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PERFORMANCE, HETEROGENEITY AND MANAGERIAL EFFICIENCY OF AFRICAN AIRPORTS: THE NIGERIAN CASE

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Abstract / Resumo

This paper analyzes unobserved managerial ability as factors affecting the performance of a representative sample of Nigerian airports by means of frontier models. The Alvarez, Arias and Greene (2004) frontier model is used. These airports are ranked according to their technical efficiency during the period 2003-2010 and homogenous and heterogeneous variables are disentangled in the cost function, which leads us to advise the implementation of common policies as well as policies by segments. Economic implications arising from the study are also considered.

Keywords Nigeria; airports; stochastic frontier models and unobserved managerial ability

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The main fields of investigation are the development economics, international economy, sociology of development, African history and the social issues related to the development. From a geographical point of view the sub-Saharan Africa; Latin America; East, South and Southeast Asia as well as the systemic transition process of the Eastern European countries constitute our objects of study.

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1. INTRODUCTION

The analysis of airport efficiency can yield significant insights into the competitiveness of airports and their potential for increasing productivity and improving resource use, Biesebroeck (2007). The research on airports has adopted DEA models (Sarkis, 2000; Sarkis and Tallury, 2004) or homogenous production frontier models (Pels *et al.*, 2001, 2003). The present paper innovates in this context, by analyzing a sample of Nigerian airports with the Alvarez *et al.* (2004) model and the cost frontier model. Therefore, this paper innovates in the airports context by going beyond DEA models and homogenous production frontier models adopting the Alvarez, Arias and Greene (2004) frontier model which enables to measure managerial effects on the frontier cost framework.

The motivations for the present research are the following. First, despite intense research on airports efficiency, no paper is found on Nigerian airports justifying the present research. Second, whilst some research on remote Nigerian airports has been published (Williams and Bräthen, 2010), the focus on African airports is an innovative approach to the analysis of airport efficiency, since there are rare papers published papers on this issue, Barros (2011). A major reason for this under research context is that ATR-Air Transport Research Society, Airport Benchmark Report published yearly does not present data on African airports. Third, benchmarking is a way for airports to manage their relative performance, and therefore a major issue of competitiveness management (Hooper and Hensher, 1997). Fourth, managerial practices vary from airport to airport, based on local traditions and the resource specificity of the airport. As there are different strategic options to be found in the different units of an industry, because of mobility impediments, not all options are available to each airport, causing a spread in the efficiency scores of this industry. The resource-based theory (Barney, 1991; Rumelt, 1991; Wernerfelt, 1984) accounts for different efficiency scores in terms of heterogeneity of resources and capabilities on which airports base their strategies. These may not be perfectly mobile across the industry, resulting in a competitive advantage for the best-performing airports. Finally, unobserved heterogeneity has been a subject of concern and analysis in many recent works such as Chesher (1984) and Chesher and Santos Silva (2002). To neglect this is likely to lead to inconsistent parameter estimates or, more importantly, inconsistent fitted parameters. From an econometric perspective, there are two types of heterogeneity: that which is related to observed variables of airports, which is described as observed heterogeneity, and that which cannot be related to the observed variables, which is known as unobserved heterogeneity. The former is captured by entering the relevant variable into the model, while the latter is captured by entering random parameters into the model. Thus, the aim of this research is twofold: first, to analyze technical efficiency of Nigerian airports and take into account the nature of the unobserved heterogeneity in the airports analyzed; second, to analyze the unobserved managerial ability in the cost frontier model and their relationship with the estimated technical efficiency scores.

The remainder of the paper is organized as follows. Section 2 presents the contextual setting, followed by a brief literature review. Section 3 describes the theoretical framework, while Section 4 explains the methodology. Section 5 presents the hypotheses. Section 6 introduces the data. Section 7 reveals the results and Section 8 discusses the findings. Finally, policy implications and our conclusions are presented in Section 9.

2. CONTEXTUAL SETTING

Nigeria, a former British colony, attained self government in 1960, maintaining its colonial structure of three regions and one central government. Administrative convenience and political expediency led to further subdivision into twelve-state structure in 1967. However, as a result of the persistent agitations for more states, the number later increased to nineteen states in 1976, twenty-one in 1987, thirty in 1991 and to the current figure of thirty-six states in 1996.

Civil aviation began in the country in 1935 when aerodromes were built in Lagos, Kano, and Maiduguri (Bureau of Public Enterprises, 2003). With the oil boom era of the 1970s the need for more airports became apparent. The major criterion for locating the new airports seems to be the desire of the government to open up corners of the country to access and development. Towards the realization of this goal, government appeared to be pursuing a policy of one airport for each state capital. Thus, as more states were created more airports were built, until cost consideration curtailed the construction of any more airports.

