A Benchmarking Study of Island Electricity Companies: The Case of the Central Electricity Board of Mauritius

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In this paper, we study the performance of the electricity company of Mauritius, the Central Electricity Board (CEB). We undertake a comparative analysis with other island companies in similar environmental conditions. We mainly rely on data available on annual reports for the CEB and four other companies operating in islands: EAC (Cyprus), CEM (Macao), EEM (Madeira), and MEA (Isle of Man). The period under study covers the years 2000–2010 and uses the Malmquist Index and Data Envelopment Analysis. For the CEB, results show that productivity change is driven mainly by technical change. CEB operational costs grew during the study period due to the increasing price of fossil fuel used in the generation of electricity. Companies less dependent on thermal production were less exposed to increasing costs.

Keywords: Mauritius, efficiency, benchmarking, Malmquist Index, DEA, island electricity companies

INTRODUCTION

We study the performance of the electricity company of Mauritius, the Central Electricity Board (CEB). For this purpose, we proceed to a comparative analysis with other companies in the same sector and facing similar environmental conditions.

To achieve this goal, the following criteria dictate the choice of companies to be compared:

- Operates in an isolated territory, by preference an island, facing similar electricity generation and distribution conditions;
- Organization is vertically integrated, that is involved in the generation, transmission, distribution, and retailing of electricity;
- Operates in a comparable economic development framework, in an upper middle-income country like Mauritius or in a high-income country (cfr. World Bank classification of economies);
- Data are available regarding production characteristics, e.g., outputs and inputs, including monetary variables;
- Data cover the period of analysis (2000–2010).

We rely on the NESIS, Network of Experts for Small Island Systems Report (2006) to make this selection. In the Appendix, we present the main characteristics of island electrical systems included in this paper. In all cases, the main electricity company (i.e., the historical operators) is integrated vertically. As observed, a variety of situations are reported: in some cases, the electrical system is interconnected with the continent or among islands (e.g., New Caledonia); Macao population density is thirty times higher than Mauritius; Mauritius and Malta belong to the middle-income country group while the other islands are classified as high-income countries. Summing up, there are a variety of situations that can facilitate a multidimensional benchmark analysis.

Based on this information, we collected yearly data from the annual reports of electricity companies operating in these islands. Unfortunately, we could not access the annual reports for several companies; e.g., the electricity systems in Spanish (Canary) and French (Corsica, Guadeloupe, Reunion, …) islands belong to main national operators, ENDESA and EDF, respectively, and publish annual reports at the company level, exclusively.

Other than CEB, we were able to collect rather complete information for the 2000–2010 period for the following four companies:

- Electricity Authority of **Cyprus** (EAC)
- Empresa de Electricidade da **Madeira** (EEM)
- Manx Electricity Authority (MEA), Isle of **Man**
- Companhia de Electricidade de **Macau** (CEM)

To compare their efficiency through benchmarking these five island electricity companies, this paper provides an assessment of economic efficiency levels as well as other sources of difference among the companies during 2000–2010. We use two methodological approaches. We first estimate the productivity change according to the Malmquist Total Factor Productivity Index (Jamasb & Pollitt, 2003; Estache, Tovar, & Trujillo, 2008). Next, we use the DEA approach (Mbangala & Perelman, 1997) to benchmark the different sub-systems of each company such as power generation, transmission, and distribution (Plane, 1999).

The paper is organized as follows. In the first section, we give an overview of the main characteristics of these companies. Other than the institutional framework in which they operate, we pay particular attention to the system of electricity generation. In Section 2, we present the results of a benchmark study using frontier analysis. More precisely, we compute technical efficiency and total factor productivity growth using Data Envelopment Analysis (DEA). Section 3 is devoted to the comparison of operational costs and of prices across companies and over time. Finally, in Section 4 we present the conclusions and derive policy recommendations.

OVERVIEW OF COMPANIES' CHARACTERISTICS

The Institutional Setting

The key features of the companies' institutional environment can be summarized by making the distinction between their legal frameworks on the one hand and the sector organization and regulatory process on the other hand. Hereafter, we present the five companies under scrutiny in this study.

The CEB (Mauritius) is a parastatal body, wholly owned by the Government of Mauritius and reporting to the Ministry of Renewable Energy and Public Utilities. It is engaged in the generation, transmission, and distribution of electricity in Mauritius and Rodrigues.

The EAC (Cyprus) is an independent, semi-government corporation. Its main objective is to perform functions relating to the generation and supply of electric energy in Cyprus. The government, through the Minister of Commerce, Industry and Tourism, is empowered to give directives to the EAC on matters appertaining to the general interest of the Republic.

EEM (Madeira) is a state-owned company. Its main objective is the generation, transport, distribution, and commercialization of electric energy in the Autonomous Region of Madeira.

The MEA (Man) is constituted under the Electricity Act as a statutory Board of Tynwald. All the companies are vertically integrated. Their role is to produce, transport, and supply electric energy. Moreover, each island operates under a regulatory body with the exception of Mauritius, where the Government is responsible for the adjustment of tariffs.

System of Electricity Generation

According to Table 1, CEB depends more on external sources for generation than the other four companies. Total energy purchases from Independent Power Producers (IPPs) and Continuous Power Producers (CPPs) accounted for 40.6% of the total energy sent out to the grid over the period 2000–2005 but this increased to 54.7% in the following period (2005–2010). By comparison, EEM (Madeira) and EAC (Cyprus), two companies not as interconnected as CEB, generated 75% and 100% of the total energy supplied to the grid, respectively, over the whole period with minimum variation.

