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Efficiency thresholds and cost structure in Senegal airports☆

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ABSTRACT

This paper assesses airport efficiency levels in Senegal under a stochastic environment where the satisficing concept for different performance thresholds is applied. A two-stage satisficing DEA-Support Vector Machine approach is used here to compute the impacts of cost structure on these thresholds. In the first stage, within the ambit of the satisficing DEA model, the probabilities of achieving a minimal performance threshold are computed in a stochastic fashion. In the second stage, Support Vector Machine regression is used to discriminate between high/low efficiency groups within a given performance threshold. This methodology was sufficiently robust to handle small samples. The results reveal that the cost of capital and the cost of labor are the cost structure variables that have the greatest impact on efficiency levels, besides cargo operations.

1. Introduction

This study focuses on the efficiency of Senegal's airports. Research into African airports is a recent and relatively understudied field in efficiency measurement (Wanke et al., 2016a). This may be due to certain factors, such as the poor quality of African data obtained from various economic sectors (Wanke et al., 2015a, 2015b) or reduced sample sizes (Barros and Wanke, 2015). Over the years, however, Data Envelopment Analysis (DEA) approaches have evolved to handle such shortcomings that may jeopardize the discriminatory power of efficiency scores, biasing them towards one.

One possible approach is to consider stochastic input and output sources in DEA by means of chance-constrained programming, developed by Charnes and Cooper (1963) and Kall (1976). In this approach, it is assumed that the efficiency of a DMU is stochastic, and the observation is an occurrence of a random phenomenon. Applications of chance-constrained DEA can be seen in studies that evaluate efficiency in some sectors around the world (Sueyoshi, 2000; Yang and Wen, 2005; Talluri et al., 2006; Li et al., 2007; Agpak and Gökçen, 2007; Yang et al., 2007; Chen, 2002; and Bhattacharya, 2009). To the best of our knowledge, however, no studies of airport efficiency have been performed using chance-constrained DEA.

It is worth mentioning that chance-constrained DEA approaches suffer from a major drawback in that they do not incorporate the concept of "satisficing". The concept of "satisficing" has its origin in the psychology literature, where Simon (1957) used the term as an alternative to the assumption of "optimizing" behavior, which is extensively used in economics. Applications of satisficing DEA models are quite scarce. For a more recent contribution regarding satisficing DEA in the field of efficiency measurement, the reader is referred to the work of Tsolas and Charles (2015). In this research, a novel satisficing DEA model for measuring airport efficiency under a stochastic environment is presented in the case of Senegal. The proposed model is applied to Senegal's airport industry to assess probabilistically the efficiency of five airports during the 1996–2015 period - a twenty-year time span. By applying the bootstrapping technique for the generation of resampled inputs and outputs, it is possible to compute not only the efficiency probability distributions for each airport, but also their satisficing probabilities in terms of a given performance threshold (for example, what is the probability of the efficiency of a given airport being higher than 70%).

Despite the numerous studies focusing on airport efficiency and

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productivity using DEA and other stochastic frontier approaches, a satisficing DEA approach to the airport industry at the country level is still missing, thus suggesting a literature gap. As a matter of fact, the comprehensive literature review on airport efficiency presented in Damacena et al. (2016) and in Wanke et al. (2016a) indicates that most research on airport efficiency is conducted by means of non-parametric models such as DEA. It is only more recently that the stochastic element inherent to input/output measurement has been treated using the bootstrapping method, either in the form of data generating processes for the inputs and the outputs (Merkert and Pearson, 2015) or a bootstrapped truncated regression (Wanke et al., 2016a), but not in the form of chance-constrained programs subject to a probability distribution. Therefore, this research also adds to the current body of literature on airport efficiency, especially the part devoted to African countries, by focusing on another stream of possible approaches for treating the stochastic element in DEA.

As regards the lack of discriminatory power of efficiency scores when samples are small, Wanke et al. (2015a, 2015b, 2016b) showed the importance of using efficiency methods with high discriminatory power towards the efficiency frontier - i.e. lower efficiency scores in contrast to traditional DEA. The authors also advocate the combination of different predictive modeling techniques to explore effectively the impact of contextual variables on efficiency measurement in what is commonly known as two-stage DEA. This paper innovates in this context by adopting Support Vector Machine (SVM) regression in the second stage of analysis. SVM regression allows discrimination between high/low efficiency groups within each performance threshold in light of a given set of contextual variables, thus permitting the identification of the most significant efficiency drivers at each performance level.

