Sub Saharan Railway Firms: Reforms and Demand Effects on Technical Efficiency - A Stochastic Frontier Analysis Between 1995 and 2005

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The purpose of this paper is to study the technical efficiency of the Sub-Saharan African railway sector and its influencing factors. This efficiency depends on several factors. Using stochastic distance function methodology for a sample of 16 Sub-Saharan firms between 1995 and 2005, we found a positive effect of the public private partnerships and of the high levels of network exploitation and freight specialization on the performance of the railway sector. We decompose the measured scores of efficiency regarding the environmental context which permits to adjust the benchmarking efficiency studies and allows setting the appropriated objectives by the policy deciders.

Keywords: sub-Saharan Africa, railway, technical efficiency, public private partnerships

INTRODUCTION

Railways transport is considered as an important locomotive of sustainable development. The improvement of the effectiveness and the quality of the railway transport let achieve different objectives such as the increasing of trade flows, the decongestion of roads and the improving of peoples' mobility. This situation is all the more important in the context of African economic development. Indeed, the lack of infrastructure and transport services remains a major obstacle to the development of trade between African countries and trade with the rest of the world. Knowing that the lack of access to transport infrastructure is one of the indicators of poverty. The heads of states and governments of the African Union members, meeting in 2005, decided to include the transport's indicators in the framework of the Millennium Development Goals for Africa (MDGs). This, in order to accelerate poverty reduction which is a fundamental objective of the international community.

The African railway sector faces two fundamental problems. The first consists in the lack of infrastructure and the smallness of the network relatively to the area. Historically, the rail network was built by private companies during the colonization period and was exclusively for the purpose of transporting raw materials from inside the country to seaports. Thus, the infrastructure has remained in the same configuration and has not face any improvements during the last five decades. Major investments from development actors and partnerships with the private sector could provide a solution in the long run to this situation.

The second problem is the poor performance that characterizes the sector particularly in the sub-Saharan countries. The recognition of this situation and the difficulties to continue subsiding the financial losses of railway companies, upwards annually of 5% of GDP, prompted politicians and donor agencies to try to reverse the direction of this financial outflow by contracting partnerships with the private sector (Thompson and al., 2001). The principal objective of these partnerships is to increase the efficiency of rail transport by the implementation of a management conform to the private sector standards.

In fact, since the early nineties, the African rail has undergone fundamental institutional reforms which are implemented under the auspices of international development institutions like the World Bank. Estache et al. (2006) report that the private operators occupy 45% of African railway transport market while the average in the developing world is 37%.

Any economic activity must meet different objectives depending on its nature. The maximization of profits can be considered as the primary aim of private companies. Public enterprises, on the other hand, reach other goals, such social equity. However, technical efficiency is considered compatible with all other goals of economic activities (Pestieau and Tulkens, 1993).

The purpose of this paper is to study the technical efficiency of the African railway sector. This efficiency depends on several factors in addition to those of the public or private management and ownership such as the geographical features, the specialisation of companies (passengers transport and/or fret transport) and the demand characteristics. Using stochastic frontier analysis for a sample of 18 sub-Saharan countries between 1995 and 2005, we determine the effects of reforms, demand characteristics and railway network specificities on technical efficiency. The rail networks of African companies are characterized by the absence of interconnection between different plots and by a very low density relatively to the size of countries (Mbangala, 2001). The transport demand, considered by average length of passengers and fret journeys, also vary depending on the countries and their geographical positions. As well as institutional reforms, these characteristics influence the operating context of these firms and hence their technical efficiencies. The reforms that the industry has experienced are diverse (Barla and Perelman, 1989). These partnerships can take the form of concessions, leasing or privatization. To study their effects on efficiency, we consider a generic binary variable to represent these partnerships. Various recent surveys address the issue of optimal forms of these partnerships, and followed the regulation that governs them, the World Bank built for this purpose a database on Public Private Partnerships (PPPs).

Despite of the major changes that have hit recently the sector, the empirical analysis of the efficiency of the African railways companies remains very limited. Mbangala and Perelman (1997) studied the efficiencies of 9 companies between 1970 and 1990 using the deterministic approach Data Envelopment Analysis (DEA). They found the positive effects of the network density and the specialisation in passenger transport on efficiency. Our paper is based on stochastic frontier analysis (SFA) which allows us to compare firms with different scales of production and to consider a multi input and multi output technology. This methodology permits to consider the effects of environmental variable which are out of the control of the managers as the demand specificities, the network density and the institutional context. It also allows to estimate the net efficiency after controlling for these exogenous factors. As the last cited article, we consider exclusively physically inputs and outputs data to estimate the technical efficiency. This avoids the utilisation of data on prices of inputs and outputs that are not always available and rarely determined by the market mechanisms. The SFA method is most appropriate in the case of developing countries characterized by data with limited reliability and contained errors of measurements. The stochastic method contrary to the deterministic methods such as DEA allows better estimates because it distinguishes between the statistical noise and the technical efficiency measures. In this paper we also control the SFA results by the DEA measurement of efficiency scores.

Oum et al. (1999) report in a survey of productivity measurement in rail transport sector that the most of analysis considers passengers kilometers and tons kilometers as the outputs of the railway activity[1]. We propose another specification of the production function with two outputs passengers and fret transported.

This choice allows us to control for demand specificities (mean lengths of passenger and fret journeys) as environmental factors influencing technical efficiency.

The paper is organised as follows. Section 2 presents the theory bases of SFA and DEA methods measuring the technical efficiency. Section 3 describes the data and the sample analyzed. Section 4 explains the specification of the production function considered and the results of the estimation. Section 5 contains the main conclusions and recommendations of economic policy.