Currently Nigeria has a total of twenty one airports five of which are international while the rest operate domestic routes. Two of the original three aerodromes had in the course of time developed into international airports. One of these was the Murtala Muhammed Airport in Lagos which was, until 1991, the seat of government. The other was Aminu Kano Airport in Kano, which selection for upgrading must have been because Kano is a commercial hub. Similar reasons appear to inform subsequent development of the three additional international airports at Kaduna, Port Harcourt and Abuja. The previous two cities have high volume of commercial activities while Abuja is the new federal capital.

The industry grew with the oil boom period of the 1970s but witnessed decline as the economic downturn set in. Facilities at most of the airports are old and poorly maintained. The industry is also faced with the problem of an aging workforce that has not benefited from a consistent replacement policy. Operational efficiency and safety are also low and the various policies introduced by successive governments to turn around the airports yielded no fruitful results (Ayodele, 2009). To address some of these difficulties government intervened decisively by promulgating the Civil Aviation Act (CAC) in 2006.

The airports are managed by the Federal Airports Authority of Nigeria (FAAN) on behalf of the Federal Government of Nigeria who owns the facilities. FAAN was established in 1995 to carry out the functions of two erstwhile organisations, the Nigerian Airports Authority (NAA) and the Federal Civil Aviation Authority (FCAA). However the need to conform to International Civil Aviation Organisation's (ICAO) requirement led to another restructuring in 1999. Since ICAO stipulates the separation of regulatory bodies from service providers it became imperative for all affiliates to establish a state organisation that will ensure compliance with air navigations. This led to the creation of a fully autonomous Nigerian Civil Aviation Authority (NCAA) in 1999 (Balogun, 2008).

As all the airports are owned by the state, there is very little room for competition. However, the industry is now going through a process of transformation that would increase the levels of competition as government is planning to concession four of the airports (Shadare, 2009). These are the Murtala Muhammed Airport, Lagos, Port Harcourt International Airport, Margaret Ekpo International Airport, Calabar and Aminu Kano International Airport, Kano. Generally, there is a shift in government policy as airports are now regarded more like commercial entities than public utilities and government is now encouraging and promoting public-private partnership in the provision of airport services (Arogunjo, 2008). This used to be the exclusive preserve of FAAN.

Table 1: Characteristics of the Nigerian Airports Analyzed in 2010

Nobs	Airport	Number of Passengers (000)	Number of Aircraft (000)	Terminal capacity (Pax)	Number of Employees
1	ABJ DOM	4865	424	252	712
2	ABJ INT'L	349244	1759	320	823
3	AKURE	281556	6120	40	64
4	BENIN	708	20	250	84
5	CAL DOM	384921	6600	108	135
6	CAL INT'L	25039	2567	100	103
7	ENUGU	41643	2955	300	132
8	IBADAN	1513	29	250	77
9	ILO DOM	71991	1647	202	64
10	ILO INT'L	185293	5600	200	98
11	JOS	146842	36	250	107
12	KAD DOM	234796	5038	285	95
13	KAD INT'L	146842	1821	250	135

14	KAN DOM	1995	336	600	411
15	KAN INT'L	103631	1759	640	469
16	MKD	15631	234	63	38
17	MAID DOM	3864858	71922	200	148
18	MAID INT'L	3361107	24927	50	115
19	MMA DOM	1198668	20313	615	1103
20	MMA INT'L	13148	800	3675	1224
21	PHC DOM	62429	1763	518	317
22	PHC INTL	40980	122	700	264
23	SOK DOM	99342	1975	194	48
24	SOK INT	10600	62	250	69
25	YOLA DOM	11731	670	108	110
26	YOLA INT'L	9522	788	120	112
27	MINNA	476063	6028	1000	89
28	KAT	34333	11614	120	105
29	OWERRI	3529162	55950	800	116
30	OSUBI	1258601	7406	65	18
	Mean	532235	8042	417	246
	Median	85666.5	1792	250	111
	Std. Dev.	1082082	16397	661.8	313.8

Source: FAAN

The Nigerian airports are distributed along the country and comprises international and regional airports.

