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Assessing productive efficiency in Nigerian airports using Fuzzy-DEA

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ABSTRACT

Performance analysis has become a vital technique for managing airport practices. However, most DEA models applied to airports assume that inputs and outputs are known with absolute precision. Here, we use Fuzzy-DEA models to capture vagueness in input and output measurements obtained from Nigerian airports. These results are subsequently treated by bootstrapped truncated regressions to control the random effects inherent to any sample. Results indicate that the joint use of bootstrapped regressions and FDEA models leads to more robust results, in the sense that fewer significant contextual variables are identified as efficiency drivers. When controlling for fuzziness and randomness, capacity cost was found to be the only significant variable, in addition to a learning component represented by trend. Policy design for Nigerian airports should focus simultaneously on third-party capacity management – such as privatization - while fostering continuous improvement practices to sustain the learning curve.

1. Introduction

Airports performance is usually analyzed in terms of efficiency or productivity. DEA – Data Envelopment Analysis – models are used in productivity and efficiency studies (Gillen and Lall, 1997; Gillen and Lall, 2001; 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, 2008a; Barros, 2009; Diana, 2010). Although European and US airports are frequently analyzed, those in Africa are rarely assessed (Barros and Marques, 2010; Barros, 2014). This paper intends to mitigate this literature gap by analyzing the efficiency of Nigerian airports using a Fuzzy DEA model.

Global investment expansion in the African countries has led Nigeria, the largest in population, to work towards the development of its transport infrastructure, more especially the aviation industry to accommodate its traffic at the airports, which comes from all over the world. The development includes both international and domestic airports in the entire country. Nigeria is aiming to be a hub in terms of economic activity, and air transport business for the West African region, as well as Africa as a whole. Due to this fact, the Nigerian government and their transport professionals have recently become very interested in assessing, and evaluating the overall performance, productivity and efficiency of the aviation industry in the country. The role of the air transportation industry in Nigeria is highly significant as it does not have any other competitor in terms of speed and safety, in the shipment of passengers and cargo across countries and within Nigeria, thereby making passenger and freight transportation very sustainable. Therefore, the airport/aviation industry stands as an important aspect of transport infrastructure which is highly needed for the country's social and economic development (Nwaogbe Obioma et al., 2015).

This paper innovates not only by focusing on Nigerian airports, but also by adopting a Fuzzy DEA (FDEA) model. We explain in detail below the motivations for this research project. The first reason is related to the evaluation of the relative efficiency of Nigerian airports using FDEA and adopting the popular α-level approach. To the best of our knowledge, this is the first time FDEA is applied to assess efficiency in the airport industry (Lampe and Hilgers, 2015). Despite the existence of different types of fuzzy approaches for handling vagueness and uncertainty within the ambit of DEA models – see Emrouznejad and Tavana (2014) for a comprehensive literature review on this subject – the α-level approach was chosen here not only because of its popularity among researchers, but also because with this approach an FDEA model is solved by parametric programming using α-levels. Solving this model at a given level of α produces interval efficiency for the Decision Making Unit (DMU) under assessment (Zerafat Angiz et al., 2010). Although these intervals, when taken in a certain number, can be used to infer the respective fuzzy

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efficiency, in this paper we are interested in using crisp values at their lower and upper bounds to assess efficiency drivers in Nigerian airports in the second stage.

The second motivation refers to expanding the literature by using conditional bootstrapped truncated regression to assess the role of major contextual variables in achieving higher levels of efficiency, considering the impact of three different FDEA models based on the α-level approach as fixed factors. In order to achieve this objective, bootstrapped truncated regressions are reformulated within the context of a two-stage approach, considering different levels of α. The third goal concerns the coverage of a significant time span of a representative sample of Nigerian airports – 2003 to 2013 – so that uncertainty in its different forms can be assessed. As a matter of fact, the outputs and inputs of airports present different forms of uncertainty within their relationships. For example, the total number of movements at an airport is an output embedded in fuzziness because of the ex-ante uncertainty associated with decisions related to the network design and the establishment of a hub or international operations. On the other hand, the number of passengers, which is not constant, changes randomly as a consequence of market demands or other economic conditions. To evaluate Nigerian airports efficiency more realistically and accurately, this study employs the fuzzy DEA model with data specified in bounded forms to measure airport efficiency.

Hence, this study proposes a predictive model for airport efficiency in Nigeria based on the operational criteria commonly found in the literature also considering uncertainty in the collection of input and output data. The remainder of the paper is organized as follows: Section 2 presents the contextual setting. Section 3 covers the literature review. Section 4 contains the data and the model. The empirical results are presented and discussed in terms of policy implications in Section 5, while the conclusions are outlined in Section 6.

