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Abstract

This paper evaluates the effect of access to improved water sources and sanitation on 41 sub-Saharan African (SSA) countries' economic efficiency and growth. For this reason Data Envelopment Analysis (DEA), bootstrap techniques and probabilistic approaches are used. The empirical results indicate that SSA countries' economic efficiency is positively influenced by the access of population both on improved water sources and sanitation. Finally, when the provision of access to improved water sources is provided to more than 50% of the population, the positive effect on countries' economic efficiency is much greater compared to the effect of providing sustainable access to improved sanitation to the same proportion of population.

Keywords: Water and anitation, Sub-Saharan African countries, economic efficiency, DEA, nonparametric techniques.

JEL Classification: C14, C69, O10, O55

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1. Introduction

According to UNICEF and the World Health Organization (WHO) an estimated 1.2 billion people are without access to safe drinking water, and 2.5 billion are without adequate sanitation (UNICEF and World Health Organization, 2008, pp. 3–5). In addition Water Aid suggests that water and sanitation produce benefits which are not always bounded on reducing disease and the burden of long-distance water collection (WaterAid, 2001, p. 27). The problem of access to improved water and sanitation is more emphatic on sub-Saharan African (hereafter SSA) countries and most of the times is associated with weak state support, unreliable and contested indicators, poor sectoral coordination and fragmented donor efforts (Gutierrez, 2007).

Furthermore, Agenor (2008) suggests that health provision interrelates to water and sanitation. With inadequate water, sanitation and waste disposal facilities, hospitals cannot provide the services that are expected from them. In addition Cain (1997) suggests that static benefit of improved sanitation is customarily measured by reduced mortality and the ability to realize scale and agglomeration economies. According to Showers (2002) much of the research is on the theory and practices of water pricing, distribution and sanitation infrastructure but no emphasis has been given to the implications of both associated rural landscapes and urban planning and policy. Showers (2002) suggests that the boundaries drawn on a map are not urban area's true boundaries, but the ones defined by water extraction and disposal.

This paper in contrast with the majority of the empirical studies tries to identify and measure separately the effect of access to improved water sources and access to sanitation on SSA countries' economic efficiency and growth. For the first time (to our knowledge) this paper applies the latest advances in DEA techniques as has been extensively analysed by Daraio and Simar (2005; 2007) in order to capture the effect of water and sanitation on SSA countries' economic efficiency. In addition bootstrap techniques for bias correction have been applied in order to improve the efficiency scores obtained (Simar and Wilson, 1998; 2000). In that respect this study employs conditional measurements of efficiency, using different smoothing techniques. Hence, by creating new conditional and unbiased estimators this study provides strong evidences of countries' economic performance levels conditioned to the accessibility of improved water sources and sanitation. As such the effect of the related investment policies can be separately established and quantified.

The structure of this study is the following. Section 2 reviews the problem in terms of exploring the relative research efforts carried out sofar. Section 3 presents the data used and discusses analytically the proposed non-parametric techniques. Section 4 refers to the empirical results derived and the last section concludes the paper.

2. Literature Review

Theoretical literature on endogenous economic growth theory concentrates on public expenditure and their effect on economic growth. In addition empirical research has established the link of the size of public expenditure and its allocation with economic growth (Gupta and Barman, 2009). According to Aschauer (1989, 2000) public expenditure on infrastructure has a significant impact on the productivity of private capital. In addition health expenditure is argued to have a positive impact on economic growth (Bloom et al. 2004; Sala-i-Martin et al., 2004). Whereas Lavy et al. (1996) and Lee et al. (1997) suggest that infrastructural facilities, like clean water, sanitation, electricity, etc., lead to an improvement in the health capital of workers which in turn has a direct impact on economic growth.

The access to improved water sources and sanitation is related to health and survival to human capital (Pradhan et al., 2003; Mangyo, 2008; Tang et al., 2008;

Mishra and Newhouse, 2009). Additionally in the ‘‘new” growth theory of Romer (1990) and Barro (1991, 1997) human capital is playing an important role in growth. As such the provision of water and sanitation has a direct impact on SSA countries' growth. Moreover, investments on infrastructure by public enterprises and especially by the central government have a positive and statistically significant effect on economic growth (Barro, 1991; Easterly and Rebelo, 1993; Aschauer, 2000; Milbourne et al., 2003). Most of the studies examining the investments of water and sanitation on SSA countries approach the subject as a unified infrastructure investment problem linked to SSA countries' economic growth. That is mainly because infrastructure is defined as capital devoted to streets and highways, sanitation and sewage, and electric, gas, and water utilities (Holtz-Eakin, 1993; Holtz-Eakin and Schwartz, 1995).

However, according to Cain (1997) water and sanitation is a twofold problem: “When water is brought into a home/ city it has to be removed. Sewage disposal poses a second, no less critical problem. The need for a sanitation strategy has faced homes and cities at every time and place in history” (p.127). Most of the time this is a unified approach with water supply and sewage disposal however in most SSA countries the problem of a unified approach to the problem remains. Therefore, the effect on SSA countries economic efficiency and growth hasn't yet been tested and quantified separately.

In addition Fischer et al. (1998) point out that the economic performance of several African countries has been mainly obtained by the removal of market distortions and to a smaller extent by structural change. However, higher investment rates have been absent from African countries economic development. According to Berthélemy and Söderling (2001) capital accumulation was the reason behind Africa's rapid growth between the periods of 1960-1970. But the instability of high rates of investment caused by the governments due to lack of economic diversification and poor policy environment was a major obstacle of African countries' economic performance (Mkandawire, 2001). Those imperfections have been mentioned by Sleuwaegen and Goedhuys (2003) especially for the case of SSA countries indicating that only formal and large-scale firms are in advantageous position due to fierce competition for resources which in turn produces a major growth barrier. Finally, Akyüz and Gore (2001) suggest that two are the main reasons behind Africa's poor economic performance. Namely the lack of outward-oriented policies as well as the lack of openness and intersectoral price distortions and the institutional and structural constrains in impeding economic growth.

Given the complexity and the "special" conditions existing on SSA countries the paper uses DEA methodology in order to measure SSA countries' relative economic efficiency. Based on the neoclassical growth model introduced by Solow (1956, 1957) which indicates that economic growth is determined by the stocks of capital and labour, our paper measures SSA countries' economic efficiencies. Similarly several studies using DEA methodology have measured countries economic efficiencies in different research contexts (Halkos and Tzeremes, 2009a, 2009b, 2009c, 2009d). In that respect our paper will be able first to measure SSA countries' economic performance and then to apply the effect of water and sanitation on the obtained countries' performance in order to produce a quantified result of the effect under examination.