3. METHODOLOGICAL FRAMEWORK: MANAGEMENT ABILITY

Management ability is a major issue in production or cost decisions. Despite its importance, it has been absent from the production and cost functions, generating the “management bias” (Griliches, 1957). Several studies have appeared in the literature to control for management efforts; they include the adoption of proxies (Dawson and Hubbard, 1985; Mefford, 1986), covariance analysis, which controls for the effect of time-invariant management, by eliminating it from the estimating equation (Mundlak, 1961) and DEA (data envelopment analysis) with a three-stage analysis (Avkiran and Rowlands, 2008). Recently, Alvarez *et al.* (2004) proposed to handle this problem as an unobservable input, which can be recovered from the estimate function under certain

hypothesis about the relationship between managerial ability and conventional inputs. This frontier model is adopted in the present research. Alvarez *et al.* (2004) introduce a fixed input to capture managerial ability, m_i , and one time-varying variable input, x_{it} , to study technical efficiency in production.. Their model is a translog production function with one time-varying variable input, x_{it} , and managerial ability, m_i , which is considered a fixed input. Their translog production function is:

$$\ln y_{it} = \alpha + \beta_x \ln x_{it} + 0.5\beta_{xx} (\ln x_{it})^2 + \beta_m m_i + 0.5\beta_{mm} (m_i)^2 + \beta_{xm} \ln x_{it} m_i + v_{it} \quad (1)$$

where subscripts i and t denote firms and time, respectively, and y_{it} , is the single output. They assume v_{it} is a symmetric random disturbance with zero mean. The model in (1) corresponds to the typical ‘average’ production function.

In order to introduce regulation into the model, first observe that it generates transaction costs, which may reduce output for a given amount of input. On the other hand, government regulation aims to influence firms’ strategies created by a lack of competition, which may have a positive impact on output. Therefore, we model regulation through a non-linear function f , with variable input, x_{it} , and managerial ability, m_i , as its arguments: $f(x_{it}, m_i)$. Given its non-linear nature, the partial derivatives of function f may have ambiguous signs, depending on specific values of its arguments. Introducing government regulation in (1) yields:

$$\ln y_{it} = \alpha + \beta_x \ln x_{it} + 0.5\beta_{xx} (\ln x_{it})^2 + \beta_m m_i + 0.5\beta_{mm} (m_i)^2 + \beta_{xm} m_i \ln x_{it} + f(x_{it}, m_i) + v_{it} \quad (2)$$

It is important to stress that government regulation affects the marginal impact of managerial ability, making it larger or smaller than the one obtained in Alvarez *et al.* (2004):

$$\frac{\partial \ln y_{it}}{\partial m_i} = \beta_m + \beta_{mm} m_i + \beta_{xm} \ln x_{it} + f_{m_i}(x_{it}, m_i) \quad (3)$$

The maximal output for given x_{it} is achieved with the maximal level of managerial input m_i^* . The stochastic production frontier may then be written as:

$$\ln y_{it}^* = \alpha + \beta_x \ln x_{it} + 0.5\beta_{xx} (\ln x_{it})^2 + \beta_m m_i^* + 0.5\beta_{mm} (m_i^*)^2 + \beta_{xm} m_i^* \ln x_{it} + f(x_{it}, m_i^*) + v_{it} \quad (4)$$

Following Alvarez *et al.* (2004) in establishing a link between technical efficiency and management, we have:

$$\ln TE_{it} = \ln y_{it} - \ln y_{it}^* = (\beta_m + \beta_{xm} \ln x_{it})(m_i - m_i^*) + 0.5\beta_{mm} [(m_i)^2 - (m_i^*)^2] + f(x_{it}, m_i) - f(x_{it}, m_i^*) \leq 0 \quad (5)$$

Of course when the firm is on the frontier and the firm is technically efficient,

$$\ln TE_{it} = 0$$

Equation (5) can be rewritten as:

$$\ln TE_{it} = \theta_i + \theta_{xi} \ln x_{it} + f(x_{it}, m_i) - f(x_{it}, m_i^*) \quad (6)$$

$$\theta_i = \beta_m (m_i - m_i^*) + 0.5\beta_m [(m_i)^2 - (m_i^*)^2]$$

$$\theta_{xi} = \beta_{xm} (m_i - m_i^*)$$

Equation (6) shows that TE has three components: An individual time-invariant effect, θ_i ; and two time-varying components, θ_{xi} , and $f(x_{it}, m_i) - f(x_{it}, m_i^*)$, since they depend on the variable input, x_{it} . One of the consequences of this specification is that the change in managerial input necessary to increase TE by a given amount differs according to input use, as well as the type of government regulation.

The effects on TE of changes in managerial ability and input use are:

$$\frac{\partial \ln TE_{it}}{\partial m_i} = \beta_m + \beta_{xm} \ln x_{it} + \beta_{mm} m_i + f_m(x_{it}, m_i) \quad (7)$$

$$\frac{\partial \ln TE_{it}}{\partial \ln x_{it}} = \beta_{xm} (m_i - m_i^*) + f_x(x_{it}, m_i) - f_x(x_{it}, m_i^*) \quad (8)$$

Notice that (7) is equal to (3), therefore an increase in managerial ability increases TE given conventional inputs, if the production function is monotonic in managerial ability.