The generating power system consists of hydroelectric power plants and thermal plants. The main generation power system is thermoelectric, fuel oil, power for CEB and EEM, which represents, respectively, 95.2% and 81.4%. At MEA, the majority of the power generated on-island is at the Combined Cycle Gas Turbine Plant (CCGT).

TABLE 1
THERMAL PRODUCTION AND PURCHASED ENERGY RATES (%)

Period	Mauritius CEB	Cyprus EAC	Macao CEM	Madeira EEM	Man MEA
Purchased (%)					
2000-2005	40.6	0.0	13.7	23.8	.
2005-2010	54.7	0.0	60.5	26.8	12.6
2000-2010	47.7	0.0	35.9	25.0	.
Thermal (%)					
2000-2005	94.4	.	42.0	78.1	40.2
2005-2010	96.0	.	43.5	86.3	42.7
2000-2010	95.2	.	42.7	81.4	41.3

Installed Capacity

Table 2 compares the evolution over time of three main indicators: generation, peak-load demand, and installed capacity. Peak-load demand increased at similar path rates in Mauritius and Madeira, 3.5% and 3.6% by year, respectively. In both cases, generation followed with rates of 4.1% and 5.0%, respectively, but installed capacity increased at a lower rate: 2.1% by year in Mauritius compared with 5.2% in Madeira.

TABLE 2
GENERATION, PEAK-LOAD DEMAND, AND INSTALLED CAPACITY (AVERAGE ANNUAL % CHANGE)

Island	Generation (GWH)	%Δ	Peak-load demand (GWH)	%Δ	Installed capacity (GWH)	%Δ
Mauritius CEB						
2000-2005	1,785.8	5.2	316.2	4.3	627.8	1.1
2005-2010	2,274.9	3.2	386.5	2.7	719.2	3.0
2000-2010	2,030.4	4.1	351.3	3.5	673.5	2.1
Cyprus EAC						
2000-2005	3,879.8	5.2	856.0	-	988.0	-
2005-2010	4,947.6	3.7	1,040.2	6.0	1,223.0	7.0
2000-2010	4,365.2	4.4	1,009.5	6.0	1,183.8	7.0

Island	Generation (GWH)	%Δ	Peak-load demand (GWH)	%Δ	Installed capacity (GWH)	%Δ
Macao CEM						
2000-2005	1,950.5	6.1	400.0	7.0	-	-
2005-2010	3,330.8	10.4	623.0	7.1	-	-
2000-2010	2,577.9	8.2	501.4	7.0	-	-
Madeira EEM						
2000-2005	769.3	7.4	145.5	5.6	443.0	0.0
2005-2010	958.3	2.1	170.1	1.6	519.0	6.5
2000-2010	844.9	5.0	156.4	3.6	493.6	5.2
Man MEA						
2000-2005	390.6	4.8	82.7	2.8	174.4	-
2005-2010	502.7	5.1	88.7	1.2	174.4	0.0
2000-2010	441.5	4.9	85.4	2.0	174.4	-

To complete this overview, Table 3 presents an overview of the prevailing situation at the middle of the decade (2005–2006) and compares the situation in the islands surveyed by the NESIS 2006 Report with the results reported in the African Infrastructure Country Diagnosis (2008) for African countries. In this table, generation and installed capacity are computed in kWh per habitant. An index of operational over installed capacity is computed (installed capacity in kWh previously multiplied by the total number of hours in a year).

From this table, we learn that even if Mauritius generation and installed capacity per habitant are the lowest among islands, they are comparable with average scores among African middle-income countries with the exception of South Africa. Nevertheless, it appears that the Mauritius electricity system has a low and safe "operation over installed capacity" ratio compared with middle-income African countries (26.2% and 96.0%, respectively).

TABLE 3
BENCHMARKING WITH MIDDLE INCOME AFRICAN COUNTRIES, CAPE VERDE, AND SOUTH AFRICA (2005–2006)

Islands	Annual generation (kWh per habitant)	Installed capacity (kWh per habitant)	Operational over-installed capacity (%)
Azores	3.230	1.079	26.2
Canary	4.483	1.203	32.6
Corsica	7.082	2.031	30.6
Cyprus	5.107	1.322	33.9
Guernsey	5.852	2.936	17.5
Guadalupe	3.962	1.068	32.5
Jersey	7.500	4.114	16.0
Macao	5.033	1.410	31.3
Madeira	3.743	1.167	28.1
Malta	5.272	1.413	32.7
Man	5.059	2.860	15.5
Martinique	3.729	965	33.9
Mauritius	1.652	552	26.2
New Caledonia	3.159	1.027	26.9
Polynesia	2.517	855	25.8
Reunion	3.017	749	35.3

Islands	Annual generation (kWh per habitant)	Installed capacity (kWh per habitant)	Operational over-installed capacity (%)
AFRICA			
Middle Income (av.)	1.475	310	96.0
South Africa	4.810	854	71.5
Cape Verde	87	150	80.4

Sources: AICD (2008), NESIS (2006) and own computations.

Electricity Distribution and Consumption

As mentioned before, island companies are vertically integrated. Particularly, they are in charge of transmission and distribution for the whole surface and living population. Table 5 presents the evolution of the number of customers, transformer capacity, and the percentage of losses.

The number of customers increased at a rate of 2.3% over the 2000–2010 period in Mauritius, a growth rate close to that observed for peak-load demand in Table 3. Transformer capacity increased at a higher rate, 6.8% yearly, which probably explains why the percentage of losses diminished slightly over the whole period. Similar paths are observed for the other companies as well.