3. Data and Methodology

3.1. Data

The paper measures countries' economic efficiency based on a production function using two inputs and one output. We use data for 41 SSA countries[1] for 2002 as has been provided by the World Bank Africa Database (2006). The inputs used are gross fixed capital formation (%GDP) and labour force (total, millions) whereas the output used is real GDP[2]. Finally, the external (or environmental) variables used are: the population with sustainable access to improved water source (%) (Z1) and the population with sustainable access to improved sanitation (%) (Z2).

3.2. Performance measurements

Based on the work of Koopmans (1951) and Debreu (1951) the production set Ψ constraints the production process and is the set of physically attainable points (x, y) :

$$\Psi = \left\{ (x, y) \in \Re_{+}^{N+M} \middle| x \ \ can \ \ produce \ \ y \right\} \tag{1},$$

where $x \in \Re_{+}^{N}$ is the input vector and $y \in \Re_{+}^{M}$ is the output vector. The first DEA estimator was introduced from Farrell (1957) measuring technical efficiency. For the input oriented efficiency score a country operating at the level (x, y) is defined as:

$$\theta(x, y) = \inf \left\{ \theta \middle| (\theta x, y) \in \Psi \right\} \tag{2}.$$

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[1] Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Dem. Rep., Congo Rep., Côte d'Ivoire, Eritrea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, São Tomé and Principe, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda and Zambia. There were excluded from our analysis due to missing data the countries of: Djibouti, Equatorial Guinea, Ethiopia, Seychelles, Somalia, Zimbabwe and Sudan.

[2] GDP has been converted to U.S. dollars using constant (2000) exchange rates. For countries where the official exchange rate does not effectively reflect the rate applied to actual foreign exchange transactions, an alternative currency conversion factor has been used (World Bank Africa Database 2006, p.112).

Furthermore, DEA became more popular when introduced by Charnes et al. (1978) in order to estimate Ψ allowing for constant returns to scale (CRS model). Later, Banker et al. (1984) introduced a DEA estimator allowing for variable returns to scale (VRS model). In this paper we use input oriented models since the decision maker through different governmental policies can have greater control over the inputs compared to the outputs used. The CRS model developed by Charnes et al. (1978) can be calculated as:

$$\hat{\Psi}_{CRS} = \left\{ \begin{array}{l} (x,y) \in \Re^{N+M} \left| y \leq \sum_{i=1}^{n} \gamma_i y_i ; x \geq \sum_{i=1}^{n} \gamma_i x_i \quad for \quad (\gamma_1, \ldots \gamma_n) \right. \\ such \quad that \quad \gamma_i \geq 0, i = 1, \ldots n \end{array} \right\} \quad (3).$$

The VRS model developed by Banker et al. (1984) allowing for variable returns to scale can then be calculated as:

$$\hat{\Psi}_{VRS} = \left\{ \begin{array}{l} (x,y) \in \Re^{N+M} \left| y \leq \sum_{i=1}^{n} \gamma_i y_i ; x \geq \sum_{i=1}^{n} \gamma_i x_i \quad for \quad (\gamma_1, \ldots \gamma_n) \right. \\ such \quad that \quad \sum_{i=1}^{n} \gamma_i = 1; \ \gamma_i \geq 0, i = 1, \ldots n \end{array} \right\} \quad (4).$$

Then in order to obtain the corresponding input oriented DEA estimators of efficiency scores we need to plug in $\hat{\Psi}_{CRS}$ and $\hat{\Psi}_{VRS}$ respectively in equation (2) presented previously.

3.3 Bias correction using the bootstrap technique

Simar and Wilson (1998, 2000, 2008) suggest that DEA estimators were shown to be biased by construction. They introduced an approach based on bootstrap techniques (Efron 1979) to correct and estimate the bias of the DEA efficiency indicators. More analytically and in order to build a bootstrap sample of the original DEA scores we follow a number of steps[3]. First, we draw a random sample of size n with replacement from the set of the $2n$ reflected DEA scores $\left\{ \hat{\delta}_i ; i = 1, \ldots, n \right\}$ such

[3] For more discussion regarding the bootstrap techniques see Simar and Wilson (1998, 2000, 2008)

as $\left\{2-\hat{\delta}_i,...,2-\hat{\delta}_n,\hat{\delta}_1,...,\hat{\delta}_n\right\}$ obtaining $\left\{\tilde{\delta}_i^*; i=1,...,n\right\}$. Then we smooth the naïve bootstrap $\tilde{\delta}_i^*$ by adding a small perturbation and a correction of the resampled sequence is applied. A small perturbation $h\varepsilon_i$ is added to $\tilde{\delta}_i^*$, where h[4] denotes the bandwidth parameter and ε_i is drawn *i.i.d.* from a standard normal distribution, to generate the smoothed pseudo-efficiency $\tilde{\tilde{\delta}}^*$. Such that: $\tilde{\tilde{\delta}}^* = \tilde{\delta}_i^* + h\varepsilon_i, i=1,...,n.$

Next we need to correct $\tilde{\tilde{\delta}}^*$ for the mean and the variance of the smoothed values. Let δ^{**} be the final corrected smoothed resample efficiencies such as: $\delta_i^{**} = \bar{\tilde{\delta}}_i^* + \frac{\tilde{\tilde{\delta}}^* - \bar{\tilde{\delta}}_i^*}{\sqrt{1+h^2/s^{*2}}}$, where $\bar{\tilde{\delta}}_i^*$ and s^{*2} are the empirical mean and variance of the n values $\tilde{\delta}_i^*$. Due to the fact that the efficiency measure is bounded on the unit interval we reflect the values smaller than one to generate δ_i^* for $i=1,...,n$:

$\delta_i^* \begin{cases} 2-\delta_i^{**} & if \quad \delta_i^{**} < 1 \\ \delta_i^{**} & otherwise \end{cases}$. As next step, a bootstrapped sample X^* is obtained as:

$$X^* = \left\{ \left(X_i^*, Y_i^*\right) \middle| Y_i^* = Y_i \quad and \quad X_i^* = \frac{\delta_i^*}{\hat{\delta}_i} X_i, i=1,...,n \right\}.$$

[4] The calculation of h is based on the "normal reference rule" introduced by Silverman (1986, p.47-48) and it can be calculated as $h = 1.06\min\left(s_n, r_n/1.34\right)n^{-1/5}$. Where s_n is the empirical standard deviation of the n values $\hat{\delta}_i$ and r_n is the interquartile range of the empirical distribution of the n data points, respectively.

Finally, we redo the above five steps B times[5] , as such we end up with B bootstrap samples X_B^*.