This model shows that TE is not a fixed effect and that it can vary over time, and the relationship between TC and managerial ability depends on the amount of managerial ability, conventional inputs and government regulation.

In order to generate the long run cost functions, notice that it should be a function of production and airport size, k:

$$C_{it} = \phi(y_{it}, k) + \psi(k) \quad (9)$$

Equation (9) describes a family of total cost curves generated by assigning different values to the parameter k. The long-run cost curve is the envelope of the short-run curves; it touches each and intersects none. By writing eq.(9) in implicit form and setting the partial derivative of it with respect to k equal to zero and eliminating k from it, and solving for C as a function of y yields:

$$C_{it} = \Phi(y_{it}) \quad (10)$$

Assuming that production costs are an increasing function of output, it is clearly evident that the cost function has the same properties as the production function analyzed above. Also notice that the efficient cost frontier has the same properties as the TE.

4. METHOD

The methodological approach adopted here is the stochastic cost econometric frontier. The frontier is estimated econometrically and measures the difference between the inefficient units and the frontier by the residuals, which are assumed to have two components: noise and inefficiency. The general frontier cost function is the form:

$$C_{it} = C(X_{it}) \cdot e^{v_{it} + u_{it}}; \forall i = 1, 2, \dots, N; \forall t = 1, 2, \dots, T \quad (11)$$

where C_{it} represents a scalar cost of the decision-unit i under analysis in the t -th period; X_{it} is a vector of variables including input prices and output descriptors present in the cost function. The error term v_{it} is assumed to be i.i.d. and represents the effect of random shocks (noise). It is independent of u_{it} , which represents technical inefficiencies and is assumed to be positive and to follow a $N(0, \sigma_u^2)$ distribution. The disturbance u_{it} is reflected in a half-normal independent distribution truncated at zero, signifying that the cost of each airport must lie on or above its cost frontier, implying that deviations from the frontier are caused by factors controlled by the airport management authority.

The total variance is defined as $\sigma^2 = \sigma_v^2 + \sigma_u^2$. The contribution of the different elements to the total variation is given by: σ_v^2 / σ^2 and σ_u^2 / σ^2 ; where σ_u / σ_v , which provides an indication of the relative contribution of u and v to $\varepsilon = u + v$. Because estimation of equation (1) yields merely the residual ε , rather than u , the latter must be calculated indirectly (Greene, 2003). For panel data analysis, Battese and Coelli (1988) used the expectation of u_{it} , conditioned on the residual value of $\varepsilon_{it} = u_{it} + v_{it}$, as an estimator of u_{it} . In other words, $E[u_{it} + v_{it} | \varepsilon_{it}]$ is the mean productive inefficiency for airport i at time t . However, the inefficiency can also be due to the airports' heterogeneity, which implies the use of a random effects model:

$$c_{it} = (\beta_0 + w_i) + \beta' x_{it} + v_{it} + u_{it} \quad (12)$$

where the variables are in logs and w_i is a time-invariant specific random term that captures individual heterogeneity. A second issue concerns the stochastic specification of the inefficiency term u , for which the half-normal distribution is assumed. For the

likelihood function, we follow the approach proposed by Greene (2005), where the conditional density of c_{it} given w_i is:

$$f(c_{it} | w_i) = \frac{2}{\sigma} \phi\left(\frac{\varepsilon_{it}}{\sigma}\right) \Phi\left(\frac{\lambda \varepsilon_{it}}{\sigma}\right), \quad \varepsilon_{it} = c_{it} - (\beta_0 + w_i) - \beta' \mathbf{x}_{it} \quad (13)$$

Where ϕ is the standard normal distribution and Φ is the cumulative distribution function. Conditioned on w_i , the T observations for airport i are independent and their joint-density is:

$$f(c_{i1}, \dots, c_{iT} | w_i) = \prod_{t=1}^T \frac{2}{\sigma} \phi\left(\frac{\varepsilon_{it}}{\sigma}\right) \Phi\left(\frac{\lambda \varepsilon_{it}}{\sigma}\right) \quad (14)$$

The unconditional joint-density is obtained by integrating the heterogeneity out of the density.

$$L_i = f(c_{i1}, \dots, c_{iT}) = \int \prod_{t=1}^T \frac{2}{\sigma} \phi\left(\frac{\varepsilon_{it}}{\sigma}\right) \Phi\left(\frac{\lambda \varepsilon_{it}}{\sigma}\right) g(w_i) dw_i = E_{w_i} \left[\prod_{t=1}^T \frac{2}{\sigma} \phi\left(\frac{\varepsilon_{it}}{\sigma}\right) \Phi\left(\frac{\lambda \varepsilon_{it}}{\sigma}\right) \right] \quad (15)$$

