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Performance and efficiency in Colombia's power distribution system: effects of the 1994 reform

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Abstract

We assess evolution in performance, efficiency and productivity of Colombia's power distribution utilities before and after the 1994 regulatory reform that introduced electricity market activities for the power sector in 12 distribution companies from 1985 to 2001. Performance is evaluated contrasting changes in mean and median by Wilcoxon Rank Sum and Pearson tests on financial and other performance indicators. Technical efficiency is measured by means of Data Envelopment Analysis (DEA). The nature of the dataset allows the estimation of Malmquist productivity index and its evolution in time. Results show a recovery after the reform in the main performance indicators of profitability, partial input productivity, and output. Plant efficiency and productivity increased after the reform, mainly in the largest utilities used as benchmarks in the DEA efficiency scores measures. Meanwhile, the less efficient power distribution companies did not improved after the reform and were not able to undertake plant restructuring to catch up in plant efficiency with respect to the Pareto efficient input allocations. Econometric results on DEA efficiency scores suggest a positive effect of policy reform.

Key words: Electricity distribution, productive efficiency, power sector Colombia, Malmquist productivity index

JEL Classification: L510, L940, Q490.

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RESUMEN

El documento evalúa el desempeño, la eficiencia y la productividad de las empresas de distribución de energía eléctrica en Colombia antes y después de la reforma regulatoria de 1994, para 12 compañías de distribución entre 1985 y 2001. El desempeño se evalúa al contrastar cambios en medias y medianas mediante las pruebas de Wilcoxon Rank-Sum y Pearson, sobre indicadores financieros y de desempeño. La eficiencia técnica se mide con la metodología de Data Evelopment Análisis (DEA). La naturaleza de los datos permita la estimación de índice de productividad de Malmquist y su evolución en el tiempo. Los resultados muestran una recuperación después de la reforma en los indicadores de ganancias, productividad parcial de insumos y del producto. La eficiencia y productividad aumento después de la reforma, principalmente en las empresas de mayor tamaño que se usan como empresas de referencia en las medidas de eficiencia DEA. Así mismo, las empresas menos eficientes no mejoraron después de la reforma y no lograron llevar a cabo una reestructuración para lograr alcanzar la eficiencia individual respecto a las distribuciones Pareto eficientes. La evaluación econométrica sobre los indicadores de eficiencia DEA sugieren un efecto positivo generado por las políticas de reforma.

Palabras clave: Distribución de electricidad, eficiencia productiva, índice de productividad de Malmquist.

Código JEL: L510, L940, Q490

1. INTRODUCTION

The 1994 regulatory reform of the Colombian power sector was one of first reforms in Latin America to introduce a market system for the wholesale electricity transactions, and the first to implement a bidding system for its pool electricity market in the region. In this sense, the reform took a step forward from the Chilean an Argentinean experiences, which wholesale electricity prices were based on declared costs rather than on marginal supply prices by 1994.[1] The reform introduced competition, established a new industry structure and a new independent regulatory agencies, setting up the basis for expansion and diversification of power generation sources, improving both the sector's efficiency and reliability.

The reform focused on offering incentives for utility efficiency and productivity levels through the introduction of market competition, independent grid access, and markup price regulation for power distribution. Inspired in the British reform, the regulatory reform split the traditional vertical monopoly structure of the power sector into four different activities: generation, transmission, distribution and commercialization of electricity. Power distribution as domiciliary public service provider faces two types of regulation. The first one is price regulation. The regulatory commission, Comisión de Regulación de Energía y Gas (CREG), currently sets the markup formula for distributors and the design of the pass through component in the final user's tariffs. In particular, CREG determines: i) direct purchase costs such as the pool sale price and transportation charges, ii) capacity charges, and iii) costs of the reserve provisions to stabilize the system and prevent bottlenecks in the transmission system.[2] The second type of regulation concerns quality control, companies are subject to sanctions if their service fails to meet minimum quality standards. The reforms and regulations led power holdings to undertake a generalized divestiture process across electricity holdings in order to fully separate power generation, transmission, distribution, and the setting up of new commercialization activities. Thus, privatization arose as one instrument for promoting market competition and industry restructuring, and became a complementary policy within a broad deregulatory context.

The aim of this paper is to provide new empirical evidence on the effects of the regulatory reform in power distribution in Colombia. To the best of our knowledge there is no a micro-study assessing the effects of a regulatory reform for power distribution. Nonetheless, several studies on the Colombian electricity sector after a decade of the regulatory reform have been published recently. Pombo and Ramírez (2003) test performance in the privatized power holdings and measured plant efficiency for Colombia's thermal stations showing a generalized increase in productive efficiency due to market entry, introduction of cost-saving technologies, and a positive effect of the new regulation that implied the setting up of a non-regulated mar-

1 A presentation of the regulatory reform in Colombia can be found in Pombo (2001). Estache and Rodriguez-Pardina (1998) and Mendoça and Dahl (1999) outlines a general presentation of the process in Latin America. Guash and Spiller (1999) and Kessides (2004) are comprehensive presentations of privatization, regulatory policy instruments, contract designing and results for several Latin American and developing countries. Nonetheless, the development of the power sector in Colombian has been poorly documented. IADB Inter-American-Development-Bank (2001) provides a short analysis of the sustainability of the power sector reforms in Latin America. For an international review see Newbery (1999).

2 For details on the British and Colombian formulas see Green and Rodriguez-Pardina (1999) and Pombo (2001).

ket of large clients that boosted transactions of forward electricity contracts. García and Arbelaez (2002) evaluate the likelihood of merging among power generators acting in the wholesale electricity market. Larsen, et al. (2004) present a set of aggregate statistics of Colombia's power sector to highlight the lessons derived from the implementation of market deregulation policies in Colombia for network industries since 1994.

Despite the above, studies on several dimensions of the electricity market are still pending, i.e., price collusion on the pool market, consumers' welfare effects, quality regulation and regulatory capture, among others topics. This paper provides empirical evidence on the effects induced by the regulatory reform, focusing on the efficiency and productivity effects upon power distribution. The paper presents an ex-post performance analysis for regional power distribution companies based on four elements: i) direct measures of productive efficiency scores and Malmquist productivity index through data envelope analysis programming (DEA), ii) changes in means and medians of firm performance variables of profitability, operating efficiency, labor, investment and sales, iii) an econometric analysis regarding the determinants and micro-fundamentals of firm efficiency scores by the regional power distributing companies, and iv) a evaluation of the policy effectiveness on plant efficiency using a two step DEA decomposition procedure of changes among policy regimes.

The paper structure is organized along four additional sections. Section 2 describes the data set and the methodology employed to assess utility efficiency in power distribution. Section 3 analyses the results of the performance indicators through the changes in means and medians and the measurement outcomes of plant efficiency and productivity through DEA efficiency scores and the construction of a Malmquist index. Section 4 reports an estimation of the policy effects on plant efficiency resulting from the industry reform and an econometric analysis about the determinants of utility efficiency scores. Section 5 concludes.

2. DATA AND METHODOLOGY

2.1 DATA

The data set used for this study includes 12 large electricity distribution companies (EDC) that cover the 20 largest cities belonging to the so-called National Interconnected System (NIS). The NIS is the result of the integration of five power systems and markets that the country used to be divided into before 1994. It covers the Andean region and the Atlantic Coast - country's northern provinces-.[3]

One effect of the 1994 regulatory reform was the separation of utility business activities that were vertically integrated under a monopoly industry. The 1994 "Electric Law" (Law 143) stated that firms, combining generation and transmission activities had to split up and sell their share of the transmission grid in order to guarantee a fair entry process for new generators. Firms sharing generation and distribution were allowed to retain ownership in both activities as long as they

[3] Nonetheless, Colombia's eastern planes, which represent 40% of country's geographical areas, are outside the NIS. They include the Orinoquía planes and the Amazon rain forest. These regions still geographically isolated and consequently they exhibit the lowest population density indicators in the country.

kept separate managerial and accounting procedures for each in order to avoid cross-subsidizing non-profitable services. The same criteria applied for new power companies. Therefore, the industry reached an almost complete separation of services, promoting competition in generation, keeping the natural monopoly structure of transmission and local distribution, and allowing some sort of contestability for the distribution services given a strict regulation and follow-up of regulatory agencies able to impose sanctions or changes in ownership upon bad performance.