The motivations for the present research are given next. Firstly, and justifying the present research, Senegal belongs to the region of Africa that is relatively unexplored in terms of airport efficiency. Secondly, this paper builds upon previous studies related to airport efficiency by evaluating the relative efficiency of Senegal's airports and their major drivers along a given performance threshold. To the best of our knowledge, this is the first time Senegal's airports have been analyzed using a satisficing DEA approach, in contrast to previous studies of this sector (Damacena et al., 2016; Wanke et al., 2016a). Thirdly, the present analysis includes an assessment of the impact of operational scope and different cost structure variables related to labor, capital, and cost-asset ratios on a given performance threshold.

Thus, the purpose of this study is to assess the determinants of efficiency within the context of Senegal's airports, based on cost structure variables commonly found in the literature. In order to achieve this objective, an efficiency analysis is developed using a two-stage approach: satisficing DEA model efficiency distributions are computed first, followed by SVM regression. The paper is structured as follows: after this introduction, the contextual setting is presented, including a description of Senegal's airports. The literature survey is then presented, followed by the methodology section, in which the two-stage satisficing DEA/SVM regression is further discussed. Section 5 presents the data, followed by a discussion of the results and the conclusion in Section 6.

2. Contextual setting

Senegal, located on the West African coast near the Gulf of Guinea, is a former French colony that became independent in 1960. Since then the country began its development. Airports are part of development infrastructure. The country has around 20 airports, but in this paper we focus on the country's 5 main airports: the capital, Dakar's, airport, followed by regional airports in main cities such as San Louis, Tambacounda, Ziguinchor, and Cap Skiring. All these airports have regular traffic leveraged on Senegal's development and population (15 million people in 2015). French is the common language and public administration follows the French tradition with an airport regulatory agency. The importance of airports in the country is due to the country geographical characteristics, with much of the northern part of Senegal's coast covered by dunes from Cap Vert to Saint-Louis, but with low rainfall as it is a desert area, and the southern part of Senegal composed of muddy estuaries with heavy rainfall. In the hinterland a sandy plain extends north to the floodplain of the Senegal River. Therefore, air travel is the most efficient mode of transportation. Table 1 presents some characteristics of Senegal's airports.

As can be seen in Table 1, the capital's airport is the most important in terms of all attributes, followed by Ziguinchor airport. The other airports do not have cargo operations and San Louis airport is the smallest in terms of traffic. Senegal's airports are a main asset of the country's infrastructure and an instrument of the country's development.

3. Literature review and research motivations

A recent review of airport efficiency papers, depicting the country of origin, the models applied and the variables used can be found in Damacena et al. (2016) and Wanke et al. (2016a). The usual sample size ranges from 11 to 67 airports while most studies relied on a single year or up to three or four-year data panels at the country level. Airport performance is usually analyzed in terms of efficiency or productivity. DEA models are used in productivity and efficiency studies (Gillen and Lall, 1997; Adler and Berechman, 2001; Barros and Dieke, 2007; Barros et al., 2011), while SFA – Stochastic Frontier Analysis – models are usually adopted for overall productivity and efficiency performance assessment (Barros and Sampaio, 2004; Barros, 2008, 2009; Diana, 2010). Although European and US airports are frequently analyzed, African ones are rarely assessed (Barros and Marques, 2010; Barros, 2014; Damacena et al., 2016; Wanke et al., 2016a).

A bibliometric analysis on the inputs and outputs used in the 27 different airport efficiency studies presented in Damacena et al. (2016) and Wanke et al. (2016a) reveals the most common ones. Specifically with respect to the inputs used, there were 95 nominations. Among them, the most frequent ones were (i) employees

Table 1
Characteristics of Senegal's airports in 2015.

Airports	Runway length (ft)	Passengers	Cargo	Aircraft Movements	Personnel Employed
Dakar	11 450	2 234 331	29 830	42 290	263
San Louis	6 372	3 202	0	811	11
Tambacounda	6 562	1 102	0	218	7
Ziguinchor	4 413	42 538	500	2 492	105
Cap Skiring	4 757	28 000	0	1 292	53