TABLE 4
CUSTOMERS, TRANSFORMER CAPACITY, AND LOSSES
(AVERAGE ANNUAL % CHANGE)

Island	Customers	%Δ	Transformer capacity (GWH)	%Δ	Losses (%)	%Δ
Mauritius CEB						
2000-2005	335,023	2.6	1,850	3.2	10.4	-2.1
2005-2010	385,517	2.1	3,428	9.9	9.0	-2.8
2000-2010	360,270	2.3	2,639	6.8	9.7	-2.5
Cyprus EAC						
2000-2005	402,806	3.0	.	.	10.0	-2.4
2005-2010	497,422	4.2	3,144	0.9	9.2	-3.2
2000-2010	445,814	3.6	.	.	9.6	-2.8
Macao CEM						
2000-2005	193,229	2.1	548	7.3	5.5	-12.6
2005-2010	213,400	1.6	632	1.9	4.1	0.6
2000-2010	202,398	1.9	586	4.6	4.9	-6.2
Madeira EEM						
2000-2005	118,393	3.3	421	2.5	11.1	-3.4
2005-2010	133,285	1.4	513	5.4	10.6	-1.3
2000-2010	124,350	2.4	458	3.8	10.9	-2.5
Man MEA						
2000-2005	43,218	2.4	.	.	9.7	0.1
2005-2010	46,303	0.8	.	.	9.4	-2.6
2000-2010	44,620	1.6	.	.	9.6	-1.3

The following two tables report information on the structure of the demand (Table 5) and on the average consumption by customer (Table 6). On the one hand, we do not observe significant differences in the structure of the demand across the five islands or significant change over time. On average, domestic demand represents one-third of total demand with the only exception being the Isle of Man where it reaches 40.0%.

TABLE 5
ELECTRICITY DISTRIBUTED TO CUSTOMERS (% IN TOTAL)

Island	Domestic	Commercial	Industrial	Irrigation	Lighting
Mauritius CEB					
2000-2005	34.6	29.1	32.8	1.7	1.6
2005-2010	32.2	33.2	31.5	1.2	1.7
2000-2010	33.4	31.2	32.2	1.5	1.7
Cyprus EAC					
2000-2005	35.0	40.5	19.7	3.1	1.7
2005-2010	36.8	41.4	16.9	3.2	1.7
2000-2010	35.8	40.9	18.4	3.1	1.7
Madeira EEM					
2000-2005	31.9	38.8	12.8	8.2	8.3
2005-2010	31.3	42.2	9.7	7.3	9.4
2000-2010	31.7	40.3	11.4	7.8	8.8
Man MEA					
2000-2005	43.1	23.4	31.9	0.5	1.1
2005-2010	35.9	22.9	25.2	15.1	1.0
2000-2010	39.8	23.1	28.9	7.1	1.0

In Table 6, we observe slight differences in average consumption by commercial and industrial customers but a huge difference in domestic consumption: 1.9 and 2.3 kWh among Mauritius and Madeira customers, respectively, and 4.1 kWh among Cyprus domestic customers.

TABLE 6
ELECTRICITY DISTRIBUTED TO CUSTOMERS (KWH BY CUSTOMER)

Island	Domestic	Commercial	Industrial	Irrigation	Lighting
Mauritius CEB					
2000-2005	1.8	15.8	76.8	73.8	80.9
2005-2010	1.9	19.6	98.9	52.7	83.5
2000-2010	1.9	17.7	87.8	63.2	82.2
Cyprus EAC					
2000-2005	4.0	19.7	67.7	11.5	9.2
2005-2010	4.3	23.0	66.1	11.8	9.0
2000-2010	4.1	21.2	67.0	11.6	9.1
Madeira EEM					
2000-2005	2.3	20.0	40.3	20.8	44.7
2005-2010	2.4	23.5	40.7	19.6	48.8
2000-2010	2.3	21.6	40.5	20.2	46.5

Table 7 reports rather similar information for 2005, allowing a comparison with AICD (2008) African countries. As expected, the situation in Mauritius is rather close to that observed among middle-income African countries. The case of South Africa, with 86.3% of the energy allowed to high-voltage customers, diverges dramatically from the rest.

TABLE 7
ELECTRICITY DISTRIBUTED AND AVERAGE CONSUMPTION (2005)

Islands	Low voltage (%)	Medium voltage (%)	High voltage (%)	Average domestic consumption (kWh/month)
Cyprus	36.4	40.4	23.2	359.0
Madeira	31.8	40.6	27.6	199.9
Man	41.3	23.0	35.7	.
Mauritius	33.9	31.3	34.7	154.9
AFRICA				
Middle-income (av.)	25.0	21.0	50.0	221.0
South Africa	7.9	5.8	86.3	336.0
Cape Verde	49.7	38.0	12.3	94.0

Sources: AICD (2008) and own computations.

Input Dotation and Sales

To complete this overview of companies' characteristics, we turn now to input dotation, staff and OPEX, and total sales. Unfortunately, complete and reliable information on capital stock is not available for most of companies and periods. When available, it is always reported in nominal values computed on behalf of national accountancy rules.

First, Table 8 presents the evolution over the whole period of staff and OPEX costs. We observe a common path, fast growth of OPEX costs, and stability in staff. The only exception is Cyprus (EAC), with a moderate growth rate in both dimensions. Sales evaluate rather at the same path as OPEX.

Given that staff cost and energy cost are likely the two main components of OPEX, we can derive from these observations that the main driver of companies' operation expenditures over the first decade of the century was probably the increasing cost of energy.