Before 1994, Colombia's power sector was divided into five big regional markets, which perform all types of activities: the Bogotá Power Company [Empresa de Energia de Bogotá (EEB)]; the Atlantic Coast Regional Electric Corporation [Corporación Regional de la Costa Atlántica (CORELCA)], Public Enterprises of Medellín [Empresas Públicas de Medellín (EPM)], Cali Power Company [Empresas Municipales de Cali (EMCALI)] and the Cauca Valley Corporation [Corporación Autónoma del Valle del Cauca (CVC)] and finally the Colombian Power Institute [Instituto Colombiano de Energía Eléctrica (ICEL)]. These holdings were formed by publicly owned utilities at municipally or regionally levels. In addition, the national grid company [Interconexión Eléctrica S.A (ISA)] was the largest nationwide power generator and transporter.[4]

Table 1 synthesizes the pre-reform and post-reform structure of each of the above holdings. There are two sources that explain power sector restructuring. One came from direct divestitures i.e.: ISA. The other relied on privatization and equity transfers contracts. Privatization started with the selling of power generating units, such as hydroelectric substations and thermal plants. Then it moved toward power distribution companies and networks. Power transmission remained concentrated in ISA as the natural monopoly.[5]

Before the reform three out of the seven power holdings participated in power generation, transmission and distribution. To comply with Law 143, EEB was partially privatized and divested into three independent firms: EMGESA (generation), EEB-transmisión (transmission) and CODENSA (distribution). CORELCA was divided into four firms: GENDELCA (generation), TRANSELCA (transmission) which was acquired for ISA, and two distribution firms ELECTRICARIBE and ELECTRO-COSTA which were sold to foreign investors. EPM split its management but kept its ownership structure. On the other hand, the reform led to privatization of CVC.

EMCALI and ICEL holdings, which were formed mainly by electricity distribution companies, were only required to separate managerial and accounting functions for each activity. Therefore, only two out of five power distribution networks have been privatized. It is important keep in mind that the city of Bogotá is still the largest shareholder of CODENSA and EMGESA. Moreover, EPM, EMCALI, and ICEL are still owned by municipalities, therefore are public utilities. They cover around 50% of residential users for the NIS. Privatization, financial restructuring, and

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4 *Interconexión Eléctrica S.A (ISA)* was founded in 1967. By that time, the sectoral development view was to consolidate ISA as the largest nationwide power generator and transporter of bulk electricity following the vertically integrated natural monopoly model of *Electricité de France*. EMCALI and CVC belong to the same regional electricity market. The city of Cali, the third largest in the country, is the capital of the Valle del Cauca province. For more details about Colombia's power sector history see the World-Bank (1991). A description of the regulatory reform is in Pombo (2001) and Interconexión-Eléctrica-S.A. (1995-1999)

5 For details of the privatization program in general and by sectors in Colombia, see Pombo and Ramírez (2003).

entry competition remain a pending and unfinished task in local power distribution. Finally, ISA was split into two independent companies: ISA the Grid Company, and ISAGEN the publicly owned enterprise that kept ISA's former power generation assets.[6]

TABLE 1
POWER DISTRIBUTION AND TRANSMISSION STRUCTURE

Before Regulatory Reform				After Regulatory Reform			
Holding / Company	Generation	Transmission	Distribution	Holding / Company	Generation	Transmission	Distribution
EEB	x	x	x	EMGESA	x		
				EEB		x	
				CODENSA			x
EPM	x	x	x	EPM	x		x
EMCALI			x	EMCALI			x
ICEL	x		x	ICEL	x		x
CORELCA	x	x	x	GENDELCA	x		
				TRANSELCA		x	
				ELECTRICARIBE			x
				ELECTROCOSTA			x
CVC	x			EPSA	x		
ISA	x	x		ISA		x	
				ISAGEN	x		

Source: CREG

The working dataset consists of 12 larger power distribution companies that belong to the pre-reform regional electricity markets, which together compose the national interconnected system. For each company we gathered information regarding the utility's financial statements, number of users by category (i.e. residential, industrial, commercial, and official), number of employees, power losses, sales, commercial demand, and final user tariffs for the 1985-2001 period.

Tables 2 and 3 report the main features of the panel structured dataset. First, the panel is balanced. There are 17 observations for each EDC. For the case of EEB where the company was broken in three independent enterprises, the series where chained with the power distribution company -CODENSA- series after 1997. The privatization of CORELCA focused on power distribution companies. Six regional power distributors companies were gathered into two utilities, ELECTROCOSTA and ELECTRICARIBE, after 1998. Thus the series

6 The 1995-1998 privatizations in Colombia implied a equity transfer of 48% for EEB, 65% in the case of CORELCA in power distribution and transmission, and 56% for EPSA. The National Grid Company ISA sold 30% of its equity through the stock market in 2000. ICEL is a holding of 14 regional power distribution companies, and EMCALI is the power distribution company of the city of Cali see Pombo and Ramírez (2003).

were chained according to the post-privatization structure. Regarding the ICEL holding, its utilities are still the same. The companies included in the study sample are: i) Centrales Eléctricas del Cauca (CEDELCA), ii) Centrales Eléctricas de Nariño (CEDENAR), iii) Centrales Eléctricas del Norte de Santander (CENS), iv) Central Hidroeléctrica de Caldas (CHEC), v) Electrificadora de Santander S.A. (ESSA), vi) Electrificadora del Huila S.A. (HUILA), and vii) Electrificadora del Tolima S.A. (TOLIMA).[7] Finally, EPM and EMCALI regional markets complete the study sample.

Table 2
Study Sample - Power Distribution Companies

<table>
<tr><th rowspan="2">Regional Market</th><th colspan="2">Before Privatization/Reform</th><th colspan="2">After Privatization/Reform</th></tr>
<tr><th>Acronym</th><th>Utility Name</th><th>Acronym</th><th>Utility Name</th></tr>
<tr><td>EEB</td><td>EEB</td><td>Empresa de Energia de Bogota</td><td>CODENSA</td><td>CODENSA S.A. ESP</td></tr>
<tr><td>EPM</td><td>EPM</td><td>Empresas Publicas de Medellin</td><td>EPM</td><td>Empresas Publicas de Medellin</td></tr>
<tr><td>CVC</td><td>EMCALI</td><td>Empresas Municipales de Cali</td><td>EMCALI</td><td>Empresas Municipales de Cali E.S.P</td></tr>
<tr><td rowspan="7">CORELCA</td><td>ELECTRANTA</td><td>Electrificadora del Atlantico</td><td rowspan="4">ELECTRICARIBE</td><td rowspan="4">Electrificadora del Caribe S.A. E.S.P</td></tr>
<tr><td>ELECTROCESAR</td><td>Electrificadora del Cesar</td></tr>
<tr><td>GUAJIRA</td><td>Electrificadora de la Guajira</td></tr>
<tr><td>ELECMAG</td><td>Electrificadora del Magdalena</td></tr>
<tr><td>ELECTROBOL</td><td>Electificadora de Bolivar S.A</td><td rowspan="3">ELECTROCOSTA</td><td rowspan="3">Electrificadora de la Costa Atlantica S.A. E.S.P.</td></tr>
<tr><td>CORDOBA</td><td>Electrificadora del Cordoba S.A</td></tr>
<tr><td>SUCRE</td><td>Electrificadora de Sucre S.A.</td></tr>
<tr><td rowspan="7">ICEL</td><td>CEDELCA</td><td>Centrales Eléctricas del Cauca</td><td>CEDELCA</td><td>Centrales Eléctricas del Cauca S.A E.S.P</td></tr>
<tr><td>CEDENAR</td><td>Centrales Eléctricas de Nariño</td><td>CEDENAR</td><td>Centrales Eléctricas de Nariño S.A E.S.P</td></tr>
<tr><td>CENS</td><td>Centrales Eléctricas Norte de Santander</td><td>CENS</td><td>Centrales Eléctricas Norte de Santander S.A. E.S.P</td></tr>
<tr><td>CHEC</td><td>Central Hidroelectrica de Caldas</td><td>CHEC</td><td>Central Hidroelectrica de Caldas S.A E.S.P</td></tr>
<tr><td>ELECTOLIMA</td><td>Electrificadora del Tolima</td><td>TOLIMA</td><td>Electrificadora del Tolima S.A E.S.P</td></tr>
<tr><td>ESSA</td><td>Electrificadora de Santander S.A</td><td>ESSA</td><td>Electrificadora de Santander S.A E.S.P</td></tr>
<tr><td>HUILA</td><td>Electrifidadora del Huila S.A</td><td>HUILA</td><td>Electrifidadora del Huila S.A E.S.P</td></tr>
</table>