THE TECHNICAL EFFICIENCY MEASUREMENT METHODOLOGY

Stochastic Frontier Analysis

The methodology considered in the analysis is the output distance function (Coelli, 1994). This method was introduced in theory by Shephard (1953, 1970) and developed further by Färe and Grosskopf (1990), Färe and Primont (1995), Grosskopf and al. (1995) and Coelli and Perelman (1996). The output distance function allows us to consider a multi-output production technology and gives us a radial measure of technical efficiency (Coelli and Perelman, 2000).

The output – oriented distance is measured relative to the production possibility set[2] *P(x)*. It reflects the distance between the observed firm's set of outputs (yi) and the frontier for a given set of inputs (x).

The output oriented distance is expressed as follows (Aigner and al., 1977)[3]:

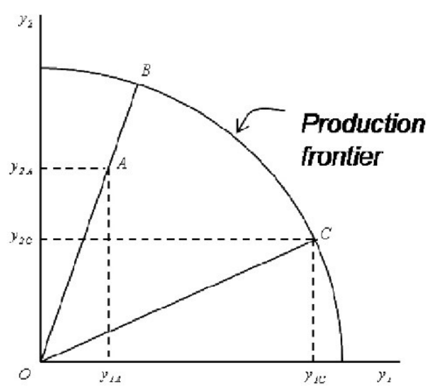
$$D_0(x, y_i) = min\,\{\delta : \delta > 0, (y_i\ /\ \delta) \in P(x)\} \quad (1)$$

The measured distance d O is the radial expansion of outputs (yi) required for the firm i to produce at the efficient level P(x) defined as:

$$P(x) = \{y : y \in P(x),\ \theta\, y \notin P(x),\ \theta > 1\} \quad (2)$$

To illustrate the Production possibility set, we consider a technology of production based on a vector of inputs x to produce two outputs y1 and y2 (figure 1).

FIGURE 1
PRODUCTION FRONTIER



The distance between a firm's production (A) and the frontier of the production possibility set (area between the frontier and the axes) indicates its efficiency. This distance δ is equal to OA/OB and it's between 0 and 1. For firms B and C, δ is equal to one. These firms are considered as efficient.

We use a translog production function to specify the relationship between inputs and outputs. Thus allows us to estimate the frontier and the distances for each firm (Lovell et al., 1994; Coelli et al., 2003).

Given M (m =1,2,..., M) outputs, K (k =1,2,..., K) inputs for I (i =1,2,..., I) firms, the translog distance function is expressed as follows:

$$ln\ D_{0i} = \alpha_0 + \sum_m \alpha_m \ln y_{mi} + 0{,}5 \sum_m \sum_n \beta_{mn} ln\ y_m\ ln\ y_{ni} + \sum_k \alpha_k ln\ x_{k,i} + 0{,}5 \sum_k \sum_l \beta_{kl}\ ln\ x_k\ ln\ x_{li} + \sum_k \sum_m \beta_{km} \ln x_{ki} \ln y_{mi} \quad (3)$$

We impose the restrictions $\sum_m \alpha_m = 1$ and $\sum_n \beta_{mn} = \sum_m \beta_{km} = 0$ to respect the homogeneity conditions. The symmetry conditions impose that $\beta_{mn}=\beta_{nm}$ and $\beta_{kl}=\beta_{lk}$. These restrictions are considered in the translog distance function through normalizing it by one output.

$$lnD_{0i}/y_{li} = \alpha_0 + \sum_m \alpha_m \ln(Y_{mi}/y_{li}) + 0{,}5 \sum_m \sum_n \beta_{mn} \ln(y_m/y_{li}) \ln(y_{ni}/y_{li}) + \sum_k \alpha_k lnx_{k,i} + 0{,}5 \sum_k \sum_l \beta_{kl} lnx_k lnx_{li} + \sum_k \sum_m \beta_{km} lnx_{ki} \ln\ (y_{mi}/y_{li}) \quad (4)$$

To estimate this specification (4) and the firms' inefficiency scores, we transform this equation to a stochastic production function respect the form: y = f (x) +v −u (Coelli and Perelman, 1996).

$$-lny_{li} = \alpha_0 + \sum_m \alpha_m \ln(y_{mi}/y_{li}) + 0{,}5 \sum_m \sum_n \beta_{mn} \ln(y_m/y_{li}) \ln(y_{ni}/y_{li}) + \sum_k \alpha_k lnx_{k,i} + 0{,}5 \sum_k \sum_l \beta_{kl}\ lnx_k\ lnx_{li} + \sum_k \sum_m \beta_{km} lnx_{ki}\ ln(y_{mi}/y_{li}) + v_i - u_i \quad (5)$$

With v_i is the statistical noise assumed to be normal distributed $N(0, \sigma_b^2)$ and u_i (= ln D_{oi}) reflects the inefficiency level. u_i is assumed to follow a normal distribution truncated at zero $u_i \sim N(\mu,\sigma_u^2)$.

The general residual of the model will be realizations of $\varepsilon_i = v_i - u_i$. Battese and Coelli (1988) consider that *exp(−u_i)*, given the random variable εi, is an appropriate predictor for the technical efficiency. That is, we may define the technical efficiency using

$$TE_i = E[exp(u_i),\ \varepsilon_i] \quad (6)$$

Firms' efficiencies depend on their environmental context. Hence, distance function (1) D0 (x, yi) will be biased and have to include the firm specific exogenous characteristics of their operating context (zi). Thus, we define the adjusted firm specific production set $P(x,z_i)$ and the efficient level of production will be expressed as follows:

$$P(x, z_i) = \{y : y \in P(x, z_i)\ ,\ \theta\ y \notin P(x, z_i),\ \theta>1\} \quad (7)$$

and the appropriate distance will be measured as:

$$D_0(x, y_i, z_i) = min\ \{\delta : \delta > 0, (y_i\ /\ \delta) \in P(x, z_i)\} \quad (8)$$

The exogenous operating characteristics have an effect on the efficiency level. They are introduced in the translog specification by assuming that u_i follows the distribution $N(\varphi_i, \sigma_u^2)$ with $\varphi_i = \delta_0 + \sum_{j=1}^{j} \delta_j z_{j,i}$ as proposed by Battese and Coelli (1995).