The log likelihood is then maximized with respect to β_0 , β , σ , λ and any other parameter appearing in the distribution of w_i . Even if the integral in expression (5) is intractable, the right-hand side of (5) leads us to propose computing the log likelihood by simulation. Averaging the expectation over a sufficient number of random draws from the distribution of w_i will produce a sufficiently accurate estimate of the integral shown in (5) to allow estimation of the parameters (see Gourieroux and Monfort, 1996; Train, 2003). The simulated log likelihood is then:

$$\log L_s(\beta_0, \beta, \sigma, \lambda, \theta) = \sum_{i=1}^N \log \frac{1}{R} \sum_{r=1}^R \left[\prod_{t=1}^T \frac{2}{\sigma} \phi\left(\frac{\varepsilon_{it} | w_{ir}}{\sigma}\right) \Phi\left(\frac{\lambda \varepsilon_{it} | w_{ir}}{\sigma}\right) \right] \quad (16)$$

where θ includes the parameters of the distribution of w_i and w_{ir} is the r -th draw for observation i . Based on our panel data, Table 3 presents the maximum likelihood estimators of model (1), as found in recent studies (see Greene, 2004 and 2005).

5. HYPOTHESES

Consider the Nigerian airports that compete to attract aircraft movements, passengers and cargo and use resources for such endeavours. This production process is defined by the following hypothesis:

Hypothesis 1 (Homogenous and heterogeneous variables): Nigerian airports' operational activity is, by this hypothesis, affected by homogenous factors as well as heterogeneous factors. Homogenous factors are those that are common to all airports and defined by technical or institutional characteristics of the airports, being almost the same for all airports. Heterogeneous factors are those that are different among airports, together with the management effect. This hypothesis is based on Chesher (1984) and Chesher and Santos Silva (2002), and neglecting this heterogeneity is likely to lead to inconsistent parameter estimates or, more importantly, inconsistent fitted parameters. This hypothesis will be tested by estimating heterogeneous parameters in the cost frontier model.

Hypothesis 2: (Managerial effects) Managerial effects on Nigerian airports' efficiency are a key issue, and the focus of the present research. By this hypothesis, the managerial effects vary along the Nigerian airports in a random form. Purchasable assets cannot be considered to represent sources of sustainable profits. Indeed, critical resources, such as managerial knowledge, are not available in the market, Wulf (2007). Rather, they are built up and accumulated on the airports' premises, their non-imitability and non-substitutability being dependent on the specific traits of their accumulation process. The difference in resources thus results in barriers to imitation (Rumelt, 1991) and in the airport managers' inability to alter their accumulated stock of resources over time. In this context, management skills constitute a unique asset and therefore, Nigerian airports are seen as exhibiting inherently different levels of efficiency; sustainable profits are ultimately a return on the unique management asset, owned and controlled by the airports (Teece *et al.*, 1997). This hypothesis will be tested by the parameter Alpha-management in the Alvarez *et al.* (2004) model.

Hypothesis 4 (Regulation): Airports regulation is desirable and necessary policy in monopoly context (Crew and kleindorfer, 1996). Airports are local monopolies and without regulation the provision of inefficient services with high prices and poor quality may arise, (Barros, Managi and Yoshida, 2010; Barros and Marques, 2009). Therefore, airports regulation based in their monopolistic feature, economies of scale, scope and density, which foster the exercise of market power (Czerny, 2006).

Hypothesis 5 (Hub) Hub airports are main airports in each country distributing the international traffic by regional airports. Based in their intense traffic and economies of scale and scope they may be more efficient than regional airports (Bazargan and Vasigh, 2003)

To test these four hypotheses, we used a stochastic random frontier model that disentangles managerial effects as fixed effects from the model, known as the Alvarez *et al.* (2004) model.

6. DATA

We use a balanced panel on Nigerian airports for the years 2003-2010 obtained from the Federal Airports Authority of Nigeria (FAAN). The variables were transformed as described in Table 2.

Table 2: Descriptive Statistics of the Data

Variable	Description	Minimum	Maximum	Mean	Standard Deviation
LogCost	Log Operational cost in US dollars	14.294	23.792	18.250	1.926
Trend	Trend variable from 1=2003 to 8=2010	1	8	4.5	2.296
Trend2	Squared value of the trend variable	1	64	25.5	21.168
LogPL	Logarithm of price of workers, measured by dividing total wages by the number of workers	6.983	16.719	11.667	0.804
LogPK	Logarithm of price of capital premises, measured amortizations divided by total assets	-0.871	-0.0007	-0.098	0.120
LogAircraft	Logarithm of the aircraft movements at each airport	7.297	3.213	-1.509	13.135
LogPassengers	Logarithm of the number of passengers at each airport i	5.666	15.167	10.894	2.068
Hub	Dummy equal to one for hub airports	0	1	0.333	0.472
Regulation	Dummy variable equal to one for the years the airports start being regulated.	0	1	0.500	0.501

