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Abstract

This paper is a first attempt at documenting economic efficiency levels in Africa's electricity distribution, their evolution and the sources of this evolution. The analysis is based on a sample of 12 operators providing services in the 12 countries members of the Southern Africa Power Pool. We focus on the changes in total factor productivity (TFP) of the largest operators in each country between 1998 and 2005. We then rely on a DEA decomposition to identify the sources of the changes in TFP. The results suggest fairly comparable levels of efficiency in the region and performance levels and evolution quite independent of the degree of vertical integration, the presence of a private actor or the main sources of energy supply. The analysis suggest that although the companies have not made significant improvements during the period of analysis in using their capital and human assets, they have done much better in adopting better technologies and better commercial practices. No clear correlation could be associated with the adoption of reforms during the last decade and data limitations impede a more refined assessment of the impact of reforms on efficiency at this stage.

Key words: Malmquist productivity, electricity, efficiency.

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1. Introduction

For over 20 years now, most Sub-Saharan African countries have lacked the ability to raise the resources needed to finance their investment needs in electricity—or in any other infrastructure sector for that matter. To try to generate the financing needed, close to 60% of the countries of SSA engaged during the second half of the 1990s in some type of reform of their power sector.[2] But these reforms were not just intended to generate new financing options for the sector. They also aimed at improving efficiency. Indeed, in a region in which the sector has tended to have higher than average costs, improving efficiency significantly would also induce a significant drop in the financing requirements of the sector.

The main purpose of this paper is to provide a first assessment of the performance changes since the main reforms took place in the late 1990s for a sample of Sub-Saharan African countries. The assessment is conducted the way an economic regulator would do it in preparation for a tariff revision under incentive based regulatory regimes.[3] The approach is now quite common in Europe and Oceania among energy, telecoms and water regulators.[4] It is in fact quite widely spread around the world in the context of performance benchmarking exercises.[5]

The poor quality of data may be why relatively little work has been done on the efficiency of infrastructure services in developing countries. Sticking to energy, the only developing countries in which efficiency measures of some type have been assessed formally or informally as part of regulatory processes are in Latin America.[6] To our knowledge, this paper is in fact the first effort to generate this type of assessment for a set of African countries.[7]

The analysis covers the 1998-2005 periods and focuses on twelve countries around the Southern African Power Pool (SAPP). SAPP was created by Southern African Development Community (SADC) in 1995. The pool includes for now Angola, Botswana, Democratic Republic of Congo (DRC), Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. The region is dominated by the state owner utility of South Africa, ESKOM which generates about two thirds of the electricity produced in the whole of Sub-Saharan Africa and about 80% of the output for the Southern Africa power community. ESKOM is indeed a major provider to many of its neighbours (Botswana, Congo, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe) through a wide transmission system. Zambia is the second largest exporter in Africa but relies mostly on hydro plants. In fact all countries but three in our sample rely at least partially on hydro sources although one of the exception is the largest player in the region, South Africa's ESKOM.

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[2] For details on the level and types of reform, see Estache and Goicoechea (2005a and b).

[3] One of its interests is that, when conducted properly, it manages to ensure that consumers get to share some of the improvements in the performance of the sector that results from reform or simply from technological change. In other words, measuring efficiency in regulated industries ensures that not all performance improvements simply become a rent for monopolies.

[4] The British water and energy regulators were the leaders. They were later followed by the energy regulators of many of the Australian states as well and Nordic energy regulators in Europe. More recently by the Dutch Electricity regulators has been the first in continental Europe to adopt efficiency measures as part of its regulatory instruments.

[5] See Jasmab and Pollit (2001) for instance for an overview on the use of benchmarking in electricity regulation. For a survey of experiences and issues, see Coelli and Lawrence (eds) (2006), 'Performance measurement and regulation of network utilities', Edward Elgar Publishing, Cheltenham, forthcoming.

[6] For a survey of efficiency measures available for infrastructure activities in developing economies, see Estache, Perelman and Trujillo (2006).

[7] There is however a paper by Plane (1999) on Ivory Coast's experience.

All the countries covered by our sample have undertaken some reform in their power sector since 1997 or so. Some have opened generation to competition. About a third has signed management contracts for at least some segments of the business and all have at least corporatized the business. All countries maintain a tight control over the distribution services and most of the countries have vertically integrated companies—with two exceptions as discussed later.

The paper provides a comparative assessment of economic efficiency levels as well as of the sources of differences across companies observed during an 8 year period ending in 2005. We estimate the productivity change using a Malmquist Total Factor Productivity (TFP) index and decompose the total change by relying on a non-parametric (DEA) framework outlined by Färe and Grosskopf (1990) and Färe et al. (1994).[8] We also decompose the changes into the catching-up and the frontier shift effects to get a sense of how much effort some of the operators are making to catch up with best practice in the region. Finally, we unbundle the catching up effect into technical efficiency and scale efficiency which gives a sense of the extent to which the efficiency gains are achieved purely from changes in input mix or from better adjustment of the size of production to the demand.

The paper is organized as follows. Section 2 briefly presents the countries covered by the sample and the reforms that have taken place in the region. In section 3 we present the methodology followed in the paper. Section 4 discusses the variables available to reflect outputs and inputs. Section 5 provides a snapshot of what partial performance indicators reveal. Section 6 provides the main results on the full efficiency assessment. Section 7 concludes.

2. Electricity in Sub-Saharan Africa

Africa enjoys some of the most significant potential fuel reserves in the world and yet its population suffers from one of the lowest electricity access rates. These access rates have generally managed to catch up with population growth during the 1990s but not much more. Access remains very low, 24% for the region. This is significantly lower than in other regions of the developing world where it is between 60% and 90% elsewhere, except South Asia where it is around 33%.[9] Moreover, the biases in access rates continue to favor urban and rich households—urban and rural areas have, respectively, average access rates of 50% and 10%—with about 67% of the population still living in rural areas. This echoes differences in relative demand by rich and poor, and urban and rural, users.