Therefore, the bootstrap bias estimate for the original DEA estimator $\hat{\theta}_{DEA}(x,y)$ can be calculated as:

$$\hat{BIAS}_B\left(\hat{\theta}_{DEA}(x,y)\right) = B^{-1}\sum_{b=1}^{B}\hat{\theta}^*_{DEA,b}(x,y) - \hat{\theta}_{DEA}(x,y) \qquad (5).$$

Furthermore, $\hat{\theta}^*_{DEA,b}(x,y)$ are the boot strap values and B is the number of bootstrap reputations. Then a biased corrected estimator of $\theta(x,y)$ can be calculated as:

$$\begin{aligned}\hat{\hat{\theta}}_{DEA}(x,y) &= \hat{\theta}_{DEA}(x,y) - \hat{BIAS}_B\left(\hat{\theta}_{DEA}(x,y)\right) \\ &= 2\hat{\theta}_{DEA}(x,y) - B^{-1}\sum_{b=1}^{B}\hat{\theta}^*_{DEA,b}(x,y)\end{aligned} \qquad (6).$$

However, according to Simar and Wilson (2008) this bias correction can create an additional noise and the sample variance of the bootstrap values $\hat{\theta}^*_{DEA,b}(x,y)$ need to be calculated. The calculation of the variance of the bootstrap values is illustrated below:

$$\hat{\sigma}^2 = B^{-1}\sum_{b=1}^{B}\left[\hat{\theta}^*_{DEA,b}(x,y) - B^{-1}\sum_{b=1}^{B}\hat{\theta}^*_{DEA,b}(x,y)\right]^2 \qquad (7).$$

We need to avoid the bias correction illustrated in (5) unless:

$$\frac{\left|\hat{BIAS}_B(\hat{\theta}_{DEA}(x,y))\right|}{\hat{\sigma}} > \frac{1}{\sqrt{3}} \qquad (8).$$

[5] According to Simar and Wilson (1998, 2000) B should be at least equal to 2000 in order to get a reasonable Monte-Carlo approximations even in the tails of the distribution.

Finally, the $(1-\alpha)$ x 100 - percent bootstrap confidence intervals can be obtained for $\theta(x,y)$ as:

$$\frac{1}{\hat{\delta}_{DEA}(x,y)-nc^{*}_{1-a/2}} \leq \theta(x,y) \leq \frac{1}{\hat{\delta}_{DEA}(x,y)-nc^{*}_{a/2}} \quad (9).$$

3.4. Testing the effect of external 'environmental' factors on the efficiency scores

In order to analyse the effect of sustainable access to improved water source (Z1) and sustainable access to improved sanitation (Z2) on the efficiency scores obtained we follow the probabilistic approach developed by Daraio and Simar (2005, 2007). They suggest that the joint distribution of (X,Y) conditional on the environmental factor Z=z defines the production process if Z=z. The efficiency measure can then be defined as:

$$\theta(x,y|z) = \inf\left\{ \theta \middle| F_X\left(\theta x|y,z\right) > 0 \right\} \quad (10),$$

where $Fx\left(x|y,z\right) = \Pr ob\left(X \leq x|Y \geq y, Z = z\right)$. Then a kernel estimator can be defined as follows:

$$\hat{F}_{X|Y,Z,n}\left(x|y,z\right) = \frac{\sum_{i=1}^{n} I\left(x_i \leq x, y_i \geq y\right) K\left(\left(z-z_i\right)/h\right)}{\sum_{i=1}^{n} I\left(y_i \geq y\right) K\left(\left(z-z_i\right)/h\right)} \quad (11),$$

where K(.) is the Epanechnikov kernel[6] and h is the bandwidth of appropriate size. Following, Bădin et al. (2010) we use a fully automatic data-driven approach for bandwidth selection based on the work of Hall et al. (2004) and Li and Racine (2004, 2007) least-squares cross-validation criterion (LSCV) which leads to bandwidths of optimal size for the relevant components of Z. This method is based on the principle of selecting a bandwidth that minimizes the integrated squared error of the resulting

[6] Other kernels from the family of continuous kernels with compact support can also be used.

estimate[7]. Li and Racine (2007) suggest that we have also to correct the resulting h by an appropriate scaling factor, that is $n^{-\frac{q}{(4+q+r)(4+r)}}$ where q is the dimension of Y and r is the dimension of Z [8]. Therefore, we can obtain a conditional DEA efficiency measurement defined as:

$$\hat{\theta}_{DEA}(x, y|z) = \inf\left\{\theta \middle| \hat{F}_{X|Y,Z,n}(\theta x|y, z) > 0\right\} \quad (12).$$

Then in order to establish the influence of an environmental variable on the efficiency scores obtained a scatter of the ratios $\frac{\hat{\theta}_n(x, y|z)}{\hat{\theta}_n(x, y)}$ against Z (in our case as mentioned there are the two external factors) and its smoothed non parametric regression lines it would help us to analyse the effect of Z on the efficiency scores. For this purpose we use the nonparametric regression estimator introduced by Nadaraya (1965) and Watson (1964) as:

$$\hat{g}(z) = \frac{\sum_{i=1}^{n} K(\frac{z - Z_i}{h})\left(\frac{\hat{\theta}_n(x, y|z)}{\hat{\theta}_n(x, y)}\right)}{\sum_{i=1}^{n} K(\frac{z - Z_i}{h})} \quad (13).$$

If this regression is increasing it indicates that Z is unfavourable to the countries' economic efficiency whereas if it is decreasing then it is favourable. When the Z is unfavourable then the environmental factor (in our case Z1 and Z2) acts like an extra undesired output to be produced demanding the use of more inputs in production activity. In the opposite case the environmental factor plays a role of a substitutive input in the production process giving the opportunity to save inputs in the activity of production.

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[7] See Bădin et al. (2010) for a Matlab routine that computes the bandwidth based on the LSCV criterion.

[8] For more information regarding LSCV criterion and its properties see Silverman (1986), Hall et al. (2004) and Li and Racine (2007).

4. Empirical Results

Measuring SSA countries' economic efficiency under the assumption of constant returns to scales (CRS model) the results reveal that efficient countries are reported to be Botswana, São Tomé and Principe and South Africa with efficiency score of 1 (or 100%). In addition table 1 provides us with the efficiency scores obtained after the correction of bias (see equation 6). However, we need to adopt the biased corrected results when standard deviation (std) is greater than the absolute value of the estimated bias (see equation 8). Therefore, the results indicate that in our analysis we need to adopt the biased corrected results (BC). In that case the ten countries with higher economic efficiency scores are reported to be Botswana (0.64), Mauritius (0.59), Gabon (0.571), São Tomé and Principe (0.545), South Africa (0.545), Namibia (0.474), Swaziland (0.342), Congo Rep. (0.201), Cape Verde (0.191) and Cameroon (0.147). Similarly, the ten countries with the lowest efficiency scores are reported to be: Chad (0.056), Liberia (0.066), Madagascar (0.058), Congo Dem. Rep. (0.056), Eritrea (0.05), Niger (0.046), Sierra Leone (0.043), Malawi (0.039), Guinea-Bissau (0.041) and Burundi (0.027).