TABLE 8
STAFF, OPEX, AND SALES
(AVERAGE ANNUAL % CHANGE AND VALUES IN CONSTANT USD AT 2010 PRICES)

Island	Staff	%Δ	OPEX (10^6 USD)	%Δ	Sales (10^6 USD)	%Δ
Mauritius CEB						
2000-2005	1.730	-0.2	338.6	5.5	423.4	3.7
2005-2010	1.720	0.5	534.3	8.3	599.0	9.4
2000-2010	1.725	0.1	416.9	6.7	511.2	6.9
Cyprus EAC						
2000-2005	2.002	1.2	659.5	3.1	925.2	1.0
2005-2010	2.325	3.9	874.1	2.1	1061.2	1.2
2000-2010	2.149	2.6	757.0	2.6	987.0	1.1
Macao CEM						
2000-2005	738	-0.8	168.6	4.7	280.8	2.7
2005-2010	710	-0.6	333.1	14.4	418.8	9.8
2000-2010	725	-0.7	243.3	9.4	343.5	6.2

Island	Staff	%Δ	OPEX (10^6 USD)	%Δ	Sales (10^6 USD)	%Δ
Madeira EEM						
2000-2005	889	-1.2	140.3	6.8	160.9	10.3
2005-2010	865	-0.3	221.0	4.3	231.3	2.7
2000-2010	879	-0.8	172.6	5.7	189.1	6.8
Man MEA						
2000-2005	281	3.5	45.5	7.9	54.7	0.1
2005-2010	270	-3.1	67.0	5.6	84.9	10.5
2000-2010	276	0.2	55.3	6.8	68.4	5.2

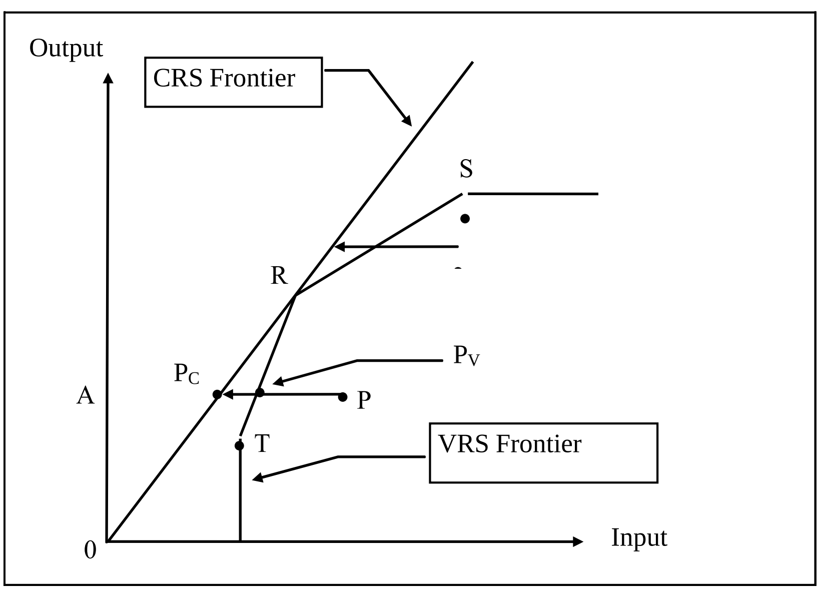
In the next section, we take advantage of the available information on companies' outputs and inputs to compute performance indicators. For this purpose, we rely on frontier analysis. This methodology offers to us the possibility to benchmark each company with its peers while at the same time taking into account the multi-dimensional nature of the activity.

TFP GROWTH AND TECHNICAL EFFICIENCY

DEA and Malmquist Index Computations

Several alternative approaches - parametric vs. non-parametric and deterministic vs. stochastic - are proposed in the specialized literature (Estache, Tovar, & Trujillo, 2008; Coelli et al., 2003). In this study, given the small number of companies available, our preference goes for a non-parametric deterministic approach, DEA (Data Envelopment Analysis). This approach relies on linear programming optimization and consists of the computation of a piecewise linear frontier as described in Figure 1.

FIGURE 1
DATA ENVELOPMENT ANALYSIS INPUT-ORIENTED TECHNICAL EFFICIENCY CALCULATION



In Figure 1, vectors P, Q, R, S, and T represent decision-making units (DMU) in our case electricity companies. DEA is asked to compute two types of benchmark, assuming either constant returns to scale (CRS) or variable returns to scale (VRS). In both cases, the optimization algorithm searches the maximum reduction on input utilization for a given level of output. For instance, under the CRS assumption, company R is the best performer on the frontier and company P's technical efficiency (TE) is measured by the segments ratio PcP/PA. Under the VRS assumption, three companies are 100% efficient on the frontier and company P's technical efficiency is measured by the segments ratio PvP/PA. Furthermore, by construction, the segments ratio PcPv/AP is identified as the scale efficiency indicator.

When panel data are available, as in the case of island electricity companies, the DEA approach can be used to compute a Malmquist Index of total factor productivity change (TFPC). For each year, a specific frontier is computed in the same way. This allows us to measure technical efficiency for each company each year and to compute technical efficiency change (TEC). Moreover, frontier shifts over time are identified as technical change (TC). Adding up TEC and TC, we obtain TFPC scores for each company each year.

The main advantage of the DEA approach, as for other frontier analysis approaches, is that by construction it relies on a benchmark framework. Another major advantage with respect to partial productivity measures of performance is that it allows multi-dimensional settings both on the output and the input sides. Finally, compared with TFPC computed on the index number approaches (Fisher, Törnqvist, …), the Malmquist TFPC computed as indicated before has another key advantage in that it does not rely on output and input prices but only on output and input quantities.

Model Specification

To take into account the main dimensions of electricity companies' production, we opt for a multi-output production technology.