Regional energy trade, particularly electric power, is a high priority for the SADC-member countries as a way to reduce the disparities in access to energy resources and consumption. A 1995 Inter-Governmental Agreement creating the SAPP is a sign of the region's commitment to this integration. It is also expected to reduce energy costs and improve supply stability for the region's 12 national utilities: Botswana Power Corporation (BPC); Electricidade de Mocambique (EDM); Angola's Empresa Nacional de Electricidade (ENE); Electricity Supply Commission of Malawi (Escom); South Africa's Eskom; Lesotho Electricity Corporation (LEC); Namibia's NamPower; Swaziland Electricity Board (SEB); the Democratic Republic of Congo's (DRC) Societe Nationale d'Electricite (SNEL); Tanzania Electric Supply Company (Tanesco); Zimbabwe Electricity Supply Authority (ZESA) and Zambia Electricity Supply Corporation (ZESCO).[10]

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[8] Malmquist indices have been used to measure efficiency changes in other regulated infrastructure services such as for water distribution, railways and port services. For a recent survey, see Jasmab and Pollit (2001).

[9] Details are available in Estache and Goicoechea (2005a).

[10] SAPP membership is presently restricted to national electricity utilities, although Hidroelectrica de Cahora Bassa (HCB) was granted temporary observer status to the three SAPP Sub-Committees (Planning, Operation and Environmental) in April 1998. At that time a moratorium was declared prohibiting any other non-utility members from joining while the SAPP considers the role in the region of Independent Power Producers (IPPs) and Independent Transmission Companies (ITCs), as

Table 1 summarizes the main characteristics of the current market structure of the countries covered by the sample. Although all countries except Angola and Namibia, have vertically integrated companies, the market structure of the sector vary significantly across countries. There are clear differences both in terms of technology and coverage. While most countries rely on at least some significant hydro sources, the largest producer, South Africa, is definitely mostly thermal—it is also the only one in Africa to have nuclear generation. In addition, to get a glimpse at the demand side, Table 1 shows that the spread of access rates is very significant across the region at the beginning of this new century but most are below 20%.

As of 2006, Southern Africa's total installed electric generating capacity was about 53,000MW (although the net generation output is only around 45,000MW). The region is getting very close to exhausting its reserve capacity according to various demand growth scenario being discussed in the region. The largest electricity generator by far was South Africa (about 80%), followed by DRC, Mozambique, Zimbabwe, and Zambia. These countries are also the largest consumers of electricity. Eskom is a major supplier to many of South Africa's neighbours. This makes for a somewhat strange characterization of the supply sources in the region. Indeed, while most countries rely on hydro sources when possible (and the potential is very far from being tapped), the strong role of Eskom as a supplier implies that the actual source of energy for many of the smaller countries is actually thermal. Around 74 percent of South Africa's electricity supply comes from coal-fired power stations. Africa's only nuclear power plant is also located in South Africa, supplying electricity to the Western Cape Province.

The experience in implementing reforms is just as diversified as the technological and coverage experience in this sample. The commitment to reform in the region was launched in 1997 when South Africa announced it would create 5 regional electricity distribution companies (REDS) which would be joint ventures formed by ESKOM and local authorities in the various countries. The REDS were expected to purchase electricity from ESKOM generation and IPPS on the basis of tariffs set by the National Electricity Regulator. The first private actor was AES when it entered the country in 2001. Malawi and Tanzania have also entered into management contracts with private operators and a number of other countries are now preparing similar reforms. Generation is now competitive, at least partially, in about half of the countries covered by the sample. About half of the countries now count an independent sector regulator.

The upshots of this brief overview are that (i) Africa operators have to address major supply gaps and (ii) any reduction in the financing costs of the expansion requirements that can be achieved from improvements in efficiency is likely to be welcome by a region which includes some of the poorest countries in the world. Efficiency measurement is thus an important regulatory tool which should be also of interest to the Ministers of Finance of the region since good measurement will eventually lead to significant cost savings in the countries starting from poor initial performance levels.

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well as implications of future utility scenarios such as unbundling and privatization.

Table 1: Electricity Sector Reform in Selected SSA countries

Country	Operator in distribution	Competition in generation	Private role in distribution	Sector regulator	Vertical integration	Main electricity source	Electricity access rates (% in 2005)
Angola	Empresa Distribuicao Electricidade (EDEL)	Yes (2003)	No	No	No D – EDEL G and T –ENE	T	20
Botswana	BPC	No	No	No	Yes	T + I	37
DRC	SNEL	No	No	No	Yes	H	6
Lesotho	LEC	Yes	Yes	Yes	Yes	H+ I	11
Malawi	ESCOM	No	Yes Management Contract (SA's TSI) (2001)	Yes	Yes	H	7
Mozambique	EdM	Yes	Yes Management Contract and small contracts	Yes Advisor (2000), Regulator (2004)	Yes but 2 more firms in G	H + I	6
Namibia	4 Regional electricity distributors (2002)	Yes	Yes	Yes (2000)	No horizontal and vertical unbundling	H + I	34
South Africa	ESKOM	Yes	No	Yes (1995)	Yes but many small D firms	T	70
Swaziland	SEB	Yes	No	Yes (2002)	Yes	H + I	27
Tanzania	TANESCO	Yes	Yes Management Contract (NetGroup) (2002)	No	Yes	H	11
Zambia	CAPC + ZESCO	Yes	Yes	Yes (1999-2000)	Yes but 2 big firms	H	19
Zimbabwe	CAPC + ZESA	Yes	No	No	Yes but 2 firms	H + I	27

Note: Tr=Transmission, G=Generation, D=distribution, H=Hydro, T=Thermal, I=Import

Source: author compilation from various sources (with a heavy reliance on the SADC website)

3. Methodology

One of the major challenges in assessing the potential efficiency of a sector, in particular for regulated industries, is the need to identify indicators which reflect the fact that operators tend to rely on a combination of inputs (e.g. labor, various types of equipment and other intermediate inputs) which can have varying relative importance across these operators. Moreover, many operators offer multiple outputs as well (distribution, supply, service assistance, etc.). Productivity measures thus need to account jointly for the multiple outputs (say M) and inputs (say K) used in the production of these outputs. This is what Total Factor Productivity (TFP) measures are intended to do. Since not every output has the same importance for any given operator and since the relative importance of every input for every output type can differ, the general formula for TFP is written as:

$$\text{TFP} = \sum_{m=1}^{M} a_m Y_m \Big/ \sum_{k=1}^{K} b_k X_k \,, \qquad (1)$$

where the a_m and b_k are weights and their choice is, as discussed later, quite important in practice.