Table 1 provides only the standard deviation and the lower and upper bounds of 95% bootstrapped confidence intervals of the biased corrected efficiency scores. The length of the interval reflects the uncertainty about the real value of the efficiency score of the country under consideration. In the same way table 1 provides the efficiency scores and the biased corrected efficiency scores when we are taking the effect of population with sustainable access to improved water source (%) (Z1) and the effect of population with sustainable access to improved sanitation (%) (Z2) on countries economic efficiency scores (CRS|z1 and CRS|z2). The results obtained taking into account the effect of Z1 and Z2 will be discussed later in our analysis.

able 1: Conditional and unconditional efficiency scores under the CRS assumption

Countries	CRS	BC	bias	std	LB	UB	CRS|z1	BC|z1	bias	std	LB	UB	CRS|z2	BC|z2	bias	std	LB	UB
Angola	0.212	0.132	-2.853	0.828	0.113	0.187	0.278	0.202	-1.348	0.346	0.167	0.265	0.309	0.213	-1.458	0.276	0.181	0.279
Benin	0.101	0.072	-4.048	2.936	0.059	0.094	0.210	0.165	-1.310	0.303	0.139	0.196	0.226	0.169	-1.497	0.332	0.142	0.207
Botswana	1.000	0.640	-0.562	0.027	0.546	0.812	0.825	0.521	-0.708	0.060	0.448	0.755	0.313	0.205	-1.697	0.357	0.176	0.281
Burkina Faso	0.068	0.047	-6.564	6.580	0.039	0.062	0.238	0.184	-1.251	0.364	0.151	0.226	0.231	0.172	-1.498	0.419	0.143	0.217
Burundi	0.027	0.016	-27.959	34.285	0.014	0.022	0.159	0.107	-3.094	1.074	0.092	0.145	0.157	0.102	-3.424	0.910	0.089	0.135
Cameroon	0.235	0.147	-2.552	0.712	0.126	0.209	0.290	0.208	-1.351	0.276	0.174	0.264	0.297	0.200	-1.627	0.268	0.172	0.258
Cape Verde	0.296	0.191	-1.858	0.292	0.164	0.243	0.457	0.312	-1.020	0.114	0.267	0.408	0.289	0.190	-1.811	0.297	0.165	0.250
Central African Republic	0.068	0.046	-7.227	5.967	0.039	0.060	0.232	0.177	-1.327	0.253	0.151	0.215	0.194	0.141	-1.934	0.423	0.121	0.175
Chad	0.056	0.040	-7.257	7.282	0.033	0.050	0.116	0.083	-3.474	1.435	0.071	0.104	0.087	0.060	-5.249	2.976	0.052	0.078
Comoros	0.110	0.063	-6.773	2.470	0.057	0.088	0.148	0.090	-4.403	1.462	0.080	0.129	0.094	0.056	-7.341	3.606	0.050	0.082
Congo, Dem. Rep.	0.056	0.033	-12.605	6.725	0.030	0.043	0.184	0.120	-2.910	0.741	0.105	0.165	0.200	0.129	-2.759	0.589	0.113	0.172
Congo, Rep.	0.286	0.201	-1.486	0.340	0.166	0.256	0.555	0.373	-0.875	0.086	0.320	0.493	0.383	0.248	-1.429	0.186	0.216	0.336
Côte d'Ivoire	0.206	0.128	-2.935	0.910	0.110	0.180	0.352	0.243	-1.285	0.228	0.204	0.321	0.336	0.229	-1.393	0.238	0.195	0.304
Eritrea	0.050	0.033	-10.200	12.554	0.028	0.044	0.106	0.075	-3.845	1.607	0.065	0.095	0.095	0.065	-4.887	1.943	0.057	0.082
Gabon	0.871	0.571	-0.602	0.039	0.481	0.754	0.747	0.488	-0.712	0.080	0.409	0.705	0.379	0.243	-1.482	0.250	0.209	0.339
Gambia	0.079	0.049	-7.805	4.887	0.042	0.066	0.112	0.071	-5.070	1.876	0.063	0.097	0.065	0.040	-9.673	5.595	0.036	0.056
Ghana	0.076	0.050	-6.888	6.155	0.042	0.069	0.162	0.120	-2.131	0.866	0.100	0.153	0.175	0.126	-2.219	0.751	0.106	0.161
Guinea	0.104	0.072	-4.351	2.879	0.059	0.096	0.381	0.283	-0.910	0.161	0.234	0.359	0.355	0.256	-1.096	0.182	0.215	0.328
Guinea-Bissau	0.041	0.023	-19.298	13.437	0.021	0.031	0.062	0.036	-11.279	9.735	0.033	0.055	0.057	0.033	-12.514	9.206	0.030	0.048
Kenya	0.119	0.070	-5.833	2.093	0.063	0.095	0.075	0.049	-6.995	3.527	0.044	0.066	0.069	0.044	-8.135	3.784	0.039	0.057
Lesotho	0.158	0.106	-3.110	0.859	0.090	0.133	0.240	0.165	-1.869	0.455	0.139	0.213	0.166	0.111	-3.007	1.038	0.095	0.149
Liberia	0.066	0.039	-10.409	7.046	0.035	0.053	0.271	0.189	-1.611	0.329	0.160	0.243	0.272	0.186	-1.694	0.296	0.159	0.238
Madagascar	0.058	0.037	-9.638	7.482	0.032	0.049	0.263	0.186	-1.588	0.420	0.155	0.247	0.199	0.142	-2.040	0.554	0.120	0.179
Malawi	0.039	0.024	-15.653	15.028	0.022	0.032	0.158	0.115	-2.367	0.753	0.098	0.144	0.174	0.125	-2.258	0.600	0.108	0.156
Mali	0.071	0.049	-6.154	6.307	0.041	0.065	0.250	0.192	-1.202	0.330	0.158	0.238	0.173	0.131	-1.841	0.582	0.110	0.161
Mauritania	0.120	0.083	-3.684	1.780	0.070	0.107	0.299	0.222	-1.158	0.177	0.190	0.276	0.246	0.173	-1.696	0.289	0.150	0.218
Mauritius	0.884	0.590	-0.563	0.037	0.494	0.763	1.000	0.588	-0.701	0.036	0.526	0.864	1.000	0.575	-0.740	0.034	0.516	0.836
Mozambique	0.067	0.046	-6.969	8.084	0.038	0.062	0.153	0.117	-2.000	0.902	0.096	0.145	0.148	0.109	-2.418	1.039	0.091	0.138
Namibia	0.690	0.474	-0.660	0.057	0.395	0.597	0.334	0.224	-1.483	0.210	0.193	0.299	0.436	0.274	-1.358	0.158	0.240	0.375
Niger	0.046	0.030	-11.552	11.573	0.026	0.040	0.185	0.141	-1.685	0.499	0.118	0.173	0.193	0.143	-1.796	0.481	0.121	0.177
Nigeria	0.192	0.109	-3.944	1.012	0.099	0.157	0.126	0.079	-4.741	2.259	0.068	0.111	0.106	0.066	-5.730	2.629	0.058	0.091
Rwanda	0.068	0.047	-6.479	5.922	0.039	0.061	0.165	0.129	-1.702	0.501	0.108	0.154	0.189	0.144	-1.673	0.472	0.121	0.176
São Tomé and Principe	1.000	0.545	-0.834	0.030	0.508	0.781	1.000	0.585	-0.709	0.040	0.515	0.881	1.000	0.575	-0.740	0.034	0.516	0.841
Senegal	0.137	0.093	-3.405	2.019	0.077	0.127	0.228	0.178	-1.214	0.321	0.147	0.215	0.286	0.209	-1.285	0.267	0.175	0.264
Sierra Leone	0.043	0.027	-14.316	18.423	0.023	0.038	0.169	0.124	-2.143	0.687	0.105	0.156	0.169	0.121	-2.352	0.637	0.103	0.152
South Africa	1.000	0.545	-0.834	0.028	0.508	0.765	1.000	0.583	-0.716	0.038	0.515	0.866	1.000	0.577	-0.734	0.037	0.516	0.857
Swaziland	0.500	0.342	-0.919	0.077	0.292	0.419	0.647	0.444	-0.706	0.071	0.372	0.587	0.456	0.303	-1.107	0.149	0.259	0.409
Tanzania	0.074	0.044	-8.968	5.508	0.039	0.060	0.130	0.085	-4.032	1.476	0.074	0.113	0.142	0.091	-3.906	1.280	0.079	0.121
Togo	0.074	0.052	-5.924	4.628	0.043	0.067	0.226	0.174	-1.316	0.264	0.148	0.209	0.199	0.146	-1.823	0.407	0.125	0.180
Uganda	0.077	0.050	-7.242	5.856	0.042	0.068	0.052	0.035	-9.543	9.841	0.030	0.047	0.073	0.050	-6.295	3.771	0.044	0.065
Zambia	0.094	0.066	-4.558	3.794	0.054	0.088	0.266	0.198	-1.276	0.259	0.166	0.243	0.195	0.145	-1.789	0.496	0.122	0.179

