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A quarter century of Data Envelopment Analysis applied to the transport sector: A bibliometric analysis☆

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ABSTRACT

This article is the first to present a comprehensive bibliometric analysis of 461 articles dealing with the application of Data Envelopment Analysis in the transport sector (1989–2016). It also provides a descriptive summary of the 35 most cited articles (scope, models and results) and a commented analysis of the most recent articles dealing with ports and airports. A Multiple Correspondence Analysis is used to characterize the main trends of research in this field. Finally, the article depicts directions which should be investigated by future analyses.

1. Introduction

The performance analysis of firms or business sectors naturally leads to productivity and efficiency measures [1–3]. These productivity measures allow determining the different efficiency gain sources for the firm, and, more precisely, what is the optimal production scale and what are the best management methods and organizations of production networks.

Two methods are mainly used to measure efficiency: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). SFA was first introduced by Aigner et al. [4] and Meeusen and Van den Broeck [5]. It consists in estimating a parametric frontier econometric model. The DEA seminal article was published by Charnes et al. [6] in 1978. DEA is a nonparametric method implemented to measure the productive efficiency of Decision Making Units (DMUs). Its main advantage over SFA is that it does not require any parametric assumption on the production frontier. The envelope of the observed DMUs' input and output levels is calculated by linear programming and can be considered as a best-practice frontier. By measuring the distance between a firm and the efficient frontier, one can then calculate the DMU's efficiency. Today, many different DEA models (two-stage DEA, input/output oriented DEA, etc.) are used in the literature and additional statistical inference methods can strengthen results validity [7].

In Operational Research in Economics and in Management Science, the number of publications using the DEA method remarkably increased since the very first article. To illustrate, Gattoufi et al. [8] identify 490 journals having published at least one paper in the field. Emrouznejad et al. [9] register more than 7000 works and 2500 authors using DEA between 1978 and 2006. They note that about 360 articles per year were published after 2004 and conclude that DEA reached its maturity phase. More recently, Liu et al. [10] count 4936 papers on DEA published between 1978 and 2010 in the ISI Web of Science database.

Until recently, the main economic sectors applying DEA were mostly the banking industry, education, health care and communication [11]. By way of illustration, the transport sector was never mentioned as a potential application field according to Seiford [12]. The sole transport sector publication cited in this 1978–1995 state-of-the-art is the work from Sexton et al. [13] on pupil transportation funding published in 1994. Moreover, the word “transport” never appears in the keywords list established from the most popular publications between 1978 and 2006 by Emrouznejad et al. [9]. Gattoufi et al. [8] are the first to identify the transport sector as a full

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division of the taxonomy of the application areas for the DEA method. However transportation appeared very recently as the fourth DEA application field according to Liu et al. [11] who state that 53% of the referred articles were published during the period 2005–2009.

As for research work on productivity analysis in the transport sector, Oum et al. [14] do not even cite DEA in their 1992 paper while thirteen years later, DEA is considered as a well-established quantitative method to measure efficiency in transport on the same terms as cost functions estimation or total factor productivity analysis [15]. In more recent surveys, DEA in the transport sector appears considered as having the same academic recognition as the traditional econometric methods when applied to transit [16,17], airports [18,19], highways [20] or railways networks [21]. The DEA method not only allows the analysis of economies of scale and economies of scope [22]. It also permits to measure the magnitude of technological change, to guide management decisions such as prices setting, vehicle size choice investment, etc. Moreover, it represents a useful tool for policy makers to set market rules such as deregulation levels or optimal market size. The DEA framework also provides comparisons between firms, networks, geographical areas, or countries.

Adolphson et al. [23] can be considered as the first publication applying DEA to the transport sector. Since then, the yearly number of publications increased at a fast rate. Markovits-Somogyi [24] published a far from comprehensive literature review on the DEA method applied to the transport industry. This state-of-the-art shows that DEA is widely applied for the evaluation of transport activities and provides some methodological conclusions about the use of DEA in this field. However, this survey turns out to be incomplete since it registers only 32% of the articles present in our database over the same period of time.