While, from an economic policy perspective, this approach is an improvement over partial productivity indicators typically used in engineering assessments, it is not problem free. The first problem is that the output weights and input weights have to each sum to one, a basic property of any TFP measure. To meet that requirement, the standard practice has been to work on the assumption that output and input markets achieve productive efficiency—i.e. output price=marginal cost and input prices=marginal product value) so that the weights are estimated by output and input share in total revenue and cost respectively.[11] But these are strong assumptions for regulated industries which is why these simple weights are often subject to strong criticisms in the context of regulated industries and alternative solutions need to be explored.

A second problem is that the index ignores that productivity improvements can result from technological changes but also from changes in behaviour due to the restructuring process or the design of the regulatory regime. From the viewpoint of a reforming government, it is important to be able to assess performance changes reflect the extent to which an operator catches up with best practice in the field for a given technology. In particular, it is important to be able to assess the capacity to achieve a given level of output at the minimum input use (if the regulator imposes the output levels on the operators and follows an input orientation in the definition of its efficiency concept). This is the relevant question because in countries, output targets are the norm (i.e output is exogenous) and input choice is endogenous. This concern implies that the contribution of the technical efficiency of the operator needs to be isolated from the other sources of changes in TFP such as scale economies which can be driven by demand consideration independent from any sector specific reform.

To be able to incorporate these various sources of efficiency changes while recognizing the limitations of the assumptions used in the simple index discussed above, it is now relatively standard practice to adopt a Malmquist index approach. The Malmquist TFP index measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. The Malmquist (input-orientated) TFP change index between period 0 (the base period) and period 1 (using period 1 technology as the reference technology) is given by (1).

[11] This is what the Tornqvist index proposes.

$$\mathrm{TFP}_1 / \mathrm{TFP}_0 = \frac{D_1(Y_0, X_0)}{D_1(Y_1, X_1)}, \qquad (2)$$

where $D_t(X_s,Y_s)$ represents the distance from the period s observation to the period t technology. A value of the ratio in equation (1) greater than one will indicate a TFP improvement. For example, a value of 1.025 corresponds to a 2.5% increase in TFP.

The initial popularity of this indicator among regulators and other users of productivity measures stems from the fact that this index avoids having to work with input and output prices and the related output and input market clearing assumptions. It relies on output and input weight estimated directly. In addition, from the viewpoint of regulated industries where many of the productions decisions in terms of timing and levels are driven by the regulatory framework and various types of obligations rather than only self-centred rational behaviour by the operators, the index has the advantage of not requiring the need to work with behavioural assumptions for these operators (e.g. profit maximization or cost minimization). Finally, the Malmquist index makes it easy to compare the catching-up effort with the frontier shift for a given sector or operator. [12]

The approach we follow here is an improvement by Färe et al. (1994) over the Malmquist index. It is the geometric mean of two Malmquist indices, one evaluated with respect to period 1 technology and the second with respect to period 0 technologies. This approach has the advantage of avoiding any bias due to the choice of the technology of reference. Doing these yields:

$$\mathrm{TFP}_1 / \mathrm{TFP}_0 = \left[\frac{D_1(Y_0, X_0)}{D_1(Y_1, X_1)} \frac{D_0(Y_0, X_0)}{D_0(Y_1, X_1)} \right]^{0.5} \qquad (3)$$

An equivalent way of writing this productivity index is

$$\mathrm{TFP}_1 / \mathrm{TFP}_0 = \frac{D_0(Y_0, X_0)}{D_1(Y_1, X_1)} \left[\frac{D_1(Y_0, X_0)}{D_0(Y_0, X_0)} \frac{D_1(Y_1, X_1)}{D_0(Y_1, X_1)} \right]^{0.5} \qquad (4)$$

where the ratio outside the square brackets measures the change in the input-oriented measure of technical efficiency between periods 0 and 1, we can call the Total Technical Efficiency Change (TTEC) which provides some insights on how much any company if catching up with better performing companies.[13] The remaining part of the index in this equation is a measure of technical change (TC) which tells us how much the production frontier is shifting.. That is:

$$\mathrm{TFPC} = \mathrm{TTEC} \times \mathrm{TC} \qquad (5)$$

To be able to isolate the scale economy effects, we follow the suggestions by Färe et al (1994) to generate a further decomposition of equation (5) which implies a constant return to scale (CRS) technical efficiency change measure (TTEC). This measure can indeed be decomposed into a "pure" technical efficiency change component and a scale efficiency change component. This is done by introducing variable returns to scale (VRS) distance functions, to obtain

[12] See Nishimizu and Page (1982);Grifell and Lovell (1993).
[13] "Farrell" measures of efficiency correspond in each case to the expansion, or the reduction, of the ray that pass through the origin. It makes reference to the Farrell'seminal paper (Farrell, 1957).

$$\mathrm{TFP}_1/\mathrm{TFP}_0 = \frac{D_0^V(Y_0,X_0)}{D_1^V(Y_1,X_1)}\left[\frac{D_1^V(Y_1,X_1)}{D_0^V(Y_0,X_0)}\frac{D_0^C(Y_0,X_0)}{D_1^C(Y_1,X_1)}\right] \times\left[\frac{D_1^C(Y_0,X_0)}{D_0^C(Y_0,X_0)}\frac{D_1^C(Y_1,X_1)}{D_0^C(Y_1,X_1)}\right]^{0.5}, \quad (6)$$

where the V and C superscripts refer to variable returns to scale (VRS) and CRS technologies, respectively.[14] Equation (5) thus gives a technical efficiency change (TEC) measure, a scale efficiency change (SEC) measure and a technical change (TC) measure. That is:

$$\mathrm{TFPC} = \mathrm{TEC}\times\mathrm{SEC}\times\mathrm{TC} \quad (7)$$

This is the decomposition looked for in this paper. It is particularly interesting in the electricity sector because it is not uncommon to have firms operating with technical efficiency (using the lowest possible level of inputs for a given level of production) but not enjoying the appropriate scale level (it is either too small or too big). In that case, there is not much the operator can do in the short run at least and it would be unfair for a regulator to penalize the operator for this scale issue because there is little it can do to cut costs further.