Our paper also measures SSA countries' economic efficiency using another popular DEA formulation which allows for variable returns to scales (VRS) (see equations 2 and 4). Table 2 provides the results obtained when allowing for variable returns to scale. The efficient countries (i.e. with efficiency score equals to 1 or 100%) are Botswana, Comoros, Liberia, Mauritius, São Tomé and Principe and South Africa. As can be realised Botswana, São Tomé and Principe and South Africa appear to be also efficient under the constant returns to scale assumption. Furthermore, the ten countries with the lowest efficiency scores are Rwanda (0.321), Nigeria (0.315), Tanzania (0.287), Zambia (0.281), Burkina Faso (0.274), Mali (0.274), Uganda (0.269), Ghana (0.258), Mozambique (0.182) and Chad (0.172). As in the case of CCR model we need to adopt the biased corrected results when standard deviation (std) is greater than the absolute value of the estimated bias (see equation 8).

Thus, the results indicate that in our analysis (and under the assumption of variable returns to scale) we need to adopt the biased corrected results (BC). The countries with the highest efficiency scores are Guinea-Bissau (0.804), Liberia (0.8), Mauritius (0.776), Comoros (0.731), Botswana (0.729), Swaziland (0.712), Namibia (0.712), Gabon (0.691), Cape Verde (0.681), São Tomé and Principe (0.67) and South Africa (0.668). At the same time the countries with the lowest efficiency scores are reported to be Rwanda (0.272), Tanzania (0.249), Zambia (0.242), Nigeria (0.238), Uganda (0.234), Mali (0.231), Burkina Faso (0.23), Ghana (0.223), Mozambique (0.153) and Chad (0.144).

Table 2: Conditional and unconditional efficiency scores under the VRS assumption