7. RESULTS

7.1 Model Specification and Results

The specification of the cost function follows microeconomic theory (Varian, 1987), adopting a translog. The costs are regressed in input prices and output descriptors. We chose a flexible functional form in order to avoid imposing unnecessary *a priori* restrictions on the technologies to be estimated (Cornes, 1992). Furthermore we do not impose normalisation of the prices but rather test if the data supports it. Each explanatory variable is divided by its geometric mean. Thus, the translog can be considered as an approximation to an unknown function and the first-order coefficients can be interpreted as the production elasticities evaluated at the sample geometric mean. The equation to estimate is:

$$\ln \text{Cost}_{it} = \beta_0 + \beta_y \sum_i \ln y_{it} + \sum_j \beta_{wj} \ln w_{ijt} + \frac{1}{2} \sum_i \ln(y_{it})^2 + \frac{1}{2} \sum_j \beta_{ww} \ln w_{ijt}^2 + \sum_j \beta_{wj} \ln w_{ijt} \ln y_{it} + \delta_{ij} \cdot t + \delta_{tij} \cdot t^2 + v_{it} + \mu_{it} \quad (17)$$

where y is the output, w denotes input price, t is a time trend, v is a random error which reflects the statistical noise and is assumed to follow a normal distribution centred at zero, while u reflects inefficiency and is assumed to follow a half-normal distribution. The results are presented in Table 3.

Table 3: Stochastic panel cost frontier (Dependent Variable: Log Cost)

Variables	Translog Non-Random Frontier Model	Alvarez, Arias and Greene (2004) model
Non-random parameters	Coefficient (t-ratio)	Coefficient (t-ratio)
Constant	-0.508 (-0.150)	-
Trend	0.114 (0.570)	0.059 (0.647)
Trend ²	-0.022 (-1.952)	-0.050 (2.453)
LogPL	0.441 (3.660)	0.226 (3.655)

Log PK	0.231 (5.940)	0.223 (4.317)
LogAircraft	-0.110 (-2.451)	-
LogPassengers	0.448 (5.760)	-
1/2logPL ²	0.782 (2.760)	0.523 (2.783)
1/2LogPK ²	0.273 (1.673)	0.210 (2.534)
1/2Log Aircraft ²	0.709 (3.218)	0.426 (2.893)
1/2Log Passengers ²	0.624 (3.167)	0.545 (3.452)
LogPL*logPK	0.297 (1.872)	0.214 (2.736)
logPL*logAircraft	0.682 (2.317)	0.418 (2.752)
LogPL*logPassengers	0.342 (3.662)	0.248 (2.854)
LogPK*LogAircraft	0.782 (1.983)	0.514 (2.673)
LogPK*logPassengers	0.226 (1.025)	0.143 (1.563)
Log Aircraft*LogPassengers	0.283 (0.513)	0.148 (1.016)
Hub	0.127 (2.584)	0.114 (3.124)

Regulation	0.682 (2.853)	0.517 (3.289)
Means for random parameters		
Constant	-	-0.211 (-1.152)
Log Aircraft	-	-0.006 (-3.982)
Log Passengers	-	0.212 (3.999)
Coefficients on unobservable fixed management		
Constant	-	0.127 (1.014)
Log Aircraft	-	0.559 (5.312)
LogPasseng	-	0.225 (4.739)
Alpha management	-	-0.001 (4.218)
Statistics of the model		
$\sigma_u = \sigma_v \sqrt{\sigma_u^2 + \sigma_v^2}^{1/2}$	0.672 (7.321)	0.820 (10.217)
$\sigma_u = \sigma_v \sqrt{\sigma_u^2 + \sigma_v^2}$	0.131 (5.946)	0.136 (3.219)
Log likelihood	-415.93	-425.16
Observations	237	237

t-statistics in parentheses (* indicates that the parameter is significant at the 1% level).

Table 3 presents the results obtained for the stochastic frontier, using Limdep 9 and assuming a half-normal distribution specification for the cost function frontier. Having

estimated two rival models, i.e., the homogeneous and heterogeneous translog frontier models and heterogeneous frontier model, we apply the likelihood test and conclude that the Alvarez *et al.* (2004) model random frontier is the most adequate functional form.

Finally, in order to differentiate between the frontier model and the cost function, we consider the sigma square and the lambda of the cost frontier model. They are statistically significant, meaning that the traditional cost function is unable to capture adequately all the dimensions of the data. Furthermore, the random cost function fits the data well, since both the R^2 and the overall F-statistic (of the initial OLS used to obtain the starting values for the maximum-likelihood estimation) are higher than the standard cost function. Lambda is positive and statistically significant in the stochastic inefficiency effects, and the coefficients have the expected signs.