Source: Superintencia de Servicios Públicos Domiciliarios (1997)

[7] Each of the ICEL companies is a regional company likewise the Regional Electric Companies in the UK. Each name is associated with one province of the country's central regions. The ICEL companies excluded from the study sample are: *Empresa Antioqueña de Energía (EADE), Electrificadora de Boyacá (EBSA), Electrificadora del Caquetá (CAQUETA), Electrificadora del Choco (CHOCO), Electrificadora del Meta (META), Empresa de Energia de Cundinamarca (EEC).* The exclusion of these EDC responds to several factors such as bad quality of the primary data, incomplete series, and most important the unavailability to estimate the basic inputs like the number of transformers, substations, and the distribution network extension necessary to perform a DEA exercise.

Second, the study sample is representative due to its high share within the entire power sector. The sample represents on average 54% of commercial demand, 75% of total customers, 70% of industry direct employment, and around 80% of industry fixed assets value. Before the reform the last indicator exhibit lower levels because the vertically integrated structure of the companies, while after 1998 integrated utilities have to keep separate records by business activity. The study sample share on the industry has increased over time and has become more representative of the industry.

TABLE 3

STUDY SAMPLE CHARACTERISTICS BY PERIOD

	Number of Employees			Commercial Demand (GWh)		
Periods	Industry	Sample	Sample Share	Industry	Sample	Sample Share
1985-1989	21,253	17,000	0.7999	29,302	17,533	0.5985
1990-1993	22,245	18,213	0.8197	34,755	21,218	0.6109
1994-1997	20,866	16,456	0.7882	42,250	22,872	0.5435
1998-2001	15,043	10,984	0.7275	42,863	24,014	0.5607
Average	19,852	15,663	0.7084	37,292	21,409	0.5318
	Number of Users			Total Fixed Assets (Millions $)		
Periods	Industry	Sample	Sample Share	Industry	Sample	Sample Share
1985-1989	4,121,812	3,198,773	0.7766	1,875,327	1,199,751	0.6398
1990-1993	5,345,779	4,095,942	0.7663	5,166,010	3,642,329	0.7051
1994-1997	6,503,943	4,996,946	0.7682	9,653,314	7,715,436	0.7993
1998-2001	7,837,579	6,005,516	0.7667	16,666,786	14,372,504	0.8623
Average	5,952,278	4,574,294	0.7572	7,854,235	6,325,275	0.8053

Notes: Value series in millions of current pesos
Source: FEN (1996), SIVICO (1997-2001)

2.2 DATA ENVELOPMENT ANALYSIS

The general approach to measure firm productive efficiency is through non-parametric linear programming Data Envelope Analysis (DEA) algorithm. The basic intuition in the measurement of a plant productive efficiency from DEA estimation is the following: consider a set of plants that use different combinations of inputs to produce a given unit of an homogeneous output (electricity fits concept). If every plant is producing efficiently, all are in best practice isoquant. In the case that one plant is demanding more inputs in order to produce that unit of output, we are able to say that the plant is inefficient relative to the best practice isoquant.

DEA uses a sequence of linear programming problems to construct the best practice (cost or production) frontier for a given a technology, in order to compute efficiency measures. Technical inefficiency is measured as the ratio of the radial distance from the origin to the combination of input usage in an input space and the radial distance from the origin to the frontier or best practice frontier, which is built from the input combinations of the remaining group of firms which are considered efficient (i.e. pair wise input - one output in an Cartesian plane). This ratio will take a value between zero and one. If a plant has an efficiency score of 1, it is technically efficient. If the score is less than 1 then the plant is inefficient. For instance if plant B has a score of 0.8 and plant A has a score of 1, given they are over the same radial measure of efficiency, plant B is 20% inefficient relative to the production frontier and Firm A. That is, if plant B uses its inputs as plant A, then she would increase its output in 20%. This measurement is called non-parametric input-oriented efficiency scores.[8]

The advantages and disadvantages of using DEA over stochastic estimation in frontier analysis to measure efficiency are well known in the literature.[9] Specifically in our work, DEA suits our needs of efficiency estimation against stochastic frontier (SF) for several reasons. First, DEA is directly aimed to frontier and efficiency estimation, rather than a central or biased tendency as in SF measures. Second, there is no a priory assumption on the analytic form of the production function. Third, is suitable for measuring technical efficiency in multi-input/output production process. Forth, allows the use of environmental variables or variables not directly included into the production function but have effects on the input/output usage. Fifth, the determination of type of returns and its effect on efficiency is straightforward. But also DEA imposes some shortcomings in our work. First, DEA results are sensitive to errors in the data, inclusion and exclusion of observations and variables, and model specification. Second, the relationship among the number of units assessed and the number of input/output variables used, also have influence on the efficiency results. These disadvantages of the methodology are addressed in different ways in our study.

On the other hand, stochastic frontiers allow for an error term in the measurement of efficiency and assume a specific functional form for the underlying technology. This last feature becomes important when the Decision Making Unit (DMU) is a profit maximizing unit and the researcher knows input prices in order to estimate plant overall economic efficiency. A stochastic error also becomes important when output or productivity is subject to external shocks. There are different problems in using stochastic frontiers. First, efficiency scores are sensitive to the assumption regarding the distributional form of the error term (Green (1980)). Second, the usage of flexible production/cost functions, which might approximate a flexible technology, is costly in terms of degrees of freedom and the large number of parameters needed in the maximum likelihood function. Third, comparing with DEA, the error term usually "absorbs" most of the inefficiency leaving few magnitudes attributable to pure technical inefficiency. Finally, stochastic frontiers does not allow for multiple efficient firms as DEA does, leaving no space for idiosyncratic differences that may suggest two different firms are efficient given its own characteristics (Cubbin and Tzanidakis (1998)).

2.3 MALMQUIST PRODUCTIVITY INDEX

One advantage of our data is that given its panel structure allows us to undertake productivity analysis by means of Malmquist productivity indices (MPI). Figure 1 illustrates the case when there is a productivity improvement without technological change, in an input oriented sense; this is input reduction given an output level. We have an efficient frontier made up of efficient combina-

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8 The literature of DEA as well as their applications is extensive. The following references provide a good introduction and reviews on the topic: Fried, et al. (1993), Coelli, et al. (1998), and Thanassoulis (2001).