Countries	VRS	BC	bias	std	LB	UB	VRS|z1	BC|z1	bias	std	LB	UB	VRS|z2	BC|z2	bias	std	LB	UB
Angola	0.415	0.332	-0.608	0.072	0.285	0.399	0.432	0.357	-0.486	0.043	0.312	0.415	0.460	0.373	-0.511	0.045	0.324	0.443
Benin	0.377	0.328	-0.399	0.039	0.287	0.367	0.411	0.354	-0.395	0.031	0.314	0.400	0.415	0.351	-0.438	0.031	0.313	0.399
Botswana	1.000	0.729	-0.371	0.024	0.613	0.962	0.830	0.625	-0.395	0.042	0.506	0.802	0.534	0.419	-0.517	0.052	0.355	0.512
Burkina Faso	0.274	0.230	-0.711	0.110	0.200	0.265	0.382	0.333	-0.388	0.035	0.292	0.370	0.379	0.328	-0.410	0.041	0.287	0.369
Burundi	0.736	0.639	-0.207	0.013	0.550	0.721	0.754	0.640	-0.237	0.015	0.551	0.740	0.749	0.626	-0.260	0.016	0.541	0.726
Cameroon	0.369	0.287	-0.773	0.138	0.242	0.354	0.407	0.343	-0.462	0.043	0.299	0.393	0.416	0.341	-0.530	0.059	0.293	0.403
Cape Verde	0.890	0.681	-0.344	0.022	0.569	0.852	0.939	0.730	-0.305	0.016	0.620	0.896	0.881	0.680	-0.337	0.019	0.581	0.852
Central African Republic	0.502	0.428	-0.345	0.026	0.372	0.485	0.545	0.464	-0.322	0.020	0.408	0.525	0.525	0.440	-0.368	0.026	0.385	0.508
Chad	0.172	0.144	-1.153	0.249	0.126	0.166	0.201	0.169	-0.938	0.159	0.150	0.194	0.187	0.158	-1.000	0.211	0.137	0.181
Comoros	1.000	0.731	-0.369	0.019	0.622	0.963	1.000	0.732	-0.365	0.019	0.630	0.952	1.000	0.742	-0.347	0.016	0.640	0.950
Congo, Dem. Rep.	0.562	0.499	-0.225	0.018	0.430	0.554	0.631	0.555	-0.217	0.015	0.485	0.619	0.636	0.554	-0.232	0.018	0.479	0.627
Congo, Rep.	0.493	0.395	-0.503	0.038	0.347	0.475	0.658	0.527	-0.378	0.034	0.442	0.638	0.544	0.427	-0.505	0.048	0.364	0.521
Côte d'Ivoire	0.543	0.460	-0.330	0.029	0.394	0.532	0.593	0.495	-0.334	0.027	0.428	0.574	0.589	0.491	-0.340	0.028	0.423	0.573
Eritrea	0.363	0.304	-0.533	0.065	0.262	0.350	0.377	0.315	-0.522	0.054	0.273	0.362	0.376	0.314	-0.519	0.051	0.276	0.362
Gabon	0.909	0.691	-0.348	0.030	0.569	0.886	0.778	0.608	-0.360	0.044	0.486	0.758	0.565	0.434	-0.532	0.053	0.365	0.542
Gambia	0.540	0.420	-0.529	0.054	0.358	0.526	0.559	0.441	-0.478	0.045	0.377	0.537	0.545	0.431	-0.485	0.041	0.372	0.525
Ghana	0.258	0.223	-0.612	0.091	0.194	0.252	0.280	0.235	-0.682	0.090	0.207	0.272	0.288	0.238	-0.732	0.090	0.209	0.279
Guinea	0.376	0.315	-0.511	0.057	0.275	0.365	0.562	0.482	-0.294	0.020	0.421	0.545	0.546	0.466	-0.313	0.023	0.405	0.530
Guinea-Bissau	0.972	0.804	-0.214	0.010	0.691	0.933	0.972	0.791	-0.236	0.010	0.685	0.939	0.972	0.793	-0.231	0.009	0.697	0.926
Kenya	0.351	0.297	-0.521	0.079	0.251	0.343	0.315	0.275	-0.465	0.067	0.239	0.310	0.309	0.266	-0.520	0.081	0.230	0.304
Lesotho	0.386	0.301	-0.724	0.111	0.252	0.369	0.416	0.331	-0.618	0.078	0.280	0.400	0.384	0.303	-0.691	0.087	0.258	0.365
Liberia	1.000	0.800	-0.251	0.009	0.704	0.962	1.000	0.769	-0.301	0.013	0.680	0.966	1.000	0.762	-0.312	0.013	0.674	0.954
Madagascar	0.346	0.304	-0.394	0.053	0.262	0.341	0.413	0.342	-0.502	0.056	0.295	0.400	0.390	0.331	-0.452	0.049	0.289	0.380
Malawi	0.420	0.365	-0.356	0.039	0.314	0.412	0.444	0.378	-0.395	0.035	0.330	0.432	0.451	0.382	-0.400	0.034	0.333	0.438
Mali	0.274	0.231	-0.682	0.106	0.202	0.265	0.392	0.343	-0.361	0.034	0.301	0.383	0.330	0.282	-0.518	0.053	0.250	0.319
Mauritania	0.609	0.520	-0.279	0.020	0.450	0.592	0.670	0.572	-0.255	0.012	0.504	0.642	0.645	0.546	-0.279	0.015	0.478	0.626
Mauritius	1.000	0.776	-0.288	0.018	0.645	0.949	1.000	0.687	-0.455	0.041	0.570	0.962	1.000	0.679	-0.473	0.042	0.561	0.955
Mozambique	0.182	0.153	-1.062	0.221	0.134	0.175	0.238	0.208	-0.611	0.094	0.182	0.232	0.236	0.204	-0.664	0.111	0.178	0.230
Namibia	0.898	0.712	-0.291	0.016	0.604	0.851	0.700	0.567	-0.336	0.019	0.492	0.672	0.756	0.597	-0.352	0.027	0.500	0.728
Niger	0.339	0.291	-0.491	0.065	0.251	0.331	0.366	0.303	-0.569	0.049	0.269	0.355	0.372	0.306	-0.574	0.046	0.273	0.358
Nigeria	0.315	0.238	-1.029	0.306	0.194	0.305	0.261	0.211	-0.907	0.210	0.177	0.252	0.245	0.201	-0.883	0.193	0.171	0.238
Rwanda	0.321	0.272	-0.567	0.071	0.238	0.311	0.357	0.300	-0.529	0.056	0.265	0.346	0.375	0.318	-0.479	0.042	0.281	0.362
São Tomé and Principe	1.000	0.670	-0.493	0.048	0.550	0.955	1.000	0.683	-0.465	0.043	0.562	0.953	1.000	0.677	-0.478	0.044	0.557	0.968
Senegal	0.355	0.301	-0.510	0.058	0.263	0.344	0.400	0.348	-0.372	0.030	0.310	0.388	0.449	0.387	-0.358	0.030	0.339	0.433
Sierra Leone	0.509	0.416	-0.442	0.035	0.364	0.496	0.524	0.416	-0.495	0.046	0.365	0.508	0.518	0.406	-0.532	0.046	0.358	0.499
South Africa	1.000	0.668	-0.498	0.048	0.553	0.960	1.000	0.681	-0.468	0.043	0.563	0.955	1.000	0.677	-0.477	0.044	0.560	0.969
Swaziland	0.899	0.712	-0.293	0.018	0.601	0.869	0.943	0.752	-0.268	0.015	0.637	0.905	0.853	0.678	-0.302	0.019	0.575	0.822
Tanzania	0.287	0.249	-0.532	0.098	0.212	0.283	0.312	0.268	-0.522	0.085	0.231	0.307	0.318	0.267	-0.603	0.095	0.229	0.311
Togo	0.401	0.346	-0.398	0.038	0.301	0.390	0.443	0.377	-0.396	0.027	0.335	0.429	0.425	0.355	-0.463	0.034	0.314	0.407
Uganda	0.269	0.234	-0.554	0.087	0.203	0.264	0.250	0.213	-0.705	0.141	0.183	0.246	0.258	0.219	-0.682	0.120	0.189	0.252
Zambia	0.281	0.242	-0.565	0.076	0.211	0.272	0.388	0.336	-0.401	0.033	0.296	0.377	0.328	0.282	-0.500	0.047	0.250	0.317

In addition to tables 1 and 2, table 3 provides descriptive statistics of the conditional and unconditional efficiency scores. As can be realized the efficiency scores under the conditions of Z1 and Z2 are increasing for both the CRS and VRS formulation. For instance the mean value of the CRS efficiency scores has increased from 0.232 under the effect of Z1 to 0.313 and to 0.272 under the effect of Z2. This can also be observed for the biased corrected efficiency scores (BCEF). In addition to table 1 figure 1 provides the kernel density functions of the original (solid line) and biased corrected (dotted line) efficiency scores.