To actually generate the TFP index and its decomposition, we need to estimate the frontier from which the distance will be measured. Because of data constraints, we do so through data envelopment analysis (DEA), the non-parametric programming method.[15] It allows the derivation of estimates of relative efficiency levels for each operator.

As seen in the formula, six distance functions must be calculated: 4 defined under constant returns to scale (CRS) and 2 under variable returns to scale (VRS). Equation (8) is one of the standard ways of presenting the underlying optimization program used in this paper:

$$\begin{aligned} &\text{Min } \theta_0 \\ &\text{s.a.} \quad Y\lambda \geq Y_0 \\ &\theta X_0 - \lambda X \leq 0 \qquad (8) \\ &\lambda \geq 0 \end{aligned}$$

where λ is a vector describing the percentage of the other operators used to construct the efficient operator, $\mathbf{X}$ and $\mathbf{Y}$ are the inputs and output vectors of the efficient operator and $\mathbf{X_0}$ and $\mathbf{Y_0}$ are the inputs and outputs of the operator under evaluation. The value of θ reflects the efficiency of this operator.

[14] This decomposition has been criticized by some authors because it measures technical change against the CRS technology instead of the VRS technology. Various alternatives have been proposed, however none of them are yet to gain widespread acceptance. See Grifell and Lovell (1999) and Balk (1999) for discussion on this issue.
[15] For more details, see Coelli et al. (1998, 2003a y b)

4. Which outputs and inputs should the efficiency analysis focus on?

The poor level and quality of economic data on infrastructure in general is common knowledge. It is probably more dramatic for Africa than for any other region of the world. The creation of regional energy regulators associations (such as AFUR which covers the whole continent or RERA for the Southern African Development Community (SADC) countries covered here) and the efforts of research centres (such as AFREN based in Kenya) have all contributed to the generation of a reasonably reliable set of data for a number of countries in that part of Africa. Their efforts make the analysis provided in this paper possible.

The main challenge is thus to make the most of the information available. This means that pragmatism will often rule over strict theory in the assessment conducted here, as is often the case in "real world" regulatory assessments of efficiency changes. While the theory would argue for a detailed structural model accounting for all possible factors, pragmatism implies that the best one can hope to achieve in practice is to estimate a single equation function.

With this pragmatic approach in mind, the first issue is to decide which output and inputs to focus on. Jasmab et al. (2004a and b) provide a detailed description of the ideal set of variables to be considered. Trying to be pragmatic, for outputs, we follow Neuberg (1977) who argues that we should at least consider both the number of customers served and total energy sold qualify as potential outputs in this sector. Note that energy delivered to final customers is not really exogenous, especially if some of the utilities are not well regulated. That is, the utility is not always compelled to provide its customers with whatever quantities they desire at given prices. Number of customers, on the other hand, cannot be controlled by utilities since in general everybody has the right to be connected to the national local distributor.

We add generation to the Neuberg (1977) list of outputs simply because it has the advantage of being a relatively well measured product of these mostly vertically integrated operators. Given that technical and commercial losses can be quite important and given that some of the sales are based on imported energy for some of the countries and some include the results from exports, this variable provides a perspective not covered by sales or number of customers.

For inputs, once more we follow the standard practice. The number of employees is the standard labor input and is relatively easily obtained. As for the capital inputs, the options are more complex. Installed capacity is widely accepted as a required variable and has been used to approximate (Kumbhakar and Hjalmarsson, 1998).

The data used here is however not perfect. In many countries, conflicts and other dramatic events have resulted in a significant deterioration of the installed capacity. The use of this proxy may thus be overestimating the actual stock of capital available. For instance, in Angola, the available capacity is only about 60% of the installed capacity. Table 2 provides a summary of the data on the twelve Southern African electricity firms for the sample. Furthermore, the data on clients does not really allow us to distinguish between large and small clients which is often a relevant dimension, in particular when scale economies need to be considered.

Table 2. Summary statistics for the full sample

Outputs	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
Generation (GWh)	19,306	221,985	102	55,024
Customers (number of)	453,310	3,758,569	2,219	879,350
Sales (GWh)	18,378	207,921	266	51,667
Inputs	**Mean**	**Maximum**	**Minimum**	
Installed Capacity (MW)	4,157	42,011	50	11,313
Labor (number of workers)	5,505	37,311	345	8,281

A few additional basic facts on the evolution of the sector in recent times are relevant to the analysis conducted in this paper. The first is that the outputs variables we are focusing on have seen some significant improvement during the period under analysis. The number of formal clients in the region has indeed increased significantly, with about 51% more clients over a 7 year period. This is matched by an increased in sales and generation of 22% and 23% respectively. But this hides a wide variety of experiences. In generation for instance, SEB and EdM stand out with a drop of 47% and 40% while, at the other extreme, ENE enjoyed an increase of 101%. The importance of drought for hydro sources is one of the factors clearly but the political instability seems to be a significant determinant of these fluctuations.

On the input side, employment has dropped by about 11% on average. The range is however wide. Some of the operators have seen employment increase such as BPC with an increase of 25% while others have seen it drop, such as Tanesco and Eskom with a drop of 31% and 20% respectively. For BPC the explanation may be the 127% increase in the number of clients and the need to address the rural electrification goals. For Tanesco, the drop is related with the adoption of a management contract with a private operator in 2001 which is associated with a 31% drop in employment. Finally, for Eskom, the adjustment took place largely between 1998 and 2001 and, in view of its size; we could not reject the assumption that the reduction in employment could simply be reflecting an improvement in scale economy. However, it could also be reflecting increased outsourcing which is not recorded in the standard statistics.