9 For a basic discussion of the issue see Pollit (1995) and Coelli, et al. (1998). Further evidence on the estimation of frontier analysis, arguments for and against see Byrnes, et al. (1986), Sengupta (1987), Seiford and Thrall (1990) and Cubbin and Tzanidakis (1998).

tions of inputs $X_{1,2}$ by firms A to E Technical inefficiency in time t for DMU G_t is given by the ratio of the radial distances OU and OG_t, and in time $t+1$ is given by the ratio of OV and OG_{t+1}; where U and V are the hypothetical input combinations that would make DMU G efficient for in each period considered.[10] Change in the productivity index is the ratio of both measures of efficiency or its change in input usage between time t and $t+1$ to become totally efficient:

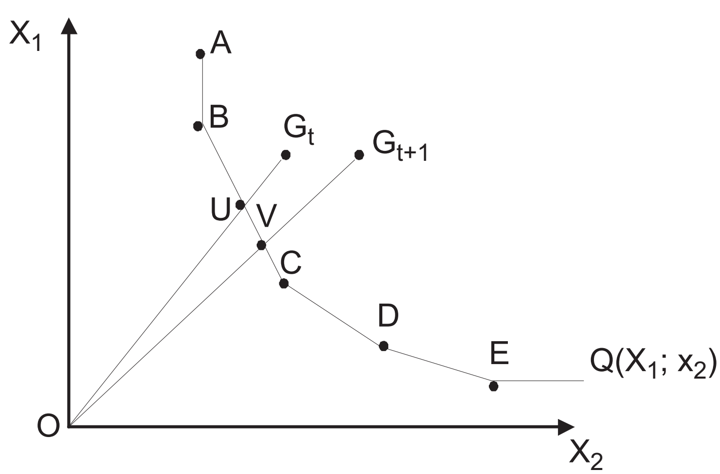
$$PI_{t+1} = \frac{OU}{OG_t} \Big/ \frac{OV}{OG_{t+1}} \tag{1}$$

Firm productivity change under this setup is equal to the shift on the radial distance from period t to $t+1$, reflecting the fact that new input combinations can eliminate technical inefficiency.

Following the case for no technological change, Figure 2 illustrates the case when there is technological change, implied by the shift in the production frontier from Q_0 to Q_1. MPI for DMU G is written as the geometric mean of productivity or input usage evolution in each period. First against Q_t and then against Q_{t+1}, as the ratio of the corresponding measures MPI is defined as the geometric mean of both effects.

FIGURE 1

PRODUCTIVITY INDEX FOR THE CASE OF NO TECHNICAL CHANGE

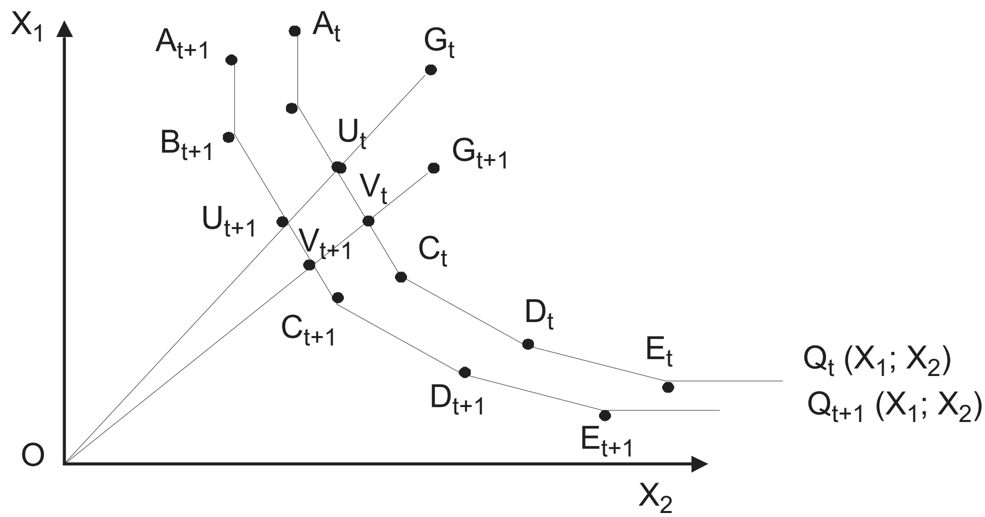


Source: (Thanassoulis, 2001)

10 Formally this is the assumption that there is a convex combination of production plans that also belongs to the constructed production set; a mathematical and economic assumptions for DEA estimation. A detailed presentations of this assumptions and variations see Tulkens and Eeckaut (1995).

FIGURE 2

PRODUCTIVITY INDEX FOR THE CASE OF TECHNICAL CHANGE



Source: (Thanassoulis, 2001)

According to Figure 2 the MPI is given by the following equation

$$MPI = \left[\frac{\left(OV_t / OG_{t+1} \right)}{\left(OU_t / OG_t \right)} \times \frac{\left(OV_{t+1} / OG_{t+1} \right)}{\left(OU_{t+1} / OG_t \right)} \right] \quad (2)$$

Equation (2) can be written as Equation (3). In this formulation the MPI is decomposed in two terms where an industry level productivity change is observed, called "boundary shift effect"[11] and firm level productivity change, called "catch-up effect" . The first one shows the radial distance between the frontiers from period t to $t+1$. The second component shows the radial distance for a given DMU to the frontier at $t+1$ relative to the distance to the frontier at t.

$$MPI = \underbrace{\frac{\left(OV_{t+1} / OG_{t+1} \right)}{\left(OU_t / OG_t \right)}}_{\text{Catch up component}} \times \underbrace{\left[\frac{OU_t}{OU_{t+1}} \times \frac{OV_t}{OV_{t+1}} \right]^{0.5}}_{\text{Boundary shift component}} \quad (3)$$

[11] Our presentation of MPI is taken from Thanassoulis (2001) and Coelli, et al. (1998). A formal derivation of the MPI can be found in Caves, et al. (1982) and its standard presentation as a geometric mean is due to Färe et al (1994).

Following the interpretation of Färe, et al. (1994), equation (3) says that changes in productivity at firm/DMU level are the cross product of gains in productive efficiency relative to industry's benchmark and, a technical change component as a result of innovation. Equation (3) is implemented in our DEA's measurement exercises straightforward under a constant returns to scale, input-oriented linear programming setup. Equation (2) implies four linear programming programs with respect to periods t and $t+1$ for each DMU: i) two linear programming problems regarding their own time-frontiers and ii) two linear programming models crossing time frontiers.[12]

3. PERFORMANCE ANALYSIS AND DEA MEASURES

3.1 NON-PARAMETRIC TESTS ON FINANCIAL INDICATORS

This section reports the results on performance for the power distribution companies and the measurements of efficiency scores across them. The first exercise relies on testing structural changes in means and medians before and after the reform for each performance indicator. The analysis follows the approach of firm assessment used in privatization and ownership studies such as Megginson, et al. (1994), La Porta and López-de-Silanes (1999) and Dewenter and Malestra (2001) who focuses on utilities' direct measures of profitability, efficiency, assets and investments, and sales before and after changes on ownership. The changes in means provide the direction of the effect the reform might have caused on firm performance. Changes in medians indicate how successful the reform was. From the statistical point of view the idea is to study the reform as an experiment where the year 1994 is a breaking point applied to matched samples, and test the null hypothesis if the reform was effective. This test is non-parametric because the data is ordered according to events belonging to individuals from different groups. Hence, the experiment is considered effective if the observed change is statistically robust and matches the expected one. The dataset is a balanced panel of the 12 utilities for the 1985-2001 period with 108 and 96 observations (N) before and after the reform, respectively.

Table 4 reports the results of the raw data and adjusted indicators.[13] The latter are ratios relative to EPM indicators. EPM was chosen as the control group since historically it has been the most efficient utility nationwide, making it an appropriate benchmark.[14] Several comments result from the raw indicators measures. First, there is general improvement in the profitability indicators. The mean (median) of net income to sales ratio rose from -11% (-2.4%) to 4.2% (3.5%) after the reform. That increase was sharper if one considers fixed capital returns. The mean (median) of operating income to PPE ratio increases from 40% (23%) to 51% (45%), and the mean (median) of operating income to net worth rose from 56% (33.6%) to 81% (48.7%). The above changes were significant at 1% percent levels.

Second, the performance in operating efficiency mirrors the profitability indicators. For instance, the mean (median) of sales to plant, property and equipment (PPE) ratio grew 43%

[12] For more details see Thanassoulis (2001).

[13] Appendix 1 reports the definition and methodology of each indicator.

[14] The reported DEA efficiency scores in the section also prove that EPM is a proper benchmark because its input-output allocations are on the production frontier.