Table 3: Average values of the efficiency scores obtained

	ES	BCES	Bias	std	LB	UB	ES	BCES	Bias	std	LB	UB
	CRS						**VRS**					
Average	0.232	0.147	-6.475	5.291	0.127	0.195	0.541	0.433	-0.495	0.066	0.369	0.523
Min	0.027	0.016	-27.959	0.027	0.014	0.022	0.172	0.144	-1.153	0.009	0.126	0.166
Max	1.000	0.640	-0.562	34.285	0.546	0.812	1.000	0.804	-0.207	0.306	0.704	0.963
Std	0.300	0.185	5.600	6.497	0.161	0.244	0.280	0.203	0.220	0.064	0.171	0.268
	CRS|z1						**VRS|z1**					
Average	0.313	0.211	-2.416	1.084	0.180	0.284	0.564	0.453	-0.444	0.049	0.389	0.545
Min	0.052	0.035	-11.279	0.036	0.030	0.047	0.201	0.169	-0.938	0.010	0.150	0.194
Max	1.000	0.588	-0.701	9.841	0.526	0.881	1.000	0.791	-0.217	0.210	0.685	0.966
Std	0.260	0.155	2.321	2.120	0.135	0.229	0.255	0.181	0.161	0.041	0.151	0.244
	CRS|z2						**VRS|z2**					
Average	0.272	0.178	-2.912	1.167	0.154	0.239	0.543	0.433	-0.478	0.052	0.373	0.524
Min	0.057	0.033	-12.514	0.034	0.030	0.048	0.187	0.158	-1.000	0.009	0.137	0.181
Max	1.000	0.577	-0.734	9.206	0.516	0.857	1.000	0.793	-0.231	0.211	0.697	0.969
Std	0.231	0.131	2.599	1.806	0.118	0.195	0.247	0.174	0.164	0.043	0.147	0.236

Figure 1: Kernel density functions of countries' economic efficiencies derived from unconditional and conditional CRS and VRS DEA models using Gaussian Kernel and the appropriate bandwidth

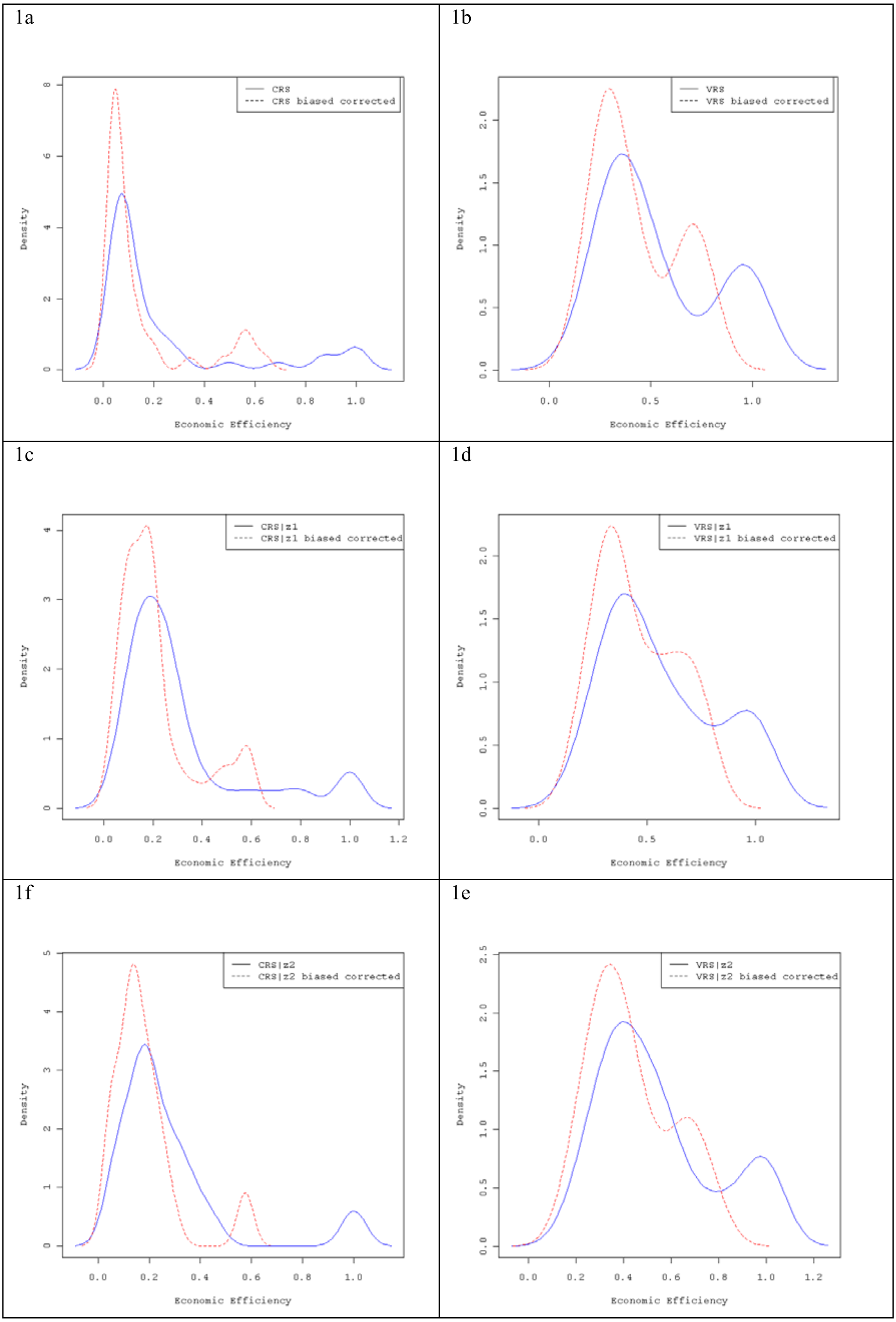
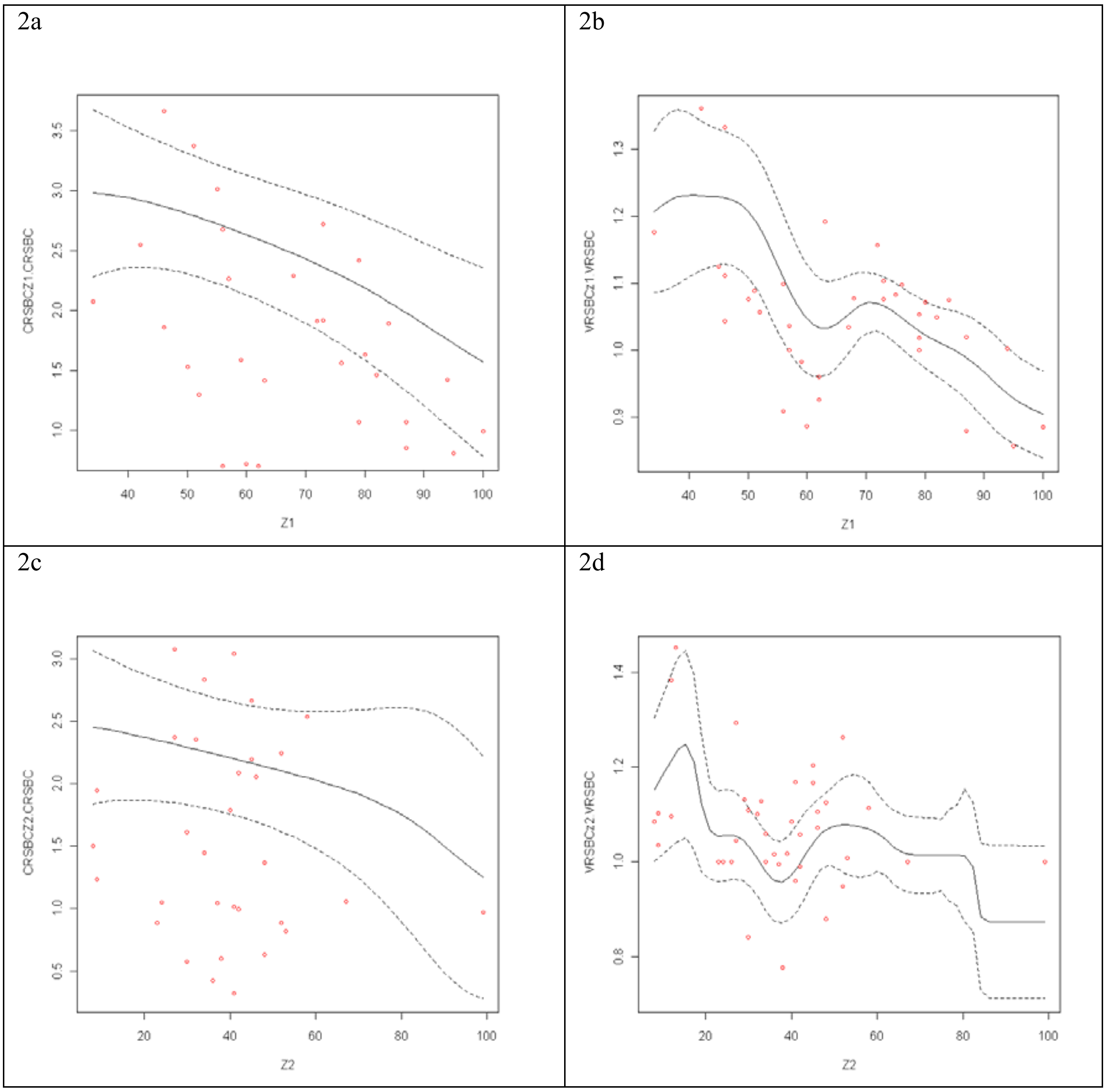