The unknown parameters β_0, β_k, δ_0, δ_j, σ_u^2 *and*, σ_v^2 are estimated simultaneously by maximum likelihood. Coelli (1992 and 1994) proposes a computer program FRONTIER for this estimation which is based on the expression of likelihood function as observed by Battese and Coelli (1993). This program is based on the reparametrisation $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2$ with γ is between 0 and 1. The measure of technical efficiency for the conditional expectation of $\exp(-u_i)$, given the random variable ε_i, is given by:

$$TE_i = E[\exp(u_i), \varepsilon_i] = \left\{exp\left[-u_i + \frac{1}{2}\sigma_*^2\right]\right\}.\left\{\Phi\left[\frac{u_i}{\sigma_*} - \sigma_*\right]/\Phi\left[\frac{u_i}{\sigma_*}\right]\right\} \quad (9)$$

where Φ (.) is the standard normal distribution function of the random variable $u_i = (1-\gamma)\left[\delta_0 + \sum_{j=1}^{J} \delta_j z_{j,i}\right] - \gamma\, \varepsilon_i$ and $\sigma_*^2 = \gamma(1-\gamma)\sigma^2$

After adjustment of gross efficiency measures by controlling for the operating context through environmental variables, we can measure the net technical efficiencies. This by replacing $\sum_{j=1}^{J} \delta_j\, z_{j,i}$ in equation of technical efficiency with *favourable* $\sum_{j=1}^{J} \delta_j\, z_{j,i}$. Favourable could be minimum or maximum depending on the environmental variables considered. The net efficiency measure assumes that all firms are confronted to the same operating environment. The difference between net and gross measures reflects the contribution of environmental factors in the technical inefficiency of the company. This decomposition of the inefficiency was proposed by Coelli et al (1999) and Gathon and Pestieau (1995).

Data Envelopment Analysis

In this paper we study technical efficiency by the stochastic method, already described, and by deterministic method Data Envelopment Analysis (Farell, 1957). This method was introduced by Charnes et al (1978) under the assumption of constant returns to scale. DEA proposes to optimize for each firm a problem of linear programming to determine its efficiency relatively to the frontier enveloping the data of the enterprises (Gathon and Perelman, 1992). This method could be described as fellow (Mbangala and Perelman, 1997): given a set of *M (m =1,2,..., M)* outputs and *K (k = 1,2,..., K)* inputs for I *(i=1,2,..., s, ..., I)* I) firms, the technical efficiency is obtained by the maximisation of the ratio:

$$Max \sum_{m=1}^{M} U_m Y_{m,s} / \sum_{k=1}^{K} V_k X_{k,s} \tag{10}$$

This, under the restrictions:

$$\sum_{m=1}^{M} U_m Y_{m,i} / \sum_{k=1}^{K} V_k X_{k,i} \leq 1,\ \ i = 1, \dots, I$$
$$U_m \geq 0, m = 1, \dots, M$$
$$V_k \geq 0, k = 1, \dots, K$$

U_m and V_k are unknown parameters to estimate. Thus, the technical efficiency of the i[th] firm is the ratio of outputs on inputs (10) under the condition that this ratio is lesser than 1 for all other firms considered. This ratio to maximise is transformed in a form of linear programming. For this goal, we suppose: $t = \sum k V_k X_{ks}$; $u_m = U_m / t$ for M (m =1,2,..., M) and $v_k = V_k / t$ for K (k =1,2,..., K).

This gives:

$$Max \sum_{m=1}^{M} u_m Y_{m,s} \tag{11}$$

Under the restrictions:

$$\sum_{m=1}^{M} u_m Y_{m,i} - \sum_{k=1}^{K} v_k X_{k,i} \leq 0,\quad i = 1, \dots, I\ ;\quad \sum_{k=1}^{K} v_k X_{ks} = 1$$
$$u_m \geq 0, m = 1, \dots, M$$
$$v_k \geq 0, k = 1, \dots, K$$

Using the duality propriety of the linear programming, we obtain the equivalent program of maximisation (11) as an envelopment formula:

$$Min\ h_s \tag{12}$$

This, under the restrictions: $h_s x_{ks} - \sum_{i=1}^{I} x_{ki} \lambda_i \geq 0$; $\sum_{i=1}^{I} y_{mi} \lambda_i - y_{ms} \geq 0$ and $\lambda_i (i = 1, \dots, N) \geq 0$. And h_s is the technical efficiency score which is equal to one if the firm is efficient. The multipliers λ_i called peers indicate how the best practice frontier is formed relative to which the s[th] firm is compared. To consider the general model of varying economics of scale (VRS) we add a new restriction $\sum\lambda_i = 1$ to the linear program (12).

We consider the DEA method as a control measure in this analysis. We base our approach on the factors effects on technical efficiency using the results of the stochastic estimation SFA. This, because the DEA is deterministic method and does not distinguish between statistic noise and the measurement of technical efficiency. Several recent developments define a statistical model allowing to determine the statistical properties of the estimators of the nonparametric frontier (Grosskopf, 1996; Simar and Wilson, 2000). These models use statistical inferences with asymptotic results or boostrap. Nevertheless, they show a major limitation which is not to take into account the outliers and measurement errors. This problem is partially solved by the contribution of Cazals et al (2002).

THE AFRICAN RAILWAY DATA

The data used in the technical efficiency of African railways companies is provided by the database built by Mbangala (2007). These data are collected in two stages. The first is starting from an initial survey of existing data and the second by checking and correction of this data with the companies directly.