The three outputs correspond to: 1) the number of customers served; 2) the GWh of electricity delivered or generated; and 3) the surface covered in squared kilometers. Proceeding in this way, we rely on the "state of the art" in the specialized literature.[1] In other words, companies serving high-density areas and companies serving rural areas mainly will be compared with their respective peers.

On the input side, unfortunately, the only information available concerns the number of employees (Staff) and operational expenditures (OPEX), including the cost of staff. As mentioned before, capital stock information is not available. For this reason we compute two different models.

Model 1 - Electricity Distribution

This model allows us to compare the companies on behalf of their electricity distribution activities (including transmission and retailing as well). Along with the number of customers and the surface covered, we include electricity distributed. Moreover, the only input is the staff, with the exception of employees working in the energy-generation activity.[2]

Outputs	# Customers (LV, MV, and HV)
	km^2
	GWh delivered
Input	Staff, excluding generation staff

Model 2 – Electricity Generation and Distribution

This is a more general model that considers vertically integrated companies as a whole. Given that in most cases the observed companies share electricity generation with other operators, the input variable (total OPEX) includes the cost of energy purchased. On the output side, a third output is generated instead of delivered electricity.

Outputs	# Customers (LV, MV, and HV)
	km^2
	GWh generated
Input	OPEX

Before presenting the computation results, it is important to note another key difference between Model 1 and Model 2 outside the nature of activities under scrutiny in each case. Model 1 relies entirely on physical quantities on both the output and input sides, whereas Model 2 uses an aggregate measure, OPEX, as an input value. Our main assumption underlying the computation of Model 2 is that OPEX, as measured in USD at 2010 constant prices, corresponds to a composite aggregation of multiple inputs entering in energy production and distribution, mainly the staff, fuel and coal, myriad materials, and so on.

Without detailed information on OPEX decomposition or the average price of each component of operational costs, OPEX is a poor proxy of a composite physical input measure. It is, by definition, sensitive to variations in relative prices. In the case of electricity companies studied here, OPEX is likely highly biased due to the evolution of fossil fuel-based energy prices, which increased dramatically over the observed period.

TFP Change

Tables 9a and 9b report the main results obtained by Malmquist TFPC Index computations using the DEA approach. A striking difference across both models is that in the first case, the electricity distribution model, the annual average productivity growth rate is 2.6% while it is negative (−3.1%) for Model 2. For CEB (Mauritius), the gap between both models is even wider: 2.2% for Model 1 and −4.2% for Model 2. Looking closely, it appears that the volatility of results over the period is dramatically high for Model 2 while practically nonexistent under Model 1.

TABLE 9A
MALMQUIST TFPC INDEX - MODEL 1 - ELECTRICITY DISTRIBUTION MODEL

Year	Mauritius CEB	Cyprus EAC	Macao CEM	Madeira EEM	Man MEA	All
2002	3.6	2.7	5.3	6.5	3.3	4.3
2003	4.2	0.7	4.4	6.3	-2.7	2.5
2004	3.3	1.9	7.6	2.4	-9.0	1.1
2005	-1.2	2.8	7.5	3.3	1.6	2.8
2006	8.0	-0.9	6.1	2.1	0.9	3.2
2007	4.6	-5.5	11.5	1.7	11.0	4.5
2008	-2.0	-1.4	7.4	1.2	15.4	3.9
2009	-2.8	-3.3	2.8	1.6	-4.1	-1.2
2001-2005	2.5	2.0	6.2	4.6	-1.8	2.7
2005-2009	1.9	-2.8	6.9	1.6	5.5	2.6
2001-2009	2.2	-0.4	6.5	3.1	1.8	2.6

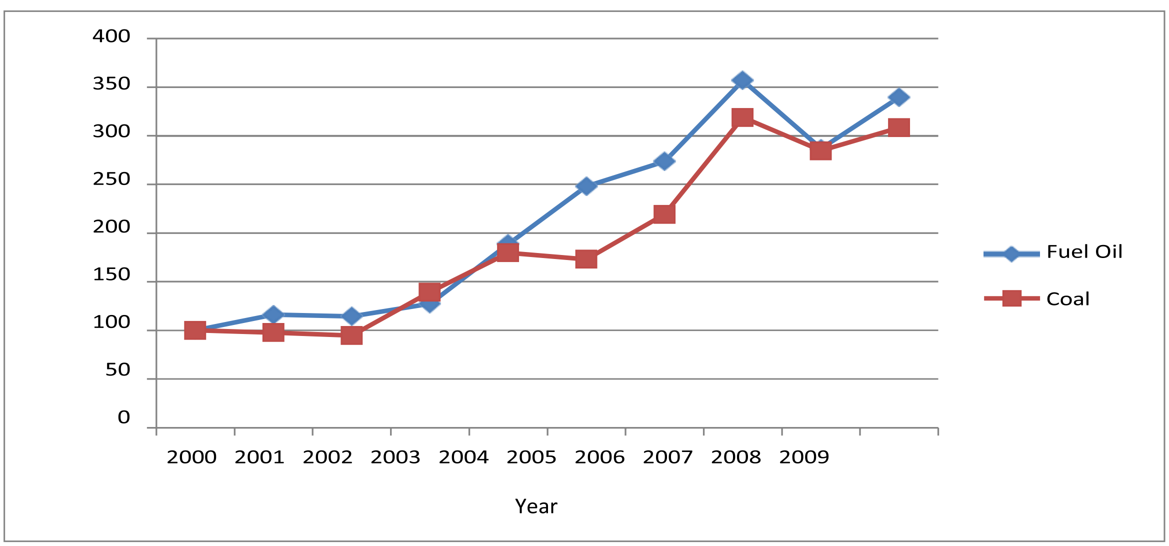
TABLE 9B
MALMQUIST TFPC INDEX - MODEL 2 - ELECTRICITY GENERATION AND DISTRIBUTION