Figure 2: Graphical representation of the global effect of sustainable access to improved water sources and sanitation on countries' economic efficiency



Again the results indicate that the effect of the external factors increase SSA countries' economic efficiencies. As can be realized the biased corrected efficiency scores are lower than the original. As has been analyzed previously the biased corrected results are preferred in our analysis. For the calculation of the density estimates we have used the "normal reference rule-of-thumb" approach bandwidth selection (Silverman 1986) and a second order Gaussian kernel. It appears that the estimates under the CRS appear to be leptokurtic compared to the estimates under VRS assumption which appear to be platykurtic. The leptokurtic distributions indicate that there is a rapid fall-off in the density as we move away from the mean. Furthermore, the pickedness of the distribution suggests a clustering around the mean with rapid fall around it.

Moreover, figure 2 provides a graphical representation of the effect of sustainable access to improved water sources (Z1) and sanitation (Z2) on SSA countries' economic efficiency. For this task we use the 'Nadaraya-Watson' estimator, which is the most popular methods for nonparametric kernel regression proposed by Nadaraya (1965) and Watson (1964) (see equation 13). For the calculation of bandwidth we have used least-squares cross-validation criterion (LSCV) which is a fully automatic data-driven approach (Hall et al., 2004; Li and Racine, 2004, 2007).

As such figures 2a-d illustrate the nonparametric estimates of the regression functions (using the conditional and unconditional biased corrected CRS and VRS efficiency estimates) and their variability bounds of point wise error bars using asymptotic standard error formulas (Hayfield and Racine, 2008). Subfigures 2a and 2c illustrate the effect of Z1 and Z2 under the CRS assumption, whereas subfigures 2b and 2d illustrate the effect of Z1 and Z2 under the VRS assumption.

When the regression is decreasing, it indicates that Z factor is favourable to efficiency. In our case the graphs for both Z1 and Z2 under the CCR and VRS hypothesis illustrate a decreasing nonparametric regression line indicating that the environmental variables (sustainable access to improved water sources and sanitation) act as substitutive input in the production process of countries' economic efficiency. Therefore, they provide the opportunity to "save" in the activity of production. As expected both the access to improved water sources and sanitation increase SSA countries' economic efficiency. But a detailed inspection of figure 2 reveals that when the provision of access to improved water sources is offered to more than 50% of the population, the positive effect on countries' economic efficiency is greater compared to the effect of providing sustainable access to improved sanitation to the same proportion of population. As in the first case the regression line is steeper this implies that improved water resources are even more crucial for the SSA countries' economic growth compared to the provision of improved sanitation. As the results indicate (see tables 1 and 2) in most of the cases the effect of access to improved water sources is a key and a major starting point for generating SSA countries' economic growth.

5. Conclusion

According to the literature there is a link between the provision of water and sanitation and countries' economic growth. For the first time this paper tests empirical the effect of water and sanitation on SSA countries' economic efficiency and growth. In addition the latest advances in DEA techniques for bias correction and probabilistic approaches have been applied in order to measure and quantify the effect of provision of improved water sources and sanitation on SSA countries' economic efficiency.

As a first stage our study measures the economic efficiency of SSA countries based on the two most popular DEA formulations (CCR and BCC models) assuming constant and variable returns to scales. After applying bootstrap algorithms for bias correction the results revealed that there are strong inefficiencies among the economic performances of the 41 SSA sampled countries. The results obtained support several studies indicating that the institutional and structural constrains among with poor policy environment was a major obstacle of African countries' economic performance (Mkandawire, 2001; Akyüz and Gore, 2001).

As a second stage in our analysis we use the probabilistic approach among with nonparametric smoothing techniques on the obtained biased corrected efficiency scores in order to measure the effect of water and sanitation. The empirical results clearly indicate that the provision of water and sanitation to SSA countries' population has a clear positive and measurable effect on economic efficiency and growth. The results complement the findings of several studies (Lavy et al., 1996; Lee et al., 1997; Showers, 2002; Bloom et al., 2004 ; Sala-i-Martin et al., 2004) indicating that the provision of water and sanitation through investment policies leads to an improvement in the health capital of workers which in turn has a direct impact on countries' economic growth. In addition the results indicate that infrastructure related to the provision of improved water source have much greater positive effect on countries economic efficiency compared with infrastructure related to sanitation.

As it appears the problem of economic efficiency and growth in SSA countries still remains and it is very much associated with the existence of poor policy environment based on weak state support, poor sectoral coordination and fragmented donor efforts and its interrelation with the investment of infrastructure aimed to deliver improved water sources and sanitation to SSA countries' human capital.

Finally, Gutierrez (2007) suggest that the funding and accountability relationships between donors, aid organisations, NGOs, local and national government bodies, and grassroots communities need to be reviewed and tools like annual budget analysis and water point mapping need to be institutionalised and being applied for more effective governance.

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