The sample consists of 18 firms for 15 countries: Benin and Niger (Organisation commune Bénin-Niger, OCBN), Ghana (Ghana Railway Corporation, GRC), Nigeria (Nigeria Railway Corporation, NRC), Burkina Faso and Ivory Cost (Abidjan-Ouagadougou Railway, SITARAIL), Cameroon (Cameroon Railway Corporation, CAMRAIL) Gabon (Société d'exploitation du Transgabonais, SETRAG), Congo - Brazzaville (Chemin de Fer Congo Océan, CFCO), the Democratic Republic of Congo (Chemin de Fer Matadi-Kinshasa, CFMK and Société nationale des chemins de fer du Congo, SNCC), Kenya (KRC), Uganda (Uganda Railway Corporation, URC), Tanzania (Tanzania Railway Corporation, TRC), Malawi (Central East Africa Railways Corps, CEAR), South Africa (South Africa Rail, SPOORNET), Mozambique (Corredor de Desenvolvimento do Norte, CDN; Caminhos de Ferro de Mocambique, CFM and Companhia dos Caminhos de Ferro de Beira, CCFB) and Zambia (Railway System of Zambia, RSZ). These companies have different sizes and characteristics. However, the SFA method allows specifying a generic production function and comparing these companies taking into account their heterogeneous sizes.

In most of the literature on the railway sector efficiency, the variables characterizing the outputs of this activity are the passengers' kilometers and freight tons kilometers transported. Our database contains such data, but also the gross data on passengers and tons of freight transported. This second type of data reflects more realistically the activity under the control of companies. Thus, excluding criteria linked more to the geographic and socioeconomic context of the firms' operations. Indeed, the kilometers that run passenger and freight are linked on the one hand to the extent of the rail network of the country and, on the other hand, to the demand coming from users. We therefore retain passengers and tons carried in our analysis as output variables, with controlling at the same time for the operational context by the environmental variables which we will detail later.

The observation of the data shows that African firms are specialized in the freight transport (table 1) with an average of 75%, this with the exception of the Nigeria's firm NRC that carries fewer goods than passengers (27%). This situation could be explained historically by the fact that railways in Africa have been built for transport of raw materials (Mlenga, 2003). We will see if this can explain partly the performance of these companies. Mbangala (2004) consider that this specialization in freight transport reduces technical efficiency of the rail sector in Africa.

TABLE 1
DESCRIPTIVE DATA (MEAN VALUES FOR THE PERIOD 1995-2005)

	Firm	Country	Network (km)	Density (km/area)	Fret (%)	MJTon (km)	MJPas (km)	Year of reform
1	CAMRAIL	Cameroon	1100	2.3	73.8	589	252	1999
2	CCFB	Mozambique	994	3.9	88.3	281	38	2004
3	CDN	Mozambique	904	3.9	60.7	513	110	2005
4	CEAR	Malawi	797	6.6	75.5	204	50	1999
5	CFCO	Congo Brazzaville	795	2.3	60.1	417	217	no
6	CFM	Mozambique	1048	3.9	87.8	154	41	no
7	CFMK	Democratic Republic of Congo	366	1.9	87.0	328	106	no
8	GRC	Ghana	947	3.9	61.5	152	135	no
9	KRC	Kenya	2065	3.6	80.9	675	623	no
10	NRC	Nigeria	3505	3.8	27.2	3595	299	no
11	OCBN	Benin - Niger	579	5.1	58.1	591	160	no
12	RSZ	Zambia	1351	3.0	75.5	334	245	2002
13	SETRAG	Gabon	649	2.4	95.5	551	400	2005
14	SITARAIL	Burkina Faso - Ivory Cost	1250	2.1	83.3	775	381	1996
15	SNCC	Democratic Republic of Congo	3641	1.9	74.2	340	323	no
16	SPOORNET	South Africa	20047	16.4	98.7	574	341	no
17	TRC	Tanzania	2605	3.8	72.2	957	567	no
18	URC	Uganda	261	5.2	96.6	236	42	no
	Mean		2384	4.23	75	626	241	-

MJPas: passenger mean journey length; MJTon: ton mean journey length

The data reports also information on inputs of the railway activity. The rolling stock is one of the pillars in this production. The equipment consists of locomotives, passenger cars and freight wagons. Given that the locomotives have various types by energy used and by their utility (maintenance, maneuver…) we exclude this variable from our database. We sum passenger cars and freight wagons for each firm to obtain uniform information on the equipment. We also dispose information on the network length exploitable. Like the rolling stock, the network is considered as the capital of the railway transport production. Network lengths of African firms vary considerably from one firm to another in our sample, the South African company SPOORNET is the greatest one with 20047 kilometers of railways lines while the Ugandan firm URC is the smallest one with 261 kilometers. The network depends on the size of the country. Then it is important to consider in the efficiency analysis the density of the network measured by the length of network divided by the area of the country. The African network is characterized by the absence of interconnections between different plots of the network but also by the low density compared to other regions of the world. Indeed, this density is in average 4.23 km of lines per 1000 square kilometers when it reached 63.1 in France. Table 1[4] shows that the SPOORNET has the largest ratio (16.44) while the density of the company SNCC of the Democratic Republic of Congo is the lowest one (1.92). We will verify if the prediction that the higher density permits greater technical efficiency matters.

The staffs employed in the railway companies are also reported by the data used in this analysis. In most public companies, the recruitment of employees is seen as a lever to meet several macroeconomic objectives such as the employment policy. In companies which face reforms as privatization or concession, there is been significant staff reductions what has changed considerably the productivity of this input. The data considers the annual staff including definitive staff, support staff and foreign technical assistance personnel. Seasonal and temporary employees are out of this aggregate.