In contrast to what happened to average employment, the capital input has increased by an average of 6%, although in this case as well the diversity of experiences is quite wide. Tanesco has increased its capacity by 42% while EdM only by 9%—dropped by 17%mostly from 2001 to 2004, during the civil war but its capacity has increased between 2004 and 2005—and the other operators has essentially maintained their capacity.

5. What do partial performance indicators reveal?

Before getting to the results of the TFP analysis, it may be helpful to get a first sense of the performance of these operators from the partial productivity indicators. The conclusions derived from these partial indicators will later be compared to those derived from the TFP calculations. These partial indicators are summarized in Table 3. It reports the ratio of each output (sales, generation and customers) to each input (labor and capital).

Table 3 shows that the South African company Eskom enjoys the highest productivity of labor both in 1998 and in 2005. Measured with respect to capital, the highest productivity is obtained by BPC when the indicator is generation/capacity but when sales/capacity is utilized SEB is the best in 1998 and BPC in 2005. In general, SEB performs well with respect to capital in terms of all the indicators except for generation/capacity. This is due to the fact that SEB has only a modest capacity and relies heavily on imports to meet its demand. Finally, in terms of customers/capacity indicator, EdM is the best performer and does so with small clients, as indicated by the sales/clients ratio. NamPower is also a top performer when considering generation/customers indicator because its trades mainly with bulk suppliers.

Table 3: Partial Productivity Indicators

Year	Utility	S/L (%)	G/L (%)	C/L (%)	S/K (%)	G/K (%)	C/K (%)	L/K (%)	S/C (%)	G/C (%)	S/G (%)
1998	**ENE** (Angola)	35	45	2,747	169	220	13,301	484	1	2	77
1998	**BPC** (Botswana)	89	54	4,036	1,120	683	51,058	1,265	2	1	164
1998	**SNEL** (DRC)	60	82	4,052	140	191	9,438	233	1	2	73
1998	**LEC** (Lesotho)	77	79	5,351	502	511	34,830	651	1	1	98
1998	**ESCOM** (Malawi)	36	47	3,246	330	426	29,612	912	1	1	77
1998	**EdM** (Mozambique)	32	9	6,653	415	114	87,340	1,313	0	0	364
1998	**NamPower** (Namibia)	230	161	281	461	323	565	201	82	57	143
1998	**ESKOM** (South Africa)	460	491	6,872	430	459	6,431	94	7	7	94
1998	**SEB** (Swaziland)	95	27	4,576	1,390	388	66,632	1,456	2	1	358
1998	**TANESCO** (Tanzania)	26	30	5,294	308	356	62,804	1,186	0	1	87
1998	**ZESCO** (Zambia)	157	192	4,172	394	481	10,473	251	4	5	82
1998	**ZESA** (Zimbabwe)	143	96	6,138	518	350	22,323	364	2	2	148
1998	**MEAN**	276	289	158	416	436	8,785	151	5	5	95
Year	**Utility**										
2005	**ENE** (Angola)	43	62	3,387	247	356	19,320	570	1	2	70
2005	**BPC** (Botswana)	124	47	7,305	1,957	740	115,715	1,584	2	1	264
2005	**SNEL** (DRC)	74	110	5,749	191	283	14,755	257	1	2	67
2005	**LEC** (Lesotho)	81	102	10,518	492	619	64,129	610	1	1	79
2005	**ESCOM** (Malawi)	40	49	5,625	340	413	47,368	842	1	1	82
2005	**EdM** (Mozambique)	44	5	11,404	561	63	145,321	1,274	0	0	890
2005	**NamPower** (Namibia)	334	186	382	757	422	866	227	87	49	179
2005	**ESKOM** (South Africa)	700	747	12,656	495	528	8,947	71	6	6	94
2005	**SEB** (Swaziland)	128	16	7,271	1,672	203	95,098	1,308	2	0	824
2005	**TANESCO** (Tanzania)	52	76	11,342	304	438	65,657	579	0	1	69
2005	**ZESCO** (Zambia)	222	233	7,787	488	513	17,148	220	3	3	95
2005	**ZESA** (Zimbabwe)	177	158	9,443	531	475	28,343	300	2	2	112
2005	**MEAN**	381	401	199	481	507	12,561	126	4	4	95

Note: L: Labor; S: Sales; G: Generation; C. Customer; K: Capacity.

The main problem with Table 3 is that it tells too wide a range of stories to allow a clear guide for policy-makers or decision-makers. The performance ranking based on these partial indicators changes too significantly according the criteria considered to provide relevant guidance on the actual performance of the sector. The partial correlation between these criteria varies from (-0.9) to (0.9). A measure able to reflect various criteria of interest jointly is thus needed. Possible such measures are discussed in the next section. Ideally, this measure should also allow a policymaker to inform the assessments made in the context of tariff revisions since efficiency gains need to be shared at some point with the users through tariff reductions.

6. So…how well did electricity companies perform in Southern Africa?

While this section tries to provide a more robust sense of the evolution of the performance than the one that could be generated from the partial indicators, its more specific purpose is to assess the current performance level and the evolution of this performance since reforms started in the region. It summarizes the results on the achievements of the last 8 years or so, on how much scope for performance improvement there is, and on the potential sources of improvements.

6.1. A broad view of what has changed in the efficiency performance

To get a sense of the progress achieved, we calculate a very basic non-parametric frontier for the two most distant years available in the data base, 1998 and 2005. This allows us to get a comparative assessment within period of the changes in the sources of technical and scale inefficiency with which firms operate. We adopt an input oriented DEA. We then conduct an assessment of the performance of the firms across periods. We used on the DEA estimation the computer program DEAP Version 2.1 (Coelli, 1996).