(67%) after the reform, and the sales to employee ratio changed in 65% (75%). The above changes are significant at 1% levels. Therefore, profitability gains are explained by the better performance in operative efficiency. There were several sources that might have had an influence on such result, such as the reform and the new regulation requiring utilities to fulfill financial, efficiency, and quality service targets. In particular, since 1995 the regulatory commission has annually set directions to improve utility performance. The covered time span after the reform for the study sample, allows us to assert that plant restructuring has taken place in those companies that underwent such processes. The most noticeable cases of firm restructuring were the privatization of the CORELCA holding and the EEB that took place from 1996 to 1998.[15]

Employment cuts and new investment were not sources of operative efficiency gains according to the results reported in Table 4. The mean (median) of total employment decreased 15% (16.5%) after the reform that is an average of 2.1% per year. The average plant size moved from 835 employees per utility before the reform to 718 employees after the reform. The mean (median) of capital stock, which is proxied by each utility PPE, increased on average in 8% (16%) after the reform that is equivalent to a growth rate of 1% (2%) per year.[16] The PPE to labor ratio also exhibited a positive change. Nonetheless, the above changes were not statistically significant.

Third, final sales pushed labor as well as capital productivity. The three output indicators show important improvements. The mean (median) of total sales at constant 1998 prices grew 50% (41.5%) implying an annual rate of 6.3% (5.2%) per year. Total sales in GWh increases by 2.8% per year after 1994 and sales to residential users did so at 3.2% per year. The above changes are significant at 1% and 10% levels. The above outcome was not induced by an increase on aggregate commercial electricity demand, which experienced a slowdown after 1995.[17] The effect came from a reduction in the non-technical losses, which implied better invoicing and tariff collection processes by the utilities. The average change in the technical loss index was 1.7 points after the reform. However, if one considers the three largest utilities there is an effective reduction of 1.5 points in the loss indices.[18] The increase in residential tariffs also contributed to boost the utilities' sales. The mean (median) increased by 33% (30%) in the post reform period. That is an annual rate of 4.1% (3.7%). In contrast, there were no statistically significant changes in industrial tariffs.

15 A complete efficiency analysis of the privatized power generation utilities is in Pombo and Ramírez (2003). The main findings regarding the sources of efficiency gains until 1998 were: i) privatization induced new investment in incumbent firms, ii) employments cuts were not significant, and iii) there were positive efforts in reducing power losses.

16 There is a caveat to bear in mind concerning PPE series. The chain for EEB only accounted the power distribution assets represented in the new company of CODENSA after 1997. We run a t-test and z-test without this utility and the changes in means were positive (6%) but no statistically significant.

17 Total aggregate demand for electricity grew on average 5.2% per year for the 1985-1994 period, while for the 1995-2001 period electricity demand grew on average at 1.3% per year.

18 They are EEB, EPM, EMCALI, which have an average market share of 62% within the study sample.

TABLE 4

TEST ON CHANGES IN PERFORMANCE: RAW AND ADJUSTED INDICATORS

Variable	Non-adjusted					Adjusted				
	N	N	Mean before	Mean after	t-stat	N	N	Mean before	Mean after	t-stat
	Before	After	Median before	Median after	z-stat	Before	After	Median before	Median after	z-stat
I. Profitability										
Net Income / Sales	108	96	-0.1104	0.0416	-3.30 [a]	99	88	-0.6651	-0.0535	-3.557 [a]
			-0.0239	0.0351	-2.45 [a]			-0.1998	0.0489	-2.395 [a]
Operating income / PPE	108	96	0.3998	0.5140	-2.19 [a]	99	88	2.2791	3.6118	-3.374 [a]
			0.2288	0.4515	-4.49 [a]			1.3208	2.6409	-4.704 [a]
Operating income / Net Worth	108	96	0.5600	0.8185	-2.39 [a]	99	88	1.9047	6.1910	-4.139 [a]
			0.3365	0.4874	-2.81 [a]			1.2121	2.8277	-6.743 [a]
II. Operating Efficiency										
Log (sales/PPE)	108	96	-1.2714	-0.8447	-4.24 [a]	99	88	0.7210	0.4547	4.300 [a]
			-1.4748	-0.7956	-4.49 [a]			0.8374	0.4270	4.415 [a]
Log (sales / employees)	108	96	4.7201	5.3771	-7.07 [a]	99	88	0.7740	0.8449	-4.910 [a]
			4.5179	5.2698	-6.63 [a]			0.7512	0.8285	-5.294 [a]
Loss index	108	96	0.2104	0.2270	-1.70 [a]	99	88	1.5934	1.6637	-0.891 [c]
			0.1870	0.2199	-2.03 [a]			1.4343	1.5743	-0.866 [c]
Loss index1	27	24	0.1817	0.1750	1.60 [b]					
			0.1626	0.1593	1.36 [c]					
III. Labor										
Log (employees)	108	96	6.7273	6.5777	1.64 [c]	99	88	0.9505	0.9428	0.539 [c]
IV. Assets										
Log (PPE)	108	96	12.7188	12.7995	-0.04 [c]	99	88	0.8527	0.8389	1.673 [b]
			12.4484	12.6076	-0.28 [c]			0.8395	0.8362	1.653 [b]
Log (PPE / Employees)	108	96	5.9915	6.2119	-1.13 [c]	99	88	0.7630	0.7504	1.395 [c]
V. Output										
Log (Sales $)	108	96	11.4474	11.9549	-3.35 [a]	99	88	0.8696	0.8950	-2.202 [a]
			11.3440	11.7588	-3.31 [a]			0.8635	0.8866	-2.293 [b]
Log (Sales residential GWh)	108	96	6.1939	6.4528	-2.02 [a]	99	88	0.7990	0.8234	-1.495 [b]
			5.9834	6.2610	-2.18 [a]			0.7724	0.8049	-1.732 [b]
Log (Sales total GWh)	108	96	6.8552	7.0775	-1.55 [b]	99	88	0.8043	0.8147	-0.622 [c]
			6.6472	6.9475	-1.74 [b]			0.7868	0.8076	-0.950 [c]
VI. Tariffs										
Log Residential tariffs	108	96	4.1688	4.5052	-12.62 [a]	99	88	1.0409	1.0313	1.419 [c]
			4.1758	4.4692	-10.33 [a]			1.0395	1.0318	2.025 [a]
Log Industrial tariffs	108	96	4.8054	4.7924	0.40 [c]	99	88	1.0192	1.0550	-4.616 [a]
			4.7858	4.7789	0.21 [c]			1.0138	1.0349	-3.895 [a]

Notes: a. significant at 5%, b. Significant at 10%, c. Non-significat significance
Value series are at 1998 prices and deflated by CPI
Loss index1: includes only the three larger systems: EEB/CODENSA, EPM, EMCALI
Includes the following 12 EDCs: CEDELCA, CENS, CEDENAR, CHEC, EPM, CODENSA/EEB, EMCALI, ELECTROCOSTA, ELECTRICARIBE, ESSA, HUILA, TOLIMA
Source: authors calculations

The industry-adjusted indicators show that profitability ratios improved. In most cases the change of means and medians doubles with respect the control group. This outcome as well as the improvement in the raw indicators suggests positive changes in managerial procedures oriented to the financial recovery of the utilities. The adjusted indicators for operative efficiency exhibited mixed results. On one hand the mean (median) capital productivity fell by -0.26% (-0.41%), but on the other the mean and median of labor productivity increased both by 7% relative to EPM after the reform. This finding suggests that EPM rationalized capital spending relative to their competitors. Also the privatized utilities were either capitalized before or after the equity transfer to private investors. For instance, the CORELCA subsidiaries were capitalized in 1997 by the government before their privatization. This caused PPE real value to double by the end of 1998 in these utilities.[19] The above changes were significant at 1 percent level. On the other hand, input levels of capital stock, employment and capital-labor ratios did not experience structural changes after the reform. The only significant change, at 10 percent level, was the mean of PPE level that decreased from 0.85 to 0.83 relative to the control group.