Table 1 shows that 7 firms of the 18 analysed have experienced institutional reforms during the considered period. The pioneer is the SITARAIL in 1996. This reform has taken the form of a concession of the line between Abidjan (Ivory Coast) and Ouagadougou (Burkina Faso) to a private consortium. The Reforms of the companies GRC, NRC, OCBN and CDE are at the stage of negotiation. Nevertheless, until now the Republic of South Africa and the Democratic Republic of Congo have not yet begun negotiations on reforms. In the most of cases, the reform has the form of concession. This model concerns the concession of operations, under several conditions specified in the contract, to a private entity and in which the state retains ownership of existing infrastructure. In general, these agreements cover periods between 15 and 30 years (Mbangala, 2007). Literature on the expected impacts of public private partnerships, such as the concession or other types of reforms, observes that these effects on the efficiency are positive. These effects pass through different channels such as the imposition of management strategies that comply with standards of private companies. Increasing staff productivity through restructuring and the rolling stock productivity by the introduction of modern equipment are other channels which allow increasing this efficiency (Thompson and al., 2001). Data shows that SITARAIL has quadrupled the staff and the passenger cars productivities in the year of the concession 1996. However, CEAR and CAMRAIL have increased these productivities after their reforms, but largely below the achievements of SITARAIL.

To undertake the effects of these reforms on technical efficiency we built a binary variable taking the value 1 from the year of implementation of these reforms. This variable will be considered as an environmental one reflecting the institutional context of railway transport.

The operational context in which involve the African railway companies depends also on the user's demand. The country geographical and socio-economic characteristics, such as its surface, the existence of multi-modal transport, the presence of exporting producers, the access to the sea and the existence of large urban metropolis, influence the demand. Thus, the passenger and the merchandises journeys lengths depend on this context. These specificities of the transport demand do not influence directly the shape of the production technology, but they influence the technical efficiency. We therefore consider the mean journey length of passengers (MJPas) and freight (MJTon) as environmental variables which are exogenous to the decision of companies. These variables are available in the database and are measured by multiplying the total of passengers and freight transported by the real journeys' lengths. The data shows (table 1) that these variables vary considerably from one railway operator to another. The Nigerian company NRC recorded the longest freight journeys (3595 km) and the Kenyan company NRC the highest passengers' journeys (623 km).

THE MODEL SPECIFICATION AND ESTIMATION

The specification of the production function of the railways companies is a translog model based on a stochastic distance function. The model is considered with output orientation. This choice is justified by the fact that in the context of sub-Saharan countries, productive resources are limited and the main goal would be to maximize their outputs given their available resources. The model 1 considers two outputs the annual number of passengers and the annual quantity of freight transported and three inputs representing the staff, the equipment and the network. The last two variables reflect the capital in the operation of rail transport. The network is considered as a quasi fixed input because it remains unchanged over time for all companies.

In this paper, we do not adhere to the empirical literature on the railways enterprise efficiency which considers generally the passengers kilometers and tons kilometers transported as outputs (Oum et al., 1999). The choice of considering passengers and freight transported allows us to control for the users' demand. The transport demand is assumed exogenous to the decision of the enterprises, but influencing their efficiencies. This demand is represented by the passenger mean journey length and the freight mean journey length. These variables could be seen as outputs but still, in our assumption, exogenous to the firms' strategies.

In addition to these two environmental variables we add to the model a third one relative to the railways sector reforms. The fourth variable, density, considers the specificities of each network. This allows to us to characterize the operational environment of these companies. The four exogenous variables are introduced into the model (1) conforming to the specification proposed by Battese and Coelli (1995).

TABLE 2
ESTIMATION RESULTS

Variables	Parameters		t - ratio
Intercept	-1.2	***	-5.50
Outputs			
[- ln y1] (Fret - tons) ~ dependent variable			
ln y2 *(Passengers)*	0.692	***	8.86
(ln y2)²	0.207	***	3.74
ln y1	0.308		
(ln y1) (ln y2)	-0.207		
(ln y1)²	0.207		
Inputs			
ln x1 *(Equipment)*	-0.201		-1.20
ln x2 *(Staff)*	-0.417	***	-2.36
ln x3 *(Network)*	-0.681	***	-4.14
(ln x1)²	0.603	***	3.56
(ln x2)²	0.763	***	3.68
(ln x1)(ln x2)	-0.405	***	-2.77
t *(Trend)*	0.008		0.13
(t)²	0.002		0.20
(ln x1)(t)	-0.014		-0.64
(ln x2)(t)	0.064	***	2.74
No separability variables			
(ln x1)(ln y2)	0.391	***	4.65
(ln x2)(ln y2)	-0.304	***	-3.92
(t)(ln y2)	0.006		0.55
(ln x1)(ln y1)	-0.391		
(ln x2)(ln y1)	0.304		
(t)(ln y1)	-0.006		
Environmental variables			
z0	0.556		1.31
z1 *(Mean journey length tons)*	0.068	*	1.50
z2 *(Mean journey length passengers)*	0.200	***	2.78
z3 *(Concession)*	-0.165		-0.65
z4 *(Density network/area)*	-0.206	*	-1.47
ML parameters			
Observations	188		
Sigma squared	0.367	***	2.72
Gamma	0.656	***	3.08
Log likelihood function	-137.00		

*ML parameters: Maximum likelihood parameters; ***, **, *: statistically significant at the level of 1%, 5% and 10% respectively.*

For reasons of lack of data for some years and for some companies, the model was estimated for a non-balanced panel. The average efficiency scores obtained by the method SFA are consistent with those obtained by the method DEA (table 3). Over the period 1995 - 2005 and for the gross efficiency scores, the companies CFM, CAMRAIL, GRC and SETRAG are the most efficient ones. In the bottom of the ranking, we find the railways firms of Kenya (KRC), of Tanzania (TRC) and of DRC (SNCC). The net efficiency scores reflect the enterprises' efficiencies when they face the same operational context, in this case the most favorable one given by the highest density, the smallest mean journeys lengths and private management. The results show that the companies improve their technical efficiency by 33% in average when they operate in a favorable context. This difference reflects the impact of the considered environmental variables (density, reforms, passengers and freight means journeys lengths) on the technical efficiency.

We will come back to the decomposition of the net technical efficiency measurement and the evolution of these efficiencies from one period to another when studying the effect of environmental variables on railways companies' efficiencies.