To control for the heterogeneity of the firms, we first calculate a model which considers the multioutput nature of the business and accounts for generation and number of clients jointly. This is model 1. To get a fuller picture of the evolution, we also calculate three other models. Each of these models relies on the same inputs (labour and capital) as the basic model. They all differ from this basic model through the choice of the output variable. Generation is used for model 2, number of clients for model 3 and sales for model 4[16]. The results are summarized in Table 4.

For each model, we compare the results under the two usual assumptions for returns to scale: constant (CRS) and variable (VRS). The VRS approach is probably the most appropriate here in view of the wide range of operators' sizes covered by our sample in a sector not typically characterized by constant returns to scale. The results for the CRS model seem to confirm this intuition. Indeed, under CRS, the operators appear to be less efficient. This is to a large extent due to the implicit assumption on the existence of an optimal size operator.

The models yield firms specific results which are then aggregated and averaged for the region. The firm specific information is less interesting because more predictable. Indeed, Eskom is on the frontier and firms who cater mostly to large clients (bulk suppliers) tend to be quite efficient in terms of generation or sales and quite inefficient when measured in terms of customers. This is the case for NamPower for instance

The computations reported in Table 4 suggest that the average efficiency levels are very similar

[16] Note that tried also to combine generation and sales as output but the results are not reported here simply because they are very similar the results obtained from Model 1 combining generation and customers as outputs.

in any given year for each output when outputs are considered one at the time, although the average technical efficiency (generation) is somewhat lower than the commercial one (customers or sales). The average efficiency level is however higher when the commercial and the technical outputs are considered jointly (model 1). Overall these efficiency levels show a significant scope for improvement. For single output models, depending on the output definition chosen, technical efficiency under VRS varied between 67% and 78% in 2005. When two outputs are considered, the scope for improvement somewhat shrinks as expected since the efficiency measure accounts for the fact that the operators are delivering more outputs with the same set of inputs.

It is useful to not that Table 4 shows that the scope for significant additional improvements in terms of scale efficiency (SE) is much more limited than for technical efficiency whatever the output measure considered. The table also shows that when multiple outputs are considered, the scope for improvements in SE are much lower, confirming the need to consider the multi-product nature of the business when assessing performance. However, in this case also, there is a difference between the technical and the commercial dimension of the business.

Table 4: Average Efficiency levels in 1998 and 2005

Average for SAPP's firms	1998			2005		
Outputs	**TTE (CRS)**	**TE (VRS)**	**SE**	**TTE (CRS)**	**TE (VRS)**	**SE**
Generation and customers. Model 1	0.858 (0.186)	0.878 (0.189)	0.977 (0.025)	0.834 (0.183)	0.874 (0.175)	0.955 (0.079)
Generation. Model 2	0.668 (0.269)	0.736 (0.273)	0.904 (0.143)	0.695 (0.292)	0.778 (0.243)	0.873 (0.251)
Customers. Model 3	0.670 (0.274)	0.774 (0.247)	0.847 (0.252)	0.678 (0.305)	0.763 (0.258)	0.872 (0.272)
Sales. Model 4	0.616 (0.314)	0.690 (0.345)	0.904 (0.120)	0.590 (0.330)	0.671 (0.352)	0.904 (0.165)

Note: Standard deviation in parenthesis

6.2. A more thorough examination of the efficiency performance

While the static comparison offered in section 6.1 is informative, it tells a very partial story, in particular with respect to the dynamics of the evolution of the performance. As always, the availability of data proved to be the main constraint in trying to figure out how much the operator's performance improved between 1998 and 2005. However, the integration of data collected from various sources allowed us to generate a complete dataset covering every year between 1998 and 2005. This dataset generates additional insights on the evolution of performance and of the main components of this performance. As explained in section 3, we do so from a Malmquist index, adopting an input oriented DEA to decompose it into its various components, since in all of these countries the industry is regulated.

We follow the same typology of outputs as in section 6.1 with the same two inputs. The results of our four basic models are shown in Tables 5 and 6. Table 5 focuses on the index measures for physical measures of output (generation and customers), Table 6 focuses on our financial measure of output (sales). Following equations (5) and (7), each table shows the average change in TFP (TFPC) as well as its components, the Total Technical Efficiency Change (TTEC) and Technological Change (TC). The TTEC is also decomposed in Technical Efficiency Change (TEC) and Scale Efficiency Change (SEC).

Table 5: Malmquist Index

	OUTPUT: Generation and Customers **INPUTS: Capital and Labour** Model 1					OUTPUT: Generation **INPUTS: Capital and Labour** Model 2					OUTPUT: Customers **INPUTS: Capital and Labour** Model 3				
Firm	*TTEC*	*TC*	*TEC*	*SEC*	*TFPC*	*TTEC*	*TC*	*TEC*	*SEC*	*TFPC*	*TTEC*	*TC*	*TEC*	*SEC*	*TFPC*
ENE (Angola)	1.028	1.031	1.029	0.999	1.060	1.069	1.003	1.069	1	1.072	0.954	1.081	0.951	1.003	1.031
BPC (Botswana)	1	1.058	1	1	1.058	1	0.999	1	1	0.999	1.04	1.074	1.036	1.003	1.116
SNEL (DCR)	0.979	1.084	0.986	0.994	1.062	1.064	1.01	1.066	0.999	1.075	0.971	1.082	0.971	1	1.051
LEC (Lesotho)	1	1.062	1	1	1.062	0.999	0.999	1	0.999	0.998	1.019	1.080	1	1.019	1.101
ESCOM (Malawi)	0.982	1.067	0.988	0.994	1.048	0.988	0.995	0.991	0.997	0.983	1.001	1.082	0.998	1.003	1.083
EdM (Mozambique)	1	1.074	1	1	1.074	0.767	0.995	0.947	0.810	0.763	1	1.076	1	1	1.076
NamPower (Namibia)	1.018	1.02	1.014	1.004	1.037	0.974	1.007	1.013	0.962	0.981	0.965	1.083	1.017	0.949	1.045
ESKOM (South Africa)	1	1.057	1	1	1.057	1	1.046	1	1	1.046	1	1.085	1	1	1.085
SEB (Swaziland)	0.959	1.072	1	0.959	1.028	1.072	1.002	1	1.072	1.074	0.978	1.091	1	0.978	1.067
TANESCO (Tanzania)	1.008	1.047	1	1.008	1.055	1.109	0.991	1.088	1.019	1.099	1.031	1.051	1	1.031	1.084
ZESCO (Zambia)	0.992	1.040	0.992	0.999	1.031	1.006	1.010	1	1.006	1.015	1.009	1.081	1.009	1.001	1.092
ZESA (Zimbabwe)	0.991	1.074	0.993	0.999	1.065	1.050	1.007	1.04	1.009	1.057	0.983	1.080	0.972	1.011	1.061
MEAN	**0.996**	**1.057**	**1**	**0.996**	**1.053**	**1.004**	**1.005**	**1.017**	**0.987**	**1.010**	**0.996**	**1.079**	**0.996**	**1**	**1.074**