Output and sales increased in all cases reflecting positive efforts in invoicing and tariff collection. In particular, residential sales and total value sales gained on average 3 percentage points relative to EPM's indicators. Higher tariffs contributed partially to this result. The measurements show that the mean (median) of the relative industrial tariff grew by 3.6% (2%) after the reform. This change is significant at 1 percent.

Table 5 reports the average tariffs for industrial and residential users by each EDC. The 1994 reform changed the trend in pricing behavior. Industrial users are better off after the reform. Prices dropped 24% since 1997, which is an annual average of 4.8% per year. This outcome is the result of the setting up of the wholesale electricity market for contracts transactions since mid 1995. Figure 3 describes residential and industrial tariffs and the series of electricity contract mean prices.[20] Residential users were affected by higher tariffs. The slope in the tariff trend became steeper after 1996. Real tariffs rose on average at a rate of 10% per year for the 1997-2001 period. The three largest utilities drove industry price setting. Among them it is clear that the former EEB, did an effort to reduce industrial tariffs and non-technical power losses. But on the other hand residential tariffs rose in 2.2 times after company's privatization in 1997.[21] Some utilities that increased both tariffs steadily since 1985, turned out to be the bad performers in terms of productive efficiency from the DEA analysis. The next section turns attention to the analysis of technical efficiency and productivity measures for the 12 power distribution companies under study.

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19 ELECRICARIBE's plant, property, and equipment rose from US$ 163 to US$ 308 millions in 1998 at constant prices of that year. ELECTROCOSTA did from US$ 90 to US$ 302 millions.

20 Notice the U-shape of contract prices. The first generation of purchase power contracts had a time span from 3 to 5 years. Clearly the inflexion point in mid 1999 is a consequence of the renewal of former contracts, the end of the second *El Niño* cycle of the nineties that shifted up spot prices up during 1997-1998, and the security deterioration regarding transmission towers blow-ups. Those elements changed agent's price expectations toward an increasing trend in electricity prices.

21 The market share of EEB is on average 28% within the study sample and 15% with respect to nationwide electricity demand.

Table 5

Industrial and Residential tariffs by company and five-year periods

Industrial Tariffs								
	CEDELCA	CEDENAR	CENS	CHEC	EEB	E-CARIBE	E-COSTA	EPM
1985-90	120.7	118.1	94.8	91.6	191.8	134.0	126.3	109.2
1991-96	120.8	155.1	127.3	120.0	153.7	153.5	155.7	119.6
1997-01	143.2	191.5	112.4	89.3	114.0	118.0	113.4	85.9
	EMCALI	ESSA	HUILA	TOLIMA	Three largest	Weighted average	Price change	
1985-90	107.7	123.3	118.3	103.3	136.3	136.8		
1991-96	121.0	124.1	152.9	120.0	131.4	138.1	0.0096	
1997-01	88.2	115.4	141.1	101.4	96.0	105.5	-0.2359	
Residential Tariffs								
	CEDELCA	CEDENAR	CENS	CHEC	EEB	E-CARIBE	E-COSTA	EPM
1985-90	69.1	59.7	63.1	55.1	55.6	71.0	70.4	54.4
1991-96	68.4	59.4	73.7	71.1	73.3	80.0	68.1	67.3
1997-01	89.3	96.5	101.9	95.2	163.0	95.5	89.6	83.1
	EMCALI	ESSA	HUILA	TOLIMA	Three largest	Weighted average	Price change	
1985-90	75.7	73.2	60.0	55.3	61.9	61.6		
1991-96	89.6	80.6	80.0	78.8	76.7	74.7	0.2120	
1997-01	92.3	100.4	99.8	107.5	112.8	111.5	0.4924	

Sources; SINSE, CREG, SSPD

Notes: The largest utilities are EEB, EPM and EMCALI

3.2 DEA efficiency scores, Malmquist productivity index and policy effectiveness

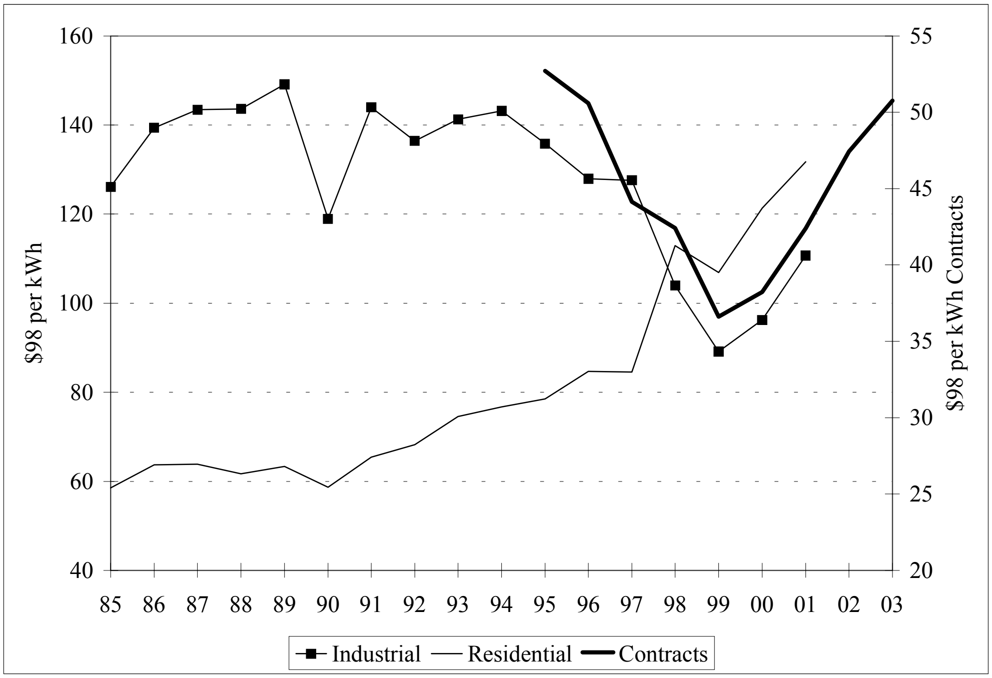
The measurement of technical efficiency for power distribution through non-parametric linear programming poses the problem of defining correctly the production function characterization of the electricity distribution industry; several studies on efficiency, performance and productivity in electricity distribution tackle this problem classifying variables within inputs, output and environmental variables. Hjalmarsson and Veiderpass (1992) do so using DEA to estimate Malmquist Productivity indices in Sweden and Førsund and Kittelsen (1998) in Norway; Miliotis (1992) uses DEA analysis to assess effects of policy and ownership in efficiency for Greece, as well as Bagdadioglu, et al. (1996) for Turkey, Pacudan and de Guzman (2002) for the Philippines, finally Agrell, et al. (2003) for Scandinavia offers a insightful discussion of DEA estimation for electricity distribution.[22]

Looking for an appropriate definition of a DEA model for power distribution and in order to obtain comparable results with the existing literature in the topic we have classified the variables into inputs, outputs and environmental ones following Neuberg (1977) and similar studies previously quoted. Several definitions of a proper DEA model for electricity distribution can be formulated, ranging from the whole consideration of inputs/outputs/environmental variables to simply defining as input the number of employees and output the number of cus-

[22] Filippini, et al. (2004) undertakes a very similar study to ours using a stochastic frontier estimation.

FIGURE 3

INDUSTRIAL, RESIDENTIAL TARIFFS AND ELECTRICITY CONTRACTS (PESOS PER KWH AT 1998 PRICES)



Source: SINSE, CREG. SSPD

tomers, leaving the remaining variables exogenous to the utilities' output decision-making. The dual classification input/output/environmental variables come along with a suitable characterization of the DMU functions. Focusing in electricity distribution if we take transformers and length of the power line network as inputs, the assumption is that those are control variables for each utility. In this industry the demand is endogenous to environmental variables such as: geographical dispersion, topography, population density, urban migration; which determine the utilities' new investment in power lines network, substations and transformers. Thanassoulis (2001) discusses the selection of variables and the definition of the input/output/environmental variables. In particular, he stresses that there must be some prior knowledge regarding the utility's operational characteristics. DEA itself imposes a constraint on the formulation of a final model, the use of a big number of inputs and outputs against a small number of DMU's assessed will bring most of the DMUs into the frontier leaving few for efficiency evaluation. Therefore, adopting a reduced model for efficiency assessment lowers the trade-off between relative efficiency and number of DMUs.