Year	Mauritius CEB	Cyprus EAC	Macao CEM	Madeira EEM	Man MEA	All
2001	12.8	10.5	3.3	1.2	-19.2	1.0
2002	-16.2	-7.7	-6.8	10.9	16.3	-1.4
2003	13.9	2.2	9.2	-7.0	-12.0	0.8
2004	-12.5	3.9	-38.3	-11.6	-3.8	-13.8
2005	-8.8	-18.7	53.5	-9.5	-4.6	-0.3
2006	-17.7	-16.3	-37.8	-17.0	-18.6	-22.0
2007	12.6	-0.9	0.4	5.8	-1.4	3.2
2008	-21.4	5.0	-1.1	-15.4	29.3	-2.2
2009	8.7	23.0	45.1	20.1	-27.3	11.1
2000-2005	-3.0	-2.5	-0.1	-3.5	-5.4	-2.9
2005-2009	-5.7	1.7	-2.7	-2.8	-6.8	-3.3
2000-2009	-4.2	-0.6	-1.3	-3.2	-6.0	-3.1

An immediate interpretation of these results is that most of the selected electricity companies experimented with opposite situations during this period. On the one hand, they improved productivity in distribution and staff use while at the same time they experienced productivity losses in their whole activity and in terms of operational expenditures.

Unfortunately, we did not have access to more detailed information on operational costs. Nevertheless, the main driver of the OPEX increase over the period is likely the cost of fossil fuel-based energy. Figure 2 illustrates this evolution, showing an increase in average prices of oil and coal close to 200%.

FIGURE 2
OIL AND COAL PRICES (BASE INDEX 2000 = 100)



Source: Energy Water Digest Statistics, Ministry of Finance and Economic Development (Mauritius)

As indicated in Section 2.1, TFPC is by construction decomposable into its two components: technical efficiency change (TEC) and technological change (TC). Table 10 reports the average values of these indexes for Models 1 and 2. In both cases, the technical change component is the main driver of TFP change.

In other words, for the small sample of island electricity companies studied, it is the general shift in the frontier benchmark, positive under Model 1 and negative under Model 2, that explains better the observed paths in productivity.

TABLE 10
MALMQUIST TFPC DECOMPOSITION

Island	**MODEL 1**			**MODEL 2**		
	Efficiency change	**Technical change**	**TFP change**	**Efficiency change**	**Technical change**	**TFP Change**
Mauritius CEB						
2000-2005	-0.5	2.9	2.5	1.1	-4.0	-3.0
2005-2010	0.8	1.1	1.9	1.2	-6.8	-5.7
2000-2010	0.1	2.0	2.2	1.2	-5.3	-4.2
Cyprus EAC						
2000-2005	0.0	2.0	2.0	2.5	-4.9	-2.5
2005-2010	0.0	-2.8	-2.8	0.0	1.7	1.7
2000-2010	0.0	-0.4	-0.4	1.4	-2.0	-0.6
Macao CEM						
2000-2005	0.0	6.2	6.2	0.0	-0.1	-0.1
2005-2010	0.0	6.9	6.9	0.0	-2.7	-2.7
2000-2010	0.0	6.5	6.5	0.0	-1.2	-1.3
Madeira EEM						
2000-2005	1.7	2.9	4.6	0.6	-4.1	-3.5
2005-2010	0.7	1.0	1.6	3.9	-6.4	-2.8
2000-2010	1.2	1.9	3.1	2.1	-5.2	-3.2
Man MEA						
2000-2005	-4.3	2.6	-1.8	0.0	-5.4	-5.4
2005-2010	5.5	0.0	5.5	-4.5	-2.4	-6.8
2000-2010	0.5	1.3	1.8	-2.0	-4.1	-6.0
All						
2000-2005	-0.6	3.3	2.7	0.8	-3.7	-2.9
2005-2010	1.4	1.2	2.6	0.1	-3.4	-3.3
2000-2010	0.4	2.2	2.6	0.5	-3.6	-3.1

Technical Efficiency

In this section, we address the technical efficiency scores obtained by companies over the period. These scores allow us to establish a ranking but mainly to compute the distance to the best practice frontier. Given that for computations we assume an input orientation, scores between 0 and 1 indicate the proportional reduction of inputs with outputs constant, thus allowing the efficiency frontier to be achieved. It is also important to note that the results correspond to year-by-year computations. That means they do not take into account potential technical change that, as was reported in the previous section, plays a major role compared with technical efficiency changes.

For both models, three results are reported: constant returns to scale (CRS) and variable returns to scale (VRS) efficiency, and scale efficiency (VRS/CRS). Either under the distribution model (1) or the generation and distribution model (2), CEB (Mauritius) lies on the VRS production frontier the whole period. However, under the CRS assumption under Model 1, the company obtains a TE score of 0.606 and 0.659 in periods 2001–2004 and 2005–2009, respectively. Compared with other companies, CEB performs better than EEM (Madeira) and MEA (Isle of Man). Furthermore, as can be observed in Table 11, technical inefficiencies in the case of CEB are the consequence of scale inefficiencies. That is, the scale of operation is not optimal.