The story emerging from the efficiency calculations conducted with physical data (Table 5) may not be as straightforward as one could have wished for. Based on a very basic correlation of performance and market structure or institutional characteristics, whatever the performance model considered, there is no clear advantage in terms of the existence of a private actor or not, in terms of the degree of dependence on hydro source, in terms of the degree of vertical integration or in terms of the existence of an independent regulator.

Note that the changes in productivity as provided by the mean calculated for each model shows some degree of consistency across models in terms of the global trend but also degree of divergence in terms of the specific performance ranking. Under all models, the changes in productivity have been positive. In other words, considered jointly the two inputs have managed to deliver more over time, whatever the outcome indicator considered. However, the range of productivity gains is quite wide, spreading on a scale of 1 to 7. It varied from 1% (or 0.14% per year) when the output is generation to 7.4% (or 1.06% per year) when the output is clients.

The overall performance of the assessment is however at least more focused than the one emerging from the partial indicators discussed earlier. For instance, the commercial (number of customers) and the technical indicators (generation) will not tell necessarily generate the same performance ranking since operators can use their resources (i.e. inputs) to emphasize either (output) dimensions in their business. The preferred model should thus be the one which addresses jointly the two sides of the business. In other words, the best model in this paper is the one that looks at both dimensions of outputs and both inputs jointly. With that model (the first set of columns in Table 5), we find an average improvement in total economic efficiency of 5.3%. as indicated by the mean for the sample of operators covered here. Only Zambia, Swaziland, Namibia and Malawi are below that total average performance.

While the overall trend is thus positive, it is also important to figure out the drivers of this positive trend. It turns out that this may be the most important observation since the results suggest that it is essentially driven by the technological change observed in the sector (i.e a frontier shift). With the exception of Namibia and to a lesser extent Angola and Tanzania, performance has hardly improves in terms of technical efficiency or scale economy which means that there is no catching up that is taking place in the management of the industry in the region.

At the operator level, there are thus some clear winners and losers from the changes in productivity and this assessment is largely although not always independent of the criteria relied upon to assess efficiency. Some of the countries have made very significant improvements such as, South Africa, with gains during the period well above the average for all models or above the average for some models but always with positive increase in the TFP like Tanzania and Zambia. Some of the countries have also suffered a drop in performance, at least in terms of some specific outputs as is the case for Mozambique and Namibia. The ranking is however not totally insensitive to the criteria used. Some operators have on average achieved significant gains in terms of the number of clients they serve, while they did not achieve gains in terms of production like Mozambique. This implies that operators have allocated a large share of their efforts to improving their ability to increase their coverage of clients. It may also reflect a policy aimed at reducing commercial losses from illegal connections. This allows the operators to meet a larger demand for a given production level.

Table 6 summarizes an assessment in terms of the financial performance of the operator by focusing on the drivers of the evolution of efficiency in terms of sales. Once more the average performance has seen an improvement by a 3.9% in efficiency over the full period of analysis but not all operators have been equally successful. The laggards include Lesotho, Malawi and Zimbabwe. As we found in terms of the physical performance indicators, the sources of the gains come improvement in technology rather than in terms of improved management or scale economies to catch up with best practice operators. In fact some operators (i.e. DCR, Lesotho, Zambia and Zimbabwe) have seen some significant declines in scale economies.

Overall, in the context under analysis here, the time span between 1998 and 2005 is probably too brief to be able to notice major significant changes from major investment in generation, in particular in a region in which most of the expansion is expected to come from the hydro side. The high technological thus seems to be the major contribution of the changes of the 1990s. There is also a sense that the ability to commercialize the services has improved significantly since efficiency has improved significantly both in terms of customers and sales. Both may be the product of the significant efforts made to improve access to the existing networks in that region, although the very models scale efficiency gains may suggest that this is not the case or at least that added populations are not really that close in location to the existing populations. Our data does not allow us to be more assertive on this explanation.

Table 6. Malmquist Index

	OUTPUT: Sales INPUTS: Capital and Labour Model 4				
	Period 1998-2005				
Firm	**TTEC**	**TC**	**TEC**	**SEC**	**TFPC**
ENE (Angola)	0.996	1.048	0.991	1.005	1.044
BPC (Botswana)	1.016	1.047	1	1.016	1.064
SNEL (DCR)	0.987	1.053	0.999	0.988	1.040
LEC (Lesotho)	0.957	1.047	1	0.957	1.002
ESCOM (Malawi)	0.968	1.045	0.974	0.994	1.012
EdM (Mozambique)	1.005	1.041	1	1.005	1.046
NamPower (Namibia)	1.013	1.053	1.004	1.009	1.067
ESKOM (South Africa)	1	1.044	1	1	1.044
SEB (Swaziland)	0.997	1.037	1	0.997	1.033
TANESCO (Tanzania)	1.015	1.047	0.973	1.043	1.063
ZESCO (Zambia)	0.985	1.053	0.999	0.986	1.037
ZESA (Zimbabwe)	0.964	1.052	0.982	0.981	1.014
MEAN	0.992	1.047	0.994	0.998	1.039