Table 1
Characteristics of the Nigerian Airports Analyzed in 2013. Source: FAAN

Airport	Number of Movements (000/year)	Terminal Capacity (Pax)	Passengers (000/year)	Headcount
ABJ DOM	424	252	4865	712
ABJ INT'L	1759	320	349,244	823
AKURE	6120	40	281,556	64
BENIN	20	250	708	84
CAL DOM	6600	108	384,921	135
CAL INT'L	2567	100	25,039	103
ENUGU	2955	300	41,643	132
IBADAN	29	250	1513	77
ILO DOM	1647	202	71,991	64
ILO INT'L	5600	200	185,293	98
JOS	36	250	146,842	107
KAD DOM	5038	285	234,796	95
KAD INT'L	1821	250	146,842	135
KAN DOM	336	600	1995	411
KAN INT'L	1759	640	103,631	469
MKD	234	63	15,631	38
MAID DOM	71,922	200	3,864,858	148
MAID INT'L	24,927	50	3,361,107	115
MMA DOM	20,313	615	1,198,668	1103
MMA INT'L	800	3675	13,148	1224
PHC DOM	1763	518	62,429	317
PHC INTL	122	700	40,980	264
SOK DOM	1975	194	99,342	48
SOK INT	62	250	10,600	69
YOLA DOM	670	108	11,731	110
YOLA INT'L	788	120	9522	112
MINNA	6028	1000	476,063	89
KAT	11,614	120	34,333	105
OWERRI	55,950	800	3,529,162	116
OSUBI	7406	65	1,258,601	18
Mean	8042	417	532,235	246
Median	1792	250	85,666.5	111
Std. Dev.	16,397	661.8	1,082,082	313.8

2. Contextual setting

Nigeria is a West African country and was formerly a British colony that attained self-government in 1960. In 1967 it adopted a subdivision into a twelve-state structure. In 1976 the number of regions increased to nineteen states, rising to twenty-one in 1987, thirty in 1991, and thirty six from 1996 onwards. Since independence, the Nigerian airport industry has played a major role through spurring economic growth, and employment opportunities, with higher tax revenues. Ultimately the airport industry acts as the landlord for the airlines that operate the transport services (Nwaogbe Obioma et al., 2013).

During colonial times, however, there were only three airports: Lagos, Kano and Maiduguri. Nigeria currently has twenty-one airports, five of which are international: the Murtala Muhammed Airport in Lagos, the seat of government until 1991; Aminu Kano Airport in Kano, a commercial hub city; Kaduna, Port Harcourt, and Abuja. The first two cities have a high volume of commercial activities, while Abuja is the new federal capital.

Today, airport facilities in Nigeria are old or poorly maintained, with an aging workforce and substandard levels of operational efficiency and safety (Ayodele, 2009). In 2006 the government promulgated the Civil Aviation Act (CAA) in order to overcome these organizational problems. The airports are managed by the Federal Airports Authority of Nigeria (FAAN), an entity established in 1995. In 1999 another restructuring project ensured conformity with the International Civil Aviation Organization (ICAO), enabling the separation of regulatory bodies from service providers. This led to the creation of a fully autonomous Nigerian Civil Aviation Authority (NCAA) in 1999 (Balogun, 2008). Table 1 presents some characteristics of the Nigerian airports.

Many studies have been conducted on Nigerian air transportation, airport capacity utilization, and airport efficiency in order to make suggestions on how to increase airport and aviation performance (Shadare, 2009). But much still remains to be done in terms of airport productivity, competitiveness, quality of service, and other operational efficiency-related aspects to enable airport operators/management, airlines and government to benchmark their airport operational activities. Throughout this process, the Nigerian government is willing to go a long way in developing its airport infrastructure and human resources in order to achieve their objective of becoming the African aviation hub by the year 2020. This study aims to help in achieving these objectives while examining the relationship between major inputs (runway dimension, terminal capacity, and number of employees) and outputs (passenger throughput and aircraft movement) by means of novel FDEA models. It is worth mentioning that, in recent years, Nigerian airports have faced fierce competition from South African and Kenyan airports especially in the international market with respect to the determination of hub operations and network design (http://www.thisdaylive.com/articles/nigerian-airports-to-improve-ranking-in-africa-by-end-of-2015/201661/).

3. Literature review

With regard to the airport industry, since most Decision Making Units (DMUs) are considered multi-input and multi-output, varied and sophisticated methods to evaluate efficiency have been tested and used in recent years (Diana, 2010). Basically, these methods can be divided into two major groups, according to Bogetoft and Otto (2010). One group encompasses the parametric models, characterized by prior definition except for a finite set of unknown parameters that are estimated from data. An example is the technique known as Stochastic Frontier Analysis (SFA), which is directly linked to the econometric