The variables have the expected signs, since all price elasticities are positive and they sum lower than one concluding that we accept the homogeneity hypothesis on prices for both models. It can be seen that the labor elasticity is 0.441 and capital elasticity is 0.231. Cost increases with the price of labour and the price of capital and with the output (passengers and planes). The cost decreases with some the square terms. Moreover, passengers and planes are statistically significant heterogeneous variables. The statistically significant random parameters vary along the sample. The identification of the mean values of random parameters implies taking into account heterogeneity when implementing cost control measures. Furthermore, the managerial parameter Alpha-management is negative and statistical significant, meaning that the management has a negative effect on cost. Additionally, the regulatory variables are statistically significant and have negative signs, meaning that they contribute to cost control. Addition, the variable *hub* is positive and statistically significant in the Alvarez, Arias and Greene (2004) model, signifying that traffic has a positive effect on efficiency and validating previous research, Barros (2009). Finally the variable regulation is also statistical significant having so also a positive effect on cost efficiency.

7.2 Efficiency Scores

The motivation and scope of this paper derive from the fact that random frontier models generally succeed at describing the costs structure of Nigerian airports. In particular, our analysis suggests that homogenous frontier models should be abandoned, since they do not capture relevant aspects of the examined context. On the contrary, random frontier models allow the homogenous and heterogeneous variables to be disentangled.

Based on the new frontier, the alternative ranking is shown in Table 4, which reports the cost average cost efficiency for each airport across the sample. The cost efficiency is defined as the ratio between the minimum cost and the actual cost, implying that it takes

values between 0 and 1. Hence, the closer to 1 is the ratio, the more efficient the airport is. Given that the dependent variable has been transformed into logarithms, we compute:

$$EC = \exp(-\hat{u}) \quad (18)$$

where the estimated value of the inefficiency (\hat{u}) is separated from the random error term (\hat{v}), using the Jondrow *et al.* (1982) formula.

Table 4: Efficiency scores

Nob s	Airport	Homogen ous Stochastic frontier efficiency scores	Alvarez <i>et al.</i> (2004) Random stochastic frontier efficiency scores
1	ABJ DOM	1.000	1.000
2	ABJ INTL	0.902	0.342
3	AKURE	0.413	0.999
4	BENIN	0.884	0.996
5	CAL DOM	0.883	0.775
6	CAL INT'L	0.987	0.113
7	ENUGU	0.999	0.998
8	IBADAN	0.954	0.756
9	ILO DOM	0.999	0.997
10	ILO INT'L	0.918	0.124
11	JOS	0.998	0.996
12	KAD DOM	0.873	0.605
13	KAD INT'L	0.962	0.416
14	KAN DOM	0.999	0.998
15	KAN INT'L	0.531	0.140
16	MKD	0.825	0.129
17	MAID DOM	0.946	0.158

18	MAID INT'L	0.920	0.231
19	MMA DOM	0.799	0.997
20	MMA INT'L	0.656	0.995
21	PHC DOM	0.956	0.886
22	PHC INT'L	0.626	0.173
23	SOK DOM	0.895	0.366
24	SOK INT'L	0.856	0.247
25	YOLA DOM	0.995	0.349
26	YOLA INT'L	0.917	0.222
27	MINNA	0.879	0.167
28	KAT	0.915	0.284
29	OWERRI	0.999	0.998
30	OSUBI	0.998	0.997
	Mean	0.882	0.581
	Median	0.917	0.510
	Std. Dev	0.145	0.373

A number of points emerge from the present study. Firstly, similarly to previous research on airports with stochastic frontier models (Pels *et al.*, 2001, 2003) significant differences in efficiency are prevalent among Nigerian airports. The efficient score is between zero (0% efficiency) and 1 (100% efficiency). Units with scores equal to 1 (100%) are efficient. A unit with a score of less than 100% is relatively inefficient, e.g. a unit with a score of 95% is only 95% as efficient as the best performing airports and the slack relative to the frontier is 5%. Scores are relative to the other units, they are not absolute. Secondly, best-practice calculations indicate that almost all Nigerian airport authorities operated at a high level of technical efficiency during the period, according to the homogenous cost frontier. However, the rankings, while being maintained in the Alvarez, Arias and Greene (2004) model, are lower, signifying that the homogenous frontier blurs heterogeneity with efficiency (Greene, 2004, 2005).