Table 6 presents the distribution into input / output / environmental variables for the estimated model. The output is represented by the energy sold in Gigawatts per hour (GWh), the input variables are: labor proxied by the number of employees in power distribution and commercialization, and capital proxied by number of transformers and length of the distribution network. The last two variables were not observed for the entire period and it was necessary to rely on backward series extrapolation.[23] The environmental variables are utility exogenous variables such as regional per capita GDP, power generating capacity, number of customers, and urban areas covered in Km2.

The data used in the DEA estimation comprised information for 12 DMUs in 17 years for a total of 204 observations; this data structure suggests a broad spectrum of DEA estimations. From estimating a year-by-year DEA to a timeless estimation considering every observation as an independent DMU, we call the former "cross-section DEA" and the latter a "pooled DEA". Within this range it is also possible to run what is known as "window DEA" which consist of several DEA estimations which sample is defined by a growing or constant number of observations (keeping a balanced sample of DMU assessed). In our estimations we chose the extreme possibilities in the spectrum, that is the cross-section and the pooled DEA in order to avoid the issues of window procedures in DEA outlined in Asmild, et al. (2004), specially for the following Malmquist estimation.[24]As mentioned previously a small sample for cross-section DEA imposes limitations to the methodology, this is why the cross section and pooled DEA offer a robustness test for our results. Bauer, et al. (1998) propose six consistency conditions that efficiency measures derived from different efficiency estimations should meet: i) Comparable distributional properties; ii) Similar efficiency rankings; iii) Similar best and worst practice institutions; iv) Reasonable stability over time estimation; v) Reasonable consistency with competitive conditions; vi) Reasonable consistency with standard non-frontier measures. Except for condition 5 the estimation results shown below meet these requirements comparing against different window and pooled DEA estimations for the model proposed in Table 6 and against an additional model where the same variables were used but the only variables classified as discretionary were employees and total customers.

TABLE 6

MODEL FOR DEA ESTIMATION IN POWER DISTRIBUTION

	Input	Output
Discretionary variables	Employees in power distribution and commercialization	Total Sales (GWh)
	Number Transformers	Total customers
	Power Lines Network (Kms.)	
Environmental	Regional GDP per-capita	Urban area served
	National installed capacity in electricity generation	

Table 7 summarizes the results of the efficiency scores of the DEA estimation under constant returns to scale and its decomposition into Variable Return to Scale (VRTS) and Scale Efficiency (SE).[25] This decomposition is useful to find if the scale of operation becomes a source of inefficiency for the firms and is obtained from equation (4).

23 Appendix 2 explains the methodology and the base regression equations that supported the backward forecasts applied to the number of transformers and power lines distance series.

24 The results for this additional estimation are quite similar to those presented here, for additional results and consistency on Bauer, et al. (1998) check list see Taborda (2003).

25 We should recall that the expected technology in power distribution is a fixed coefficient constant return to scale (CRTS) according to the peak-load model in Steiner (1957).

$$CRTS = VRTS \times SE \tag{4}$$

Under the assumption of CRTS, DEA efficiency scores show that six out of the twelve electricity distribution companies are totally efficient. The lowest efficiency score corresponds to CHEC for 13 years and CEDELCA for 3 years. For the period under study four utilities exhibit VRTS meaning that they could reduce technical inefficiency through internal scale economies by means of an increase in sales, customers or in area served. Four utilities present serious technical inefficiencies in power distribution according to these measurements: CEDELCA, CHEC, ESSA and HUILA, which exhibit decreasing trends. Moreover, their efficiency scores worsened after the reform. CEDELCA and CHEC ended up on average with scores equal or less than 40% in 2001, while ESSA and HUILA exhibited efficiency scores of 57% and 65% respectively. Such inefficiency is reflected by an operative scale problem illustrated by the scale efficiency parameter that by 2001 three of them had scales below of 71%. Those are utilities that serve medium-sized cities with low population density. In addition, these utilities show on average high financial and operating costs, high levels of non-technical losses in power distribution, and contraction in their regional per-capita consumption of electricity relative to the benchmark utilities.[26] On the other hand, ELECTROCOSTA was only the case that showed an efficiency improvement after its privatization in 1997 reaching efficiency scores of 1.

For yardstick regulation purposes (Shleifer (1985)), DEA output also suggests the frontier reference DMU(s) the inefficient DMU should mimic in order to become efficient. We will concentrate in the EDC that are stable frontier reference DMUs, which are several continuous years as reference DMU for the group of inefficient ones. EEB stand as a reference benchmark for all the inefficient EDC, specifically for ESSA, CHEC and HUILA for 14, 15 and 16 years, respectively; while EPM is reference for CEDELCA, CHEC, and ESSA for 7, 7 and 5 years, respectively. Finally, ELECTRICARIBE is reference for Huila, ESSA and CENS for 16, 16 and 8 years

Productivity measurement is carried out by means of Malmquist productivity indices (MPI), which complements the DEA efficiency analysis. According to equation (2). The measurement of efficiency scores for two-year periods across the sample of DMUs will yield three types of firms. The firs type, are the efficient DMUs in period t and $t+1$ who remain on the frontier. Their radial distance for each period will be equal to 1, there is no gain in "catch-up effect" but its productivity gain is reflected through the industry's boundary displacement or "boundary effect". The second type are non efficient firms in both periods, but for period $t+1$ their inefficiency has been reduced, those firms are experiencing both effects, catch-up and boundary productivity improvements, they are closing their distance against the frontier in time $t+1$ and at the same time are moving along with the frontier. Finally there is a third group of firms who lost relative efficiency at time $t+1$, from its observed efficiency level observed in t. Figure 4 and Table 8 report the results of the Malmquist productivity decomposition. For each utility the MPI is estimated by equation (2) based on the cross-section DEA estimations. The table

[26] The privatization process had a sudden stop in 1999. Private investors have not been interested in the former ICEL subsidiaries (CEDELCA, CEDENAR, CENS, CHEC, ESSA, HUILA, and TOLIMA) and EMCALI due to their long-term financial, labor and pension liabilities. Sector authorities have stressed the financial problem and the call for State capitalization.

TABLE 7

DEA EFFICIENCY SCORES - POWER DISTRIBUTION COMPANIES

Constant Returns to Scale								
	1986-1987	1988-1989	1990-1991	1992-1993	1994-1995	1996-1997	1998-1999	2000-2001
CEDELCA	0.71	0.76	0.87	0.78	0.72	0.58	0.67	0.34
CEDENAR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CENS	1.00	0.83	1.00	0.89	0.85	0.92	0.96	1.00
CHEC	0.55	0.56	0.62	0.49	0.45	0.52	0.40	0.40
EEB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ELECTRICARIBE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ELECTROCOSTA	0.91	0.96	1.00	0.97	0.98	1.00	1.00	1.00
EMCALI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EPM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ESSA	0.84	0.79	0.89	0.84	0.82	0.72	0.59	0.57
HUILA	0.91	0.72	0.92	0.83	0.69	0.92	0.69	0.65
TOLIMA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Variable Returns to Scale								
CEDELCA	1.00	1.00	1.00	1.00	1.00	0.92	1.00	0.99
CEDENAR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CENS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CHEC	0.55	0.57	0.64	0.50	0.45	0.53	0.48	0.56
EEB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ELECTRICARIBE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ELECTROCOSTA	0.97	1.00	1.00	0.97	1.00	1.00	1.00	1.00
EMCALI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EPM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ESSA	0.86	0.79	0.89	0.84	0.82	0.73	0.61	0.66
HUILA	0.97	0.80	1.00	0.89	0.77	1.00	0.94	1.00
TOLIMA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Scale efficiency								
CEDELCA	0.71	0.76	0.87	0.78	0.72	0.62	0.67	0.35
CEDENAR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CENS	1.00	0.83	1.00	0.89	0.85	0.92	0.96	1.00
CHEC	1.00	1.00	0.97	0.99	1.00	0.98	0.84	0.71
EEB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ELECTRICARIBE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ELECTROCOSTA	0.94	0.96	1.00	1.00	0.98	1.00	1.00	1.00
EMCALI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EPM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ESSA	0.98	1.00	1.00	1.00	1.00	0.99	0.96	0.87
HUILA	0.93	0.89	0.92	0.93	0.91	0.92	0.74	0.65
TOLIMA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: authors' calculation
Note: Averages for two years

presents the average for two sub-periods, emphasizing the turning point created by the 1994 reform. The last two columns report the average of the 12 utilities under study, and the cumulative MPI indices that reflect the evolution of productivity levels across time.[27]