TABLE 11
TECHNICAL AND SCALE EFFICIENCY

Island	MODEL 1			MODEL 2		
	Technical efficiency		Scale efficiency	Technical efficiency		Scale efficiency
	CRS	VRS		CRS	VRS	
Mauritius CEB						
2001-2004	0.606	1.000	0.606	0.914	1.000	0.914
2005-2009	0.659	1.000	0.659	0.914	0.989	0.924
2001-2009	0.627	1.000	0.627	0.914	0.996	0.918
Cyprus EAC						
2001-2004	1.000	1.000	1.000	0.980	1.000	0.980
2005-2009	1.000	1.000	1.000	0.992	1.000	0.992
2001-2009	1.000	1.000	1.000	0.985	1.000	0.985
Macao CEM						
2001-2004	1.000	1.000	1.000	0.996	1.000	0.996
2005-2009	1.000	1.000	1.000	0.989	1.000	0.989
2001-2009	1.000	1.000	1.000	0.993	1.000	0.993
Madeira EEM						
2001-2004	0.456	0.620	0.735	0.795	0.839	0.948
2005-2009	0.499	0.644	0.775	0.792	0.843	0.940
2001-2009	0.473	0.630	0.751	0.794	0.841	0.944
Man MEA						
2001-2004	0.447	1.000	0.447	1.000	1.000	1.000
2005-2009	0.500	1.000	0.500	0.958	1.000	0.958
2001-2009	0.468	1.000	0.468	0.983	1.000	0.983
ALL						
2001-2004	0.702	0.924	0.760	0.937	0.968	0.968
2005-2009	0.732	0.929	0.788	0.929	0.966	0.962
2001-2009	0.714	0.926	0.771	0.934	0.967	0.966

OPERATIONAL COST, SALES, AND AVERAGE PRICES

In this section, we analyze and compare the evolution of costs, sales, and average prices across companies and over time. We present these data using a series of tables. The first, Table 12, reports the ratio between OPEX and sales. When this index is close to 1.0 or higher, the company has a small margin or even a deficit and, as a consequence, has limited capacity to invest.

According to Table 12, CEB (Mauritius) was in a favorable situation at the beginning of the period. The situation deteriorated up to 2006 with an OPEX/Sales ratio of 1.037 but recovered at the end with a ratio of 0.833 in 2009. MEA (MAN) followed a similar path over the period while EEM (Madeira) improved slowly. The situation of EAC (Cyprus) and CEM (Macao) also deteriorated but both companies kept a favorable margin.

TABLE 12
OPERATIONAL COST IN RELATION WITH SALES: OPEX/SALES INDEX

Year	Mauritius CEB	Cyprus EAC	Macao CEM	Madeira EEM	Man MEA
2000	-	0.693	0.563	1.010	0.622
2001	0.742	0.678	0.544	0.993	0.810
2002	0.827	0.708	0.619	0.887	0.778
2003	0.720	0.708	0.519	0.725	0.921
2004	0.837	0.716	0.699	0.845	0.970
2005	0.921	0.768	0.621	0.859	0.909
2006	1.037	0.802	0.689	0.999	0.882
2007	0.919	0.802	0.770	0.932	0.871
2008	0.964	0.886	1.041	0.975	0.686
2009	0.833	0.835	0.746	0.916	0.801
2010	-	0.802	0.761	-	0.723
2000-2005	0.809	0.712	0.594	0.886	0.835
2005-2010	0.938	0.825	0.801	0.955	0.792
2000-2010	0.867	0.763	0.688	0.914	0.816

The next two tables report average OPEX costs and prices by kWh delivered. A net difference appears between companies. CEM (Macao) and MEA (Isle of Man), the two companies interconnected, show lower average costs and charge lower prices (nearly 50% lower) than the others. On Table 13, we observe that CEB (Mauritius) price growth was faster during the last years of the period.

TABLE 13
AVERAGE OPERATIONAL COST OF ENERGY DELIVERED: OPEX/KWH (USD, 2010)

Year	Mauritius CEB	Cyprus EAC	Macao CEM	Madeira EEM	Man MEA
2000	0.231	0.220	0.087		0.118
2001	0.197	0.192	0.085	0.211	0.137
2002	0.233	0.192	0.088	0.181	0.117
2003	0.194	0.174	0.079	0.186	0.130
2004	0.216	0.166	0.127	0.204	0.133
2005	0.234	0.197	0.079	0.220	0.137
2006	0.274	0.225	0.122	0.261	0.157
2007	0.237	0.220	0.116	0.248	0.166
2008	0.297	0.199	0.117	0.285	0.119
2009	0.276	0.158	0.080	0.239	0.159
2010	-	0.179	0.094	-	0.138
2000-2005	0.217	0.190	0.091	0.200	0.129
2005-2010	0.271	0.196	0.106	0.258	0.148
2000-2010	0.239	0.193	0.098	0.226	0.137

TABLE 14
AVERAGE PRICE PER KWH (USD, 2010)

Year	Mauritius CEB	Cyprus EAC	Macao CEM	Madeira EEM	Man MEA
2000	-	0.317	0.155	-	0.189
2001	0.265	0.283	0.155	0.212	0.169
2002	0.281	0.271	0.142	0.204	0.151
2003	0.269	0.246	0.153	0.257	0.141
2004	0.259	0.232	0.182	0.241	0.137
2005	0.254	0.256	0.127	0.256	0.151
2006	0.264	0.280	0.177	0.261	0.178
2007	0.258	0.274	0.150	0.266	0.190
2008	0.308	0.224	0.113	0.292	0.173
2009	0.332	0.189	0.107	0.261	0.198
2010	0.326	0.223	0.124	-	0.191
2000-2005	0.266	0.268	0.153	0.234	0.156
2005-2010	0.298	0.238	0.134	0.270	0.186
2000-2010	0.282	0.254	0.144	0.250	0.170

The last two tables concern CEA (Mauritius) exclusively. In Table 15, we compare the evolution of average kWh prices charged for different customers. Commercial and lighting kWh prices increased faster than kWh prices for other customers.