In this paper, we intend to deliver a first comprehensive list of references of twenty-eight years of research in the field (1989–2016) and a bibliometric analysis. We summarized information on the scope, models and results of the 35 most cited articles according to the transport mode. Moreover, we provide an analysis of the various DEA methods that are implemented for a sample of articles published in 2014 and focused on airports and ports efficiency specifically. We also analyze the inputs/outputs used and their underlying production models. Our goal, here, is to deliver an original contribution which analyzes the transport sectors which are studied and to determine academic research trends and directions which should be investigated by future analyses.

The article is organized as follows. Section two presents our methodology. Section three analyzes, on a univariate basis, the different variables characterizing the publication flow such as the number of publications, the journals, the authors, the geographical areas that are studied, the citations and the analyzed transport modes. In section four, a multiple correspondence analysis (MCA) is presented for a better understanding of the link between the previous variables. Section five summarizes the main results of the in-depth analysis of the ports and airports industry in 2014 and Section six gathers our concluding remarks.

2. Methodology

The following bibliographic analysis is based on articles published in academic refereed journals in English. We considered that the most widely spread and, consequently influential work, is written in English. This is why we excluded papers published in other languages though it may be possible to find significant contributions among them. We first listed all published articles with keywords related to DEA applied to transport economics using Scopus database, Google Scholar and Econlit. We used keywords such as DEA, Data Envelopment Analysis, efficiency, performance, productivity combined with keywords related with transport such as Transport, Transportation, Transport system, Air transport, Airport, Airline, Port, Seaport, Maritime, Bus, Transit, Urban transport, Road, Road haulage, Railroad, Railway. We then conducted a thorough analysis of the references quoted in each article. This provided a first articles database and a list of journals. Each of these journals summaries was then scanned to collect additional articles. In order to gather all significant contributions to the domain under study, we considered some chapters from handbooks and conference proceedings and we did not exclude meta-analyses and surveys. We aimed at obtaining a comprehensive list. However, we may have left aside a few uncited papers. We focused on articles that use the DEA method and its refinements (NDEA, Super Efficiency DEA, bootstrap analysis, etc.) applied to the transportation fields (air, maritime, rail, road, transit and transports policy). The references research was conducted from April 2012 to November 2016.

For each paper, we registered the journal, the authors' names, the number of authors, the authors' institutions, the publication year, the transport "mode" (air, maritime, rail, road, transit or transport policy), the transport mode sub-categories (airlines, airports, ports, railway networks, railway companies, haulage companies, transport demand management (TDM[1]), shipping companies, mass-transit networks), data regional area, data countries, number of intra-database citations.

We first analyzed each variable independently and then conducted a Multiple Correspondence Analysis (MCA) to study the multidimensional links between these variables and determine homogenous groups mainly based on transportation modes.

3. Monovariate analysis

3.1. Number of publications

Overall, we identified 461 articles published between 1989 and 2016.[2] The average number amounts to 16.5 articles per year over the twenty-eight years. The highest number of annual publications is registered in 2016 (54 articles) as shown in Fig. 1.

Following Gattoufi et al. [25] work on DEA general literature, we estimated an exponential trend for the annual number of publications in our field.[3] The resulting curve is shown in Fig. 1. In the transport sector, the average annual growth rate amounts to 18.5%. This result can be compared to that of Gattoufi et al. [25] who estimated an annual growth rate of 25.5% for the general DEA literature between 1981 and 2000.

As Fig. 2 shows, an increase in the number of published articles is observed in the early 2000s and widely accelerates since 2008. Using cumulated data (Fig. 2), three different time periods can be distinguished in terms of publication rhythm. Paralleling the product life cycle proposed by Emrouznejad et al. [9], we propose the following publication sequences:

- The first period (1992–1998) displays an average of 3.4 publications per year, which corresponds to the seminal phase of the method in the transportation analysis field (average annual growth rate: 47% - Coefficient of Variation (CV): 2.98);

[1] TDM or transport policy are not actual transport modes but research fields that could not be classified among the other transport mode categories.

[2] A file listing the 461 references is available at https://www.dropbox.com/s/z9jf5h4tq7cahj8/Appendix%20references%20database.pdf?dl=0.

[3] For statistical analyses conveniences, we mainly focus on the period 1992–2016 during which articles are steadily published.

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