7. Concluding comments

The analysis presented leaves a somewhat sweet and sour taste. The “sweet taste” stems from the mere possibility of a first efficiency diagnostic which reduces the very noisy information generated by partial indicators in terms of absolute and relative performance assessment. The analysis indeed provides a relatively robust set of results. It shows much more clearly than the partial indicators analysis could that the major improvements in the sample countries covered here can be assigned to two very clear sources: the adoption of better technologies and the improvements in commercial practices. It also shows that no significant improvements have been observed on the technical side. In more concrete terms, this can be interpreted as follows. The combination of labor and capital has not been used more effectively to generate more electricity (i.e. no change in technical efficiency and hence no catching up with best practice in management of the business) but the technological opportunities have been better internalized to increase the volume of electricity generated (technological improvements) and the ability to reach more customers and sell more has improved significantly over a 6 year period. This is quite consistent with what is typically expected from reforms of the kind adopted in the region and aimed at commercializing the electricity sector.

The sour taste stems from several sources. The first is that while the reforms seem to have achieved some success, there is still some way to go. The results suggest that it is still to early to tell a very clear story on what specific market structure or institutional characteristic works best. The potential for performance improvements in the region continues however to be high. The second is linked to the doubts that linger any time data quality and volume is so limited. The third is that, given the data limitations, the regulators of the sector in the region are likely to have a hard time coordinating directly the evolution of tariffs to the evolution of the efficiency performance. Much more data is needed, in particular on the cost side of the business, to achieve any fair decision on this front. Until this is done, “cost-plus” is likely to continue to be the de-facto regulatory regime. This means that the opportunities to implement incentive based regulation are likely to continue to be limited. It also means that the gains from reforms may simply become long lasting rents for the operators. The current users are not necessarily going to see much of these gains transformed into lower prices and the users for which service is currently not available or not affordable may not be able to see much improvement in their fate. Probably more so than in most of the other parts of the world, it is essential to ensure equitable access to ensure that efficiency is tracked properly.

References

Balk, B. (1999). *Scale efficiency and productivity change*. Paper presented at the 6th European Productivity Workshop, October 1999, Copenhagen.

Coelli (1996). A Guide to DEAP Version 2.1. A Data Envelopment Analysis (Computer) Program. *CEPA, Working Paper 96/08.* Department of Econometrics, University of New England. Armidale.

Coelli and Lawrence (eds) (2006), *Performance measurement and regulation of network utilities*, Edward Elgar Publishing, Cheltenham, forthcoming.

Coelli, T., Rao, D.S.P. and Battese, G.E. (1998). *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Coelli, T.; Estache, A.; Perelman, S. and Trujillo, L. (2003a). *A Primer on Efficiency Measurement for Utilities and Transport Regulators*. WBI Development Studies. The World Bank. Washington, D.C.

Estache, A. and A. Goicoechea (2005a). A "research" database on infrastructure economic performance. *World Bank Policy Research Working Paper*, No3643.

Estache, A. and A. Goicoechea (2005b), How widespread were private investment and regulatory reform in infrastructure utilities during the 1990s?, *World Bank Policy Research Working Paper*, No3595.

Estache, A.; Perelman, S. and Trujillo, L. (2006). Infrastructure performance and reform in developing and transition economies: evidence from a survey of productivity measures . In Coelli and Lawrence (eds), *Performance measurement and regulation of network utilities*, Edward Elgar Publishing, Cheltenham, forthcoming.

Farell, M.J. (1957), The measurement of Productive Efficiency, *Journal of the Royal Statistical Society,* A CXX (Part 3), 253-290.

Färe. R. and S. Grosskopf, S., (1990). A distance function approach to price efficiency, *Journal of Public Economics*, 43, pp.123-126.

Färe, R., Grosskopf, S., Norris, M. and Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Changes in Industrialized Countries. *American Economic Review* 84 (1): 66-83.

Grifell, E. and Lovell, C.A.K. (1999). A Generalized Malmquist Productivity *Index. Sociedad de Estadística e Investigación Operativa*, 7, 81-101.

Grifell, E. and Lovell, C.A.K. (1993). Deregulation and Productivity Decline: The case of Spanish Saving Banks. *Working Paper, 93-02 (June)*. Department of Economics. University of North Carolina.

Hjalmarsson, L. and A. Veiderpass, "Efficiency and Ownership in Swedish Electricity Retail Distribution," *Journal of Productivity Analysis* 3:1-2 (1992a), 7-23.

Hjalmarsson, L. and A. Veiderpass, "Productivity in Swedish Electricity Retail Distribution," *Scandinavian Journal of Economics* 94:S (1992b), 193-205.

Kumbhakar, S and Hjalmarsson, L, (1998). Relative Performance of Public and Private Ownership under Yardstick Competition: Electricity Retail Distribution. *European Economic Review*, 42.

Jasmab, T. and Pollitt, M. (2001), Benchmarking and regulation: international electricity experience, *Utilities Policy*, 9, 107-130.

Jasmab, T., Newbery, D. and Pollitt, M. (2004a), Core indicators for determinant and performance of electricity sector in developing countries, *Cambridge Working Paper in Economics*, CWPE 0438.

Jasmab, T., Motta, R., Newbery, D. and Pollitt, M. (2004b), Electricity Sector Reform in Developing Countries: A survey of Empirical Evidence on Determinants and Performance, *Cambridge Working Paper in Economics*, CWPE 0439.

Kumbhakar, S. and L. Hjalmarsson, “Relative Performance of Public and Private Ownership under Yardstick Competition: Electricity Retail Distribution,” *European Economic Review* 42:1 (1998), 97-122.

Neuberg, L. (1977) , “Two Issues in the Municipal Ownership of Electric Power Distribution Systems,” *Bell Journal of Economics* 8:1 (1977), 303-323.

Nishimizu, M., and Page, J. (1982). Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1965-78. *Economics Journal* 92. 920-36.

Plane, P. (1999), “Privatization, Technical Efficiency and Welfare Consequences: The Case of the Cote d’Ivoire Electricity Company”, *World Development*, 27(2), 341-360.