Fourthly, the efficiency scores presented in Table 4 are average values for the period, whereas the airport authorities are analyzed across all years and the result is the same. Therefore, the overall conclusion is that Nigerian airports display a ranking signifying that there are different efficiencies in different airports and therefore the best practice

managerial procedures should be followed by the least performing units in a benchmark exercise.

8. FINDINGS

This article has proposed a framework for the comparative evaluation of Nigerian airports and the rationalization of their operational activities. The analysis was carried out through implementation of the Alvarez *et al.* (2004) random or heterogeneous stochastic frontier model, which allows for the incorporation of multiple inputs and outputs in determining the relative efficiencies and the inclusion of heterogeneity in the data. For comparative purposes, a traditional homogenous frontier model is also presented.

The main policy implication of the findings of the present analysis is that heterogeneity must be considered a major issue in the Nigerian airports, together with management. Moreover, management does not contribute to cost control, but hub do. Finally, the regulation contributes to efficiency, with private airports being more efficient than public airports.

With regard to the hypotheses, we accept Hypothesis 1, on the basis of the heterogeneous variables estimated (*planes* and *passengers*). Furthermore, we accept Hypothesis 2 because the variable *Alpha-management effect* is negative and statistically significant. Additionally, we accept Hypothesis 3, based on the positive and statistically significant parameter of the regulatory dummy variables. In addition, finally, we accept Hypothesis 4, since *hub* is positive and statistically significant. These latter three results are of paramount importance and a distinctive outcome of the present research since, previously, the frontier models tended to blame management for the inefficiency based on Leibenstein X-Inefficiency. The present study does not lead us to apportion the responsibility for inefficiency on airport management. Furthermore, while variations may exist along the sample, the average result for the regulatory variables is positive, contradicting results obtained in other fields (Zhang, Parker and Kirkpatrick, 2008). Furthermore, the rankings displayed signify that regional distinctions at the Nigerian level do not exert a tangible effect on the results, meaning that in terms of airport activities, Nigeria is a relatively heterogeneous country. Hence, it is the regional distribution of the airport that explains inefficiency. Finally, the spread in the efficiency rankings reflects different levels of performance based in the estimated cost frontier model.

Accordingly, public policies towards airports should take into account such heterogeneity. For instance, the authorities could implement policies by segments defined by the outputs with the aim of regulating aircraft and passenger movements at the Nigerian airports.

Concerning the results of the model, the cost increases with the homogeneous and heterogeneous variables. The identification of the mean values of random parameters implies taking into account the heterogeneity when implementing policies for cost control.

This is an intuitive result, since airports are not homogenous. There are small, large and medium-sized airports. These tangible characteristics are translated into different performances obtained in the market, resulting in different clusters within the market. These clusters are distinguished from each other on the basis of the outputs, signifying that there is an investment in this field that must be made by all airports homogenously. This result also signifies that other outputs are relatively homogenous.

How can we explain the efficiency rankings? These are endogenous results of the model, which can be explained by traffic and the regional distribution of airports. Other factors, such as ethnic and cultural traditions, which are not investigated in the present research may explain part of the observed inefficiency.

In comparison with the previous literature in this area, our research overcomes the bias towards DEA models in studies on airports. With regard to the stochastic frontier model, Pels, Nijkamp and Rietveld (2001) adopt the production function framework, which is clearly inadequate whenever there are various outputs; moreover, they adopted homogenous frontier models and therefore, no direct comparisons can be made. The comparison between homogenous and heterogeneous frontier models is undertaken in the present research, concluding that heterogeneity better captures the cost structure of the Nigerian airports, based on the log likelihood test. Additionally, the present research adopts as inputs and outputs, variables which vary along the period and along the sample, while previous research adopted invariant inputs such as check-ins, aircraft parking spaces and terminal size (Pels, Nijkamp and Rietveld, 2001), which vary along the sample but do not vary along the period. Possibly, the main limitation of the present research relates to the data span, which is, to some extent, short for econometric purposes and which obliged a parsimonious specification of the cost function estimated. Therefore, a larger data set is needed to confirm the validity of the present results.

The general conclusion is that Nigerian airports are heterogeneous, while several reasons beyond management control, namely, regulation and hub, also explain the differences in the rankings, for example, the use of inputs, or outputs generated by inputs in the production function.

9. CONCLUSIONS

This paper analyzes the technical efficiency of Nigerian airports from 2003 to 2010, taking into account the endogenous managerial practices, ownership and regulatory control on the heterogeneous cost frontier. The general conclusion is that common policies can be defined for Nigerian airports based on the average values of the homogeneous variables, whereas segmented policies may be prescribed to account for heterogeneous variables. Given that the scale parameters of heterogeneous variables are statistically significant, we recognize such heterogeneity, which entails managerial insights and policy implications.

Further research is needed to confirm the present conclusions.

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