TABLE 3
SFA AND DEA AVERAGE EFFICIENCIES

	Firm	**Country**	N	**SFA**		**DEA**
				Gross	**Net**	
	All			0.457	0.872	0.583
1	CAMRAIL	Cameroon	11	0.647	0.922	0.637
2	CCFB	Mozambique	11	0.654	0.900	0.487
3	CDN	Mozambique	11	0.688	0.915	0.814
4	CEAR	Malawi	11	0.809	0.918	0.561
5	CFCO	Congo Brazzaville	11	0.388	0.797	0.398
6	CFM	Mozambique	11	0.835	0.937	0.875
7	CFMK	DRC	11	0.477	0.879	0.675
8	GRC	Ghana	11	0.788	0.934	0.727
9	KRC	Kenya	11	0.223	0.795	0.167
10	NRC	Nigeria	11	0.382	0.858	0.446
11	OCBN	Benin - Niger	11	0.657	0.901	0.825
12	RSZ	Zambia	11	0.481	0.879	0.433
13	SETRAG	Gabon	11	0.542	0.917	0.854
14	SITARAIL	Burkina Faso - Ivory Coast	9	0.300	0.823	0.280
15	SNCC	DRC	11	0.248	0.745	0.272
16	SPOORNET	South Africa	11	0.906	0.930	0.985
17	TRC	Tanzania	11	0.289	0.846	0.303
18	URC	Uganda	3	0.471	0.836	1.000

The estimations of parameters of the model show that the inputs variables are statistically significant and present the expected signs. We will study the optimum size of the network by examining later the scale elasticities. The temporal trend is not significant, this means that the sector has not experienced any major technological progress during the period 1995 – 2005.

The signs of the environmental variables parameters reflect the effect of these variables on the technical inefficiency. So a negative sign indicates a positive impact on the efficiency. The effect of the institutional reform seems insignificant to the performance of companies that have applied it. This can be explained by heterogeneity of these reforms and the diversity in their application. However, if we observe changes in the efficiency scores (annexe A) estimated after the year of the establishment of the PPPs, we see that there have been greater or lesser improvements for some companies and weaker or non-existent in others. Indeed, we observe that for the Malawian company CEAR which has undergone reform in 1999 and for the Zambian firm RSZ reformed in 2002, the effects of these reforms were not observed and the scores of efficiencies remained stable. This is also the case of the Cameroonian company CAMRAIL, for which the implementation of the institutional reform was hold in 1999, led to a decline in its technical efficiency. By contrast, the two firms of Mozambique, reformed in 2004 and 2005, CDN and CCFB increased their efficiencies respectively from 82% to 91% and from 51% to 71% in the year of their concession. The SITARAIL also has increased its efficiency by 18% in 1996 following its concession to a private consortium. If we simulate that all railway firms have experienced a concession, we see that the average gross efficiency 45.6% increase to the net efficiency under the condition of the concession 47.4% as reported in the first row of table 4.

As PPPs, users demand has an effect on the technical efficiency of the railway enterprises. The estimated parameters of the passengers and freight mean lengths variables are statistically significant and have a negative sign. This means that when these journeys are longs the operational context of the firm become unfavorable for its technical efficiency. Table 4 shows that the gross efficiencies, estimated by the method SFA, for companies that transport passengers and cargo on shorter journeys are greater than those transporting their users on longer journeys. This finding is also borne out clearly for the efficiencies estimated by DEA.

TABLE 4
SFA AND DEA EFFICIENCIES BY CATEGORIES

			SFA						DEA
	N	Scale elasticity	Gross	Net	MJTon Net	MJPas Net	Concession Net	Density Net	
All	18	-1.015	0.456	0.870	0.462	0.565	0.474	0.791	0.597
MJPas (km)									
< 250	6	-1.331	0.683	0.913	0.686	0.709	0.703	0.903	0.690
250 - 290	5	-1.306	0.508	0.864	0.511	0.577	0.527	0.825	0.659
> 290	7	-0.535	0.335	0.840	0.343	0.475	0.350	0.697	0.472
MJTon (km)									
< 320	5	-1.307	0.680	0.903	0.682	0.709	0.699	0.887	0.730
320 - 580	7	-0.886	0.461	0.861	0.464	0.550	0.481	0.799	0.633
> 580	6	-0.921	0.353	0.855	0.363	0.497	0.368	0.718	0.443
Density (line km by 1000 km² of area)									
< 3.75	8	-1.071	0.364	0.840	0.367	0.479	0.379	0.734	0.464
3.75 - 4.75	6	-0.936	0.520	0.897	0.536	0.630	0.542	0.827	0.609
> 4.75	4	-1.021	0.669	0.895	0.671	0.709	0.688	0.868	0.843
Size of the network (km)									
< 1000	9	-1.461	0.575	0.886	0.578	0.630	0.598	0.860	0.704
1000 - 1800	4	-1.132	0.490	0.888	0.495	0.597	0.498	0.834	0.556
> 1800	5	-0.118	0.318	0.830	0.327	0.459	0.335	0.667	0.435

The literature on the railways sector efficiency has proven in various analyses that the density of networks allows better technical efficiency. This is also valid for companies in sub-Saharan Africa as highlighted by the negative sign of the estimated parameter (table 2). We report in table 4 that enterprises with network densities higher than 4.75 km per 1000 km2 have an average technical efficiency estimated by SFA of 66.9% and an average efficiency estimated by DEA of 84.3%. On the other hand, enterprises with densities less than 3.75 have average efficiencies of 36.4% (SFA) and 46.4% (DEA).

At this level, we can define the most favorable operational context allowing a greater technical efficiency in the railway transport sector in sub-Saharan Africa. This context is which firms advantage the transport of passengers and cargo on shorter journeys. This could be reached by organizing interconnections transits and optimizing the utilisation of available productive resources. This context is even more favorable if the enterprises are subject to private management under good conditions like what happens in CDN and SITARAIL and operate on a network with a high density relatively to the area of activities.