TABLE 15
AVERAGE PRICE PER KWH BY CUSTOMER TYPE, CEB (MAURITIUS) (USD, 2010)

Year	Domestic	Commercial	Industrial	Irrigation	Lighting
2000	-	-	-	-	-
2001	0.277	0.332	0.197	0.140	0.353
2002	0.287	0.372	0.199	0.150	0.397
2003	0.277	0.351	0.188	0.142	0.379
2004	0.266	0.333	0.181	0.138	0.359
2005	0.263	0.325	0.173	0.135	0.352
2006	0.270	0.351	0.177	0.138	0.371
2007	0.262	0.342	0.172	0.135	0.356
2008	0.304	0.414	0.203	0.159	0.432
2009	0.328	0.442	0.212	0.164	0.458
2010	0.323	0.432	0.207	0.166	0.448
2001-2005	0.274	0.343	0.188	0.141	0.368
2005-2010	0.297	0.396	0.194	0.152	0.413
2001-2010	0.286	0.369	0.191	0.147	0.391

Finally, Table 16 reports average costs by kWh generated and purchased, and the average cost of distribution. Unfortunately, detailed information at this level is only available for CEB (Mauritius) and not for the whole period. It clearly appears that distribution costs remained rather stable over the period while generation costs increased dramatically. No significant difference appears, however, between costs of energy purchased or self-produced.

TABLE 16
AVERAGE COST BY KWH, CEB (MAURITIUS) (USD, 2010)

Year	Generated	Purchased	Distribution
2000	0.138	-	
2001	0.138	-	0.020
2002	0.145	-	0.018
2003	0.136	-	0.018
2004	0.140	0.172	0.025
2005	0.170	0.193	0.012
2006	0.190	0.183	0.024
2007	0.189	0.189	0.020
2008	0.224	0.223	0.021
2009	0.217	0.236	0.017
2010	-	-	-
2000-2005	0.144	0.183	0.019
2005-2010	0.205	0.208	0.020
2000-2010	0.169	0.200	0.019

CONCLUSION

Some preliminary conclusions can be drawn from this comparative study. In terms of technical efficiency and productivity growth, CEB performances are comparable to those of the other companies. In spite of a positive growth trend in electricity distribution activities, the whole activity (vertically integrated) appears to have suffered a negative trend over the period. In both cases, productivity change is driven more by a general trend (technical change) than by a company's specific situation (technical efficiency). CEB operational costs increased throughout the observed period due to the increasing price of fossil fuel entering in the generation of electricity. Companies that are less dependent on thermal production were less exposed to increasing costs. The evolution of the ratio between operational costs and sales, close to 100%, indicates that CEB had a small margin to invest over the period 2000–2010. Other firms faced a similar situation for the same reasons. Only CEM (Macao) and MEA (Isle of Man) were less concerned by this issue. Prices charged to customers are comparable to those applied by the other islands' companies with the exception of CEM (Macao) and MEA (Isle of Man). CEB indicators in terms of population coverage (100%) and quality (frequency/duration of interruptions and percentage of energy lost in transmission and distribution) reach the high standards observed in developed countries.

To conclude, we would like to emphasize that the results presented here, particularly the benchmark analysis, are based on a limited number of case observations (five island companies) and with restricted access to information. If we have to make a recommendation for future work on these issues, then it would certainly be that an effort is necessary to collect systematically data on integrated island electrical systems at the level of individual operators. In addition, this data must include detailed information on costs, if possible, on quantities and prices of energy consumption as well as on the replacement cost of capital.

ACKNOWLEDGEMENT

Translated & edited by American Publishing Services (https://americanpublishingservices.com/).

ENDNOTES

1. See, for instance, Jamasb and Pollitt (2001).
2. Information on staff structure by activities is reported by NESIS (2006). We assume that the percentage of staff allocated to generation activities remained constant over the whole 2000–2010 period.

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APPENDIX: ISLAND ELECTRICAL SYSTEMS (2006)

Island	#	Characteristics				Energy System		
		Surface (km^2)	**Population (x 1,000)**	**Density**	**GDP/h (1000 USD)**	**Inter-Connected**	**Supply (GW)**	**Customers (x 1,000)**
Azores	9	2,330	241.7	103.7	12.0	N	781	111.9
Canary	3	7,492	1,995.8	266.4	17.4	N	8,948	1,066.8
Corsica	1	8,722	279.0	32.0	20.7	Y	1,976	214.9
Cyprus	1	9,259	854.3	92.3	19.4	N	4,363	454.6
French Polynesia	19	3,500	259.8	74.2	17.1	N	654	73.8
Guernsey	1	63	59.8	949.3	36.0	Y	350	28.4
Guadalupe	3	1,780	453.0	254.5	14.8	N	1,795	208.1
Jersey	1	118	88.0	745.8	46.0	Y	660	45.8
La Reunion	1	2,510	784.0	312.4	14.3	N	2,365	301.1
Macao	1	29	513.4	17,952.0	21.1	Y	2,584	206.5
Madeira	2	797	245.0	307.4	17.1	N	917	130.8
Malta	3	316	404.0	1,278.5	10.9	N	2,130	245.0
Man	1	572	80.1	140.0	28.3	Y	405	46.0
Martinique	1	1,100	399.0	362.7	17.6	N	1,488	175.6
Mauritius	2	1,969	1,260.0	639.9	4.1	N	2,082	375.0
New Caledonia	2	3,969	140.2	35.3	22.8	Y	443	53.0
Mean		2,783	503.6	1,471.6	20.0		1,996	233.6