-technologies to define the overall efficiency. Indeed, the additive efficiency decomposition could be of interest in another sector and context, but this is definitely not applicable to the transportation service, as the sole generation of transportation services, without considering the level of use by customers, could never be regarded as a desirable situation.

The paper is organized as follows. After this introduction, the modeling framework and estimation methods are detailed in Section 3. Section 4 gives a brief overview of the data and variables used in the analysis while Section 5 discusses our empirical findings. Section 6 concludes. We also include an appendix in which the construction of the data set, for which we followed [49] and [50], is presented in detail.

2. Literature review

There is now a remarkable number of studies devoted to measuring different aspects related to the efficiency and productivity of airlines. Some early (TFP) applications assessed US airline productivity during the 1970s [12]. Others examined TFP for international airlines, comparing US airlines under deregulation with non-US airlines (see [26,13,55]). These early findings, in general, showed an increase in the productive efficiency of US airlines after deregulation, and that US airlines performed better than non-US carriers.

We identify another two broad strands of empirical literature which use frontier methodologies; nonparametric and parametric methods in airline efficiency studies. Among the former, Data Envelopment Analysis, (DEA) [14] has traditionally been the most popular choice, whereas among the latter Stochastic Frontier Analysis (SFA) [2,41] predominates.

While DEA has the great advantage of being able to handle multiple inputs and outputs more easily, it is criticized for its inability to accommodate either measurement errors or other noise in the data. In contrast, SFA is a parametric methodology that is not subject to these limitations. Unfortunately, SFA also has its drawbacks, the most stringent limitation being that it is subject to the parametric "straitjacket"—since both a functional form for the production function, and the distribution of the efficiencies has to be chosen.

The literature, however, has made progress both in the parametric and nonparametric fields—especially the latter (see for instance [52]). Several comparisons of both strands have appeared in the literature (parametric vs. nonparametric methods), among which we can highlight the recent study by [6]. These authors compare the kernel SFA estimator of [22] with the nonparametric bias-corrected DEA estimator of [35], finding conditions under which both estimators would yield similar results. A more recent comparison of DEA and SFA is provided in the bibliometric analysis of [36].

In the particular case of the airline industry, several published studies considered both parametric and nonparametric methods. Some studies based on SFA (or other parametric methods) have focused on the case of US airlines [3], others have compared the