We note also (table 4) that companies with the largest networks are those that have the worst technical efficiency scores. For firms with network lengths less than 1000 km, the estimated efficiencies by SFA and DEA are respectively 57.5% and 70.4%. This is due to the importance of maintenance costs for the large networks which means, in this context of developing countries with limited resources, an insufficient maintenance. From the production point of view, we observe that companies with the largest networks have the smallest scale elasticities. Table 4 shows that the highest average scale elasticities correspond to companies with networks lengths less than 1000 km. The observation of the scale elasticities for all firms shows that the optimal size of railway network is approximately 1000 km. This means that we must encourage the policy of subdivision of large networks before their concession as what has been done in several Latin American railways firms (Estache and al., 2006).

We have also sought the effect of the dominance of freight transport in companies on their efficiency. We do not find any clear impact. This could be explained by the fact that the freight transport is a major part of these railways companies.

CONCLUSION

In this paper, the application of a translog specification for a stochastic distance function taking into account the specificities of users, demand has allowed to reflect the importance of the operational context of African railways companies on their technical efficiency. Indeed, measures of gross and net efficiencies show that if all firms benefit from the favorable operational environment, their average efficiency increases by 33%. A favorable demand structure is which the passengers and freight mean journeys lengths are small. This enables companies to optimize their utilisation of available productive resources by the mobilization of these resources on long journeys and therefore long periods of time to serve a minority of customers. These results imply that African companies should encourage shorter transport journeys by establishing transits through interconnections in the hub points of their networks.

The operational environment considers also the institutional reforms that African railway firms face. These reforms have mostly taken the form of concession. Analyses of this context's effects show that some companies, notably those of Mozambique, have significantly increased their technical efficiencies from the implementation of these PPPs.

Other features help to explain the technical efficiency scores estimated by SFA and DEA methods. It seems in fact that the most efficient companies are those characterised by high networks densities. The sizes of rail networks themselves contribute to the explanation of the relative efficiencies of sub-Saharan companies. Indeed, the less efficient firms have the greatest networks. We explain that by the lack of maintenance of these large networks. In this sense, the study of scale elasticities shows that the optimum size of the network is approximately 1000 km. This result implies that the actors in charge of infrastructure in Africa should encourage the subdivision of networks to obtain optimal size companies before putting them in concession.

ENDNOTES

1. Passengers kilometers and tons kilometers are obtained by multiplying passengers and fret transported by a real or average length of each trip.
2. For more the proprieties about the production set P(x) see Fare et al. (1994)
3. Min (minimum) is used to define the output distance function rather than inf (infimum). This allows to assume the absence of the possibility that the minimum may not exist (i.e., $\delta = +\infty$ is possible).
4. Table 1 reports the data mean values for each railway company for the period 1995-2005.

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APPENDIX
SFA AND DEA EFFICIENCY SCORES

Year	PPPs	SFA Gross	SFA Net	DEA
CAMRAIL (Cameroon)				
1995	0	0.695	0.926	0.687
1996	0	0.687	0.925	0.673
1997	0	0.661	0.923	0.619
1998	0	0.612	0.917	0.538
1999	1	0.571	0.914	0.535
2000	1	0.730	0.931	0.804
2001	1	0.701	0.927	0.719
2002	1	0.645	0.921	0.622
2003	1	0.629	0.919	0.607
2004	1	0.624	0.919	0.609
2005	1	0.599	0.916	0.594
CCFB (Mozambique)				
1995	0	0.682	0.909	0.420
1996	0	0.765	0.924	0.560
1997	0	0.739	0.920	0.483
1998	0	0.643	0.899	0.265
1999	0	0.563	0.878	0.205
2000	0	0.613	0.892	0.243
2001	0	0.698	0.910	0.341
2002	0	0.735	0.917	0.568
2003	0	0.514	0.861	0.271
2004	1	0.711	0.906	1.000
2005	1	0.634	0.888	1.000
CDN (Mozambique)				
1995	0	0.580	0.898	0.455
1996	0	0.535	0.890	0.474
1997	0	0.650	0.910	0.999
1998	0	0.623	0.900	0.690
1999	0	0.656	0.904	0.683
2000	0	0.737	0.919	1.000
2001	0	0.745	0.921	0.929
2002	0	0.753	0.922	0.914
2003	0	0.717	0.916	0.809
2004	0	0.829	0.937	1.000
2005	1	0.911	0.956	1.000
CEAR (Malawi)				
1995	0	0.815	0.921	0.473
1996	0	0.795	0.917	0.451
1997	0	0.801	0.918	0.540
1998	0	0.796	0.916	0.543
1999	1	0.811	0.917	0.527
2000	1	0.837	0.924	0.590
2001	1	0.831	0.923	0.614
2002	1	0.821	0.920	0.614

Year	PPPs	SFA Gross	SFA Net	DEA
CFCO (Congo)				
1995	0	0.630	0.917	0.570
1996	0	0.694	0.926	0.738
1997	0	0.566	0.910	0.506
1998	0	0.525	0.905	0.450
1999	0	0.117	0.376	0.034
2000	0	0.444	0.874	0.291
2001	0	0.557	0.908	0.458
2002	0	0.453	0.884	0.283
2003	0	0.368	0.855	0.220
2004	0	0.462	0.893	0.358
2005	0	0.516	0.903	0.468
CFM (Mozambique)				
1995	0	0.828	0.934	0.734
1996	0	0.858	0.941	0.864
1997	0	0.881	0.946	1.000
1998	0	0.890	0.948	1.000
1999	0	0.891	0.949	0.988
2000	0	0.854	0.940	0.701
2001	0	0.843	0.938	0.808
2002	0	0.812	0.932	0.791
2003	0	0.733	0.917	0.860
2004	0	0.777	0.926	0.882
2005	0	0.844	0.940	1.000
CFMK (DRC)				
1995	0	0.444	0.875	0.444
1996	0	0.673	0.918	1.000
1997	0	0.664	0.918	1.000
1998	0	0.634	0.914	0.976
1999	0	0.485	0.893	0.729
2000	0	0.492	0.886	0.578
2001	0	0.467	0.876	0.484
2002	0	0.459	0.877	0.560
2003	0	0.366	0.836	0.379
2004	0	0.302	0.789	0.271
2005	0	0.561	0.901	1.000
GRC (Ghana)				
1995	0	0.796	0.930	0.845
1996	0	0.796	0.930	0.797
1997	0	0.802	0.931	0.808
1998	0	0.726	0.920	0.464
1999	0	0.782	0.929	0.564
2000	0	0.716	0.923	0.451
2001	0	0.652	0.924	0.474
2002	0	0.835	0.940	0.728

Year	PPPs	SFA Gross	SFA Net	DEA
2003	1	0.807	0.916	0.598
2004	1	0.801	0.914	0.609
2005	1	0.792	0.911	0.614
KRC (Kenya)				
1995	0	0.248	0.796	0.164
1996	0	0.199	0.743	0.143
1997	0	0.232	0.814	0.172
1998	0	0.213	0.775	0.131
1999	0	0.261	0.814	0.152
2000	0	0.178	0.754	0.164
2001	0	0.189	0.770	0.175
2002	0	0.217	0.796	0.175
2003	0	0.301	0.843	0.177
2004	0	0.252	0.833	0.232
2005	0	0.215	0.823	0.153
NRC (Nigeria)				
1995	0	0.633	0.917	0.704
1996	0	0.559	0.904	0.640
1997	0	0.605	0.918	0.718
1998	0	0.187	0.713	0.183
1999	0	0.333	0.880	0.437
2000	0	0.515	0.896	0.638
2001	0	0.346	0.832	0.314
2002	0	0.274	0.826	0.241
2003	0	0.521	0.897	0.396
2004	0	0.549	0.902	0.428
2005	0	0.310	0.804	0.207
OCBN (Benin-Niger)				
1995	0	0.795	0.930	1.000
1996	0	0.842	0.939	1.000
1997	0	0.750	0.923	0.946
1998	0	0.772	0.926	0.941
1999	0	0.783	0.927	0.966
2000	0	0.762	0.924	0.796
2001	0	0.695	0.911	0.611
2002	0	0.691	0.909	0.594
2003	0	0.701	0.912	0.625
2004	0	0.577	0.885	0.596
2005	0	0.330	0.756	1.000
RSZ (Zambia)				
1995	0	0.475	0.892	0.328
1996	0	0.620	0.914	0.421
1997	0	0.759	0.930	0.560
1998	0	0.563	0.905	0.385
1999	0	0.550	0.903	0.375
2000	0	0.568	0.905	0.377
2001	0	0.604	0.912	0.455

Year	PPPs	SFA Gross	SFA Net	DEA
2003	0	0.878	0.947	0.948
2004	0	0.887	0.949	1.000
2005	0	0.877	0.947	0.916
SITARAIL (Burkina Faso Ivory Coast)				
1995	0	0.166	0.642	0.094
1996	1	0.347	0.861	0.280
1997	1	0.321	0.851	0.256
1998	1	0.273	0.823	0.192
1999	1	0.286	0.820	0.217
2000	1	0.302	0.839	0.240
2001	1	0.348	0.871	0.304
2002	1	0.318	0.857	0.261
2003	1	0.660	0.914	0.673
SNCC (DRC)				
1995	0	0.079	0.364	0.079
1996	0	0.157	0.689	0.184
1997	0	0.169	0.678	0.158
1998	0	0.338	0.841	0.308
1999	0	0.597	0.907	0.496
2000	0	0.513	0.895	0.385
2001	0	0.428	0.884	0.309
2002	0	0.410	0.886	0.309
2003	0	0.338	0.864	0.233
2004	0	0.376	0.883	0.287
2005	0	0.405	0.875	0.243
SPOORNET (South Africa)				
1995	0	0.896	0.925	0.964
1996	0	0.919	0.937	0.937
1997	0	0.915	0.936	1.000
1998	0	0.911	0.935	1.000
1999	0	0.913	0.937	0.963
2000	0	0.909	0.932	0.982
2001	0	0.906	0.929	1.000
2002	0	0.897	0.924	1.000
2003	0	0.893	0.922	0.992
2004	0	0.899	0.925	0.998
2005	0	0.905	0.929	1.000
TRC (Tanzania)				
1995	0	0.412	0.881	0.479
1996	0	0.375	0.869	0.387
1997	0	0.322	0.840	0.289
1998	0	0.356	0.842	0.273
1999	0	0.240	0.824	0.263
2000	0	0.256	0.841	0.278
2001	0	0.267	0.843	0.271

Year	PPPs	SFA Gross	SFA Net	DEA
2002	1	0.617	0.909	0.477
2003	1	0.637	0.911	0.606
2004	1	0.287	0.794	0.456
2005	1	0.241	0.739	0.321
SETRAG (Gabon)				
1995	0	0.626	0.928	0.848
1996	0	0.604	0.925	0.809
1997	0	0.593	0.924	0.820
1998	0	0.557	0.919	0.833
1999	0	0.537	0.916	0.832
2000	0	0.572	0.921	0.877
2001	0	0.562	0.920	0.856
2002	0	0.474	0.905	0.790
2003	0	0.478	0.906	0.794
2004	0	0.495	0.910	0.934
2005	1	0.517	0.909	1.000

Year	PPPs	SFA Gross	SFA Net	DEA
2002	0	0.277	0.851	0.288
2003	0	0.285	0.856	0.288
2004	0	0.255	0.841	0.267
2005	0	0.235	0.824	0.245
URC (Uganda)				
1995	0	0.708	0.913	1.000
1996	0	0.562	0.880	1.000
1997	0	0.315	0.737	1.000

PPPs: Institutional reform