Three main comments arise from this exercise. First, the utilities used as benchmarks in the DEA analysis show small or negligible changes in their MPI indices. This is the case of EEB, EPM, EMCALI, ELECRICACARIBE, and TOLIMA.[28] Every year these utilities are on the production

27 We choose to estimate year-by-year Malmquist index in order to avoid the problems related with Malmquist decomposition into catch up and boundary effects outlined in Asmild, et al. (2004).

28 The former three are the largest power distributors nationwide with an average market share above 60% within the study sample. They are the electricity distributors of the three largest cities in the country: Bogotá, Medellín, and Cali.

frontier and are the source behind overall efficiency boundary shifts. On average, boundary changes were 4.8% per year after the reform in contrast to the 3.2% average for the pre-reform period. Second, there were no improvements in the utilities' efficiency catch-up. Except for one case, all non-benchmark DMUs exhibit values less than one, meaning that those utilities are farther from their boundary after the reform. Third, the source of productivity is mainly driven from the sharp increase observed in the boundary effect after the reform. Moreover, the most inefficient utilities present the higher boundary shifts rates after the reform. For instance, CEDELCA had a 23% annual average boundary shift after 1995, followed ESSA with 13.8%, and HUILA with 7.7%.

The above findings confirm that there were important productivity gains in the power distribution system after the 1994 regulatory reform, explained by a strong and positive evolution of the largest utilities placing a veil of good indicators over the less efficient firms. The above results are conclusive in the direction that the overall gain in productive efficiency came from changes from the benchmark utilities and there was no effort for low performers to catch-up to the industry's average efficiency levels; basically the same result observed in performance analysis where big EDC outperformed over the sample. The assessment of policy effectiveness is an important issue analyzing competition policy and market reforms. DEA allows evaluating efficiency within a group of DMU's working under different policy regimes.

TABLE 8

MALMQUIST PRODUCTIVITY DECOMPOSITION BY POWER DISTRIBUTION COMPANY

Total Malquist Index														
	CEDELCA	CEDENAR	CENS	CHEC	EEB	E-CARIBE	E-COSTA	EMCALI	EPM	ESSA	HUILA	TOLIMA	Sample average	MPI Levels
1987-1994	1.075	1.001	1.050	1.057	1.000	1.000	1.021	1.002	1.000	1.063	1.050	1.000	1.027	109.183
1995-2000	1.050	1.000	1.044	1.051	1.001	1.000	1.019	1.000	1.005	1.056	1.050	1.000	1.023	130.793
Average	1.064	1.001	1.048	1.054	1.001	1.000	1.020	1.001	1.002	1.060	1.050	1.000	1.025	118.445
Std deviation	0.088	0.003	0.071	0.079	0.002	0.000	0.034	0.005	0.008	0.097	0.099	0.000	0.027	13.564
Boundary shift														
	CEDELCA	CEDENAR	CENS	CHEC	EEB	E-CARIBE	E-COSTA	EMCALI	EPM	ESSA	HUILA	TOLIMA	Sample average	MPI Levels
1987-1994	1.077	1.001	1.065	1.081	1.000	1.000	1.012	1.002	1.000	1.067	1.082	1.000	1.032	110.204
1995-2000	1.230	1.000	1.028	1.087	1.001	1.000	1.011	1.000	1.005	1.138	1.077	1.000	1.048	145.399
Average	1.143	1.001	1.049	1.084	1.001	1.000	1.012	1.001	1.002	1.097	1.080	1.000	1.039	125.287
Std deviation	0.286	0.003	0.096	0.134	0.002	0.000	0.021	0.005	0.008	0.138	0.178	0.000	0.063	23.247
Catch-up														
	CEDELCA	CEDENAR	CENS	CHEC	EEB	E-CARIBE	E-COSTA	EMCALI	EPM	ESSA	HUILA	TOLIMA	Sample average	MPI Levels
1987-1994	1.007	1.000	0.996	0.987	1.000	1.000	1.009	1.000	1.000	1.003	0.986	1.000	0.999	100.717
1995-2000	0.948	1.000	1.022	0.980	1.000	1.000	1.008	1.000	1.000	0.948	0.999	1.000	0.992	97.452
Average	0.982	1.000	1.007	0.984	1.000	1.000	1.009	1.000	1.000	0.979	0.992	1.000	0.996	99.318
Std deviation	0.242	0.000	0.118	0.120	0.000	0.000	0.039	0.000	0.000	0.140	0.160	0.000	0.046	4.710

Source: Author's calculation

Notes: Before the reform period = 1987-1994; after the reform period = 1995-2000. MPI = Malmquist productivity index. MP index level = $MPI_{t-1} \cdot (1+\Delta\%MPI_t)$

The procedure is called by Thanassoulis (2001) as "disentangling managerial and policy efficiency", an application of the work of Charnes, et al. (1981); which implies a window DEA analysis for two periods chosen on the change of regulation and industry structure. From a benchmarking regulation perspective, disentangling managerial effect from the regulatory effect becomes a useful and innovative application of the methodology to assess policy effectiveness, in our case to assess regulatory change on public utilities.[29]

The intuition behind disentangling managerial from policy efficiency is to separate the effects induced in efficiency from variables directly related to the DMU's activity from idiosyncratic variables affecting the industry, in our case the introduction of a new industry and regulatory framework. In order to apply the procedure we have defined two policy groups, according to the pre and post reform periods, all the estimations were done grouping the data in a "pooled DEA" in order to introduce the changes in the industry as a policy for a homogeneous set of firms.[30] The approach involves a two-step procedure. The first stage consists in obtaining DEA efficiency scores for each policy group (pre and post reform). Therefore, each inefficient DMU in each policy group is brought to the frontier using the feasible combination of inputs that would take them to become totally pareto efficient. In the first stage we have observed inefficiency for DMU into its policy group and then we have eliminated the inefficiency concerning the management under the specific policy, in our case the inefficiency under pre and post regulatory reform assigned to management of EDC. Afterwards the second step starts by pooling all units from both policies, and run a new DEA. Any inefficiency scores obtained is attributable to the corresponding policy. Summing up, at the first stage managerial inefficiency is eliminated by taking all units under a specific policy to the frontier, at the second stage policy inefficiency is observed given that there is no other source, besides that the DMU's are working under a new set of constraints, i.e. new regulatory and industry structure.

Table 9 summarizes the results of this exercise, which are very consistent with those reported in our performance, efficiency and productivity analysis. It is undeniable the positive effect on efficiency because the reform reducing drastically any remaining inefficiency. According to Table 9, nine out of twelve utilities reduced, on average, 6 points its inefficiency because of the reform. The remaining units stayed fairly constant. Again we have a set of EDC which efficiency was strongly and positively affected by regulatory reform, while the already efficient ones kept its position.

The next section turns attention to modeling efficiency scores under constant and variable return to scale as functions of utility characteristics, ownership structure, and regulatory policy variables for the study sample of power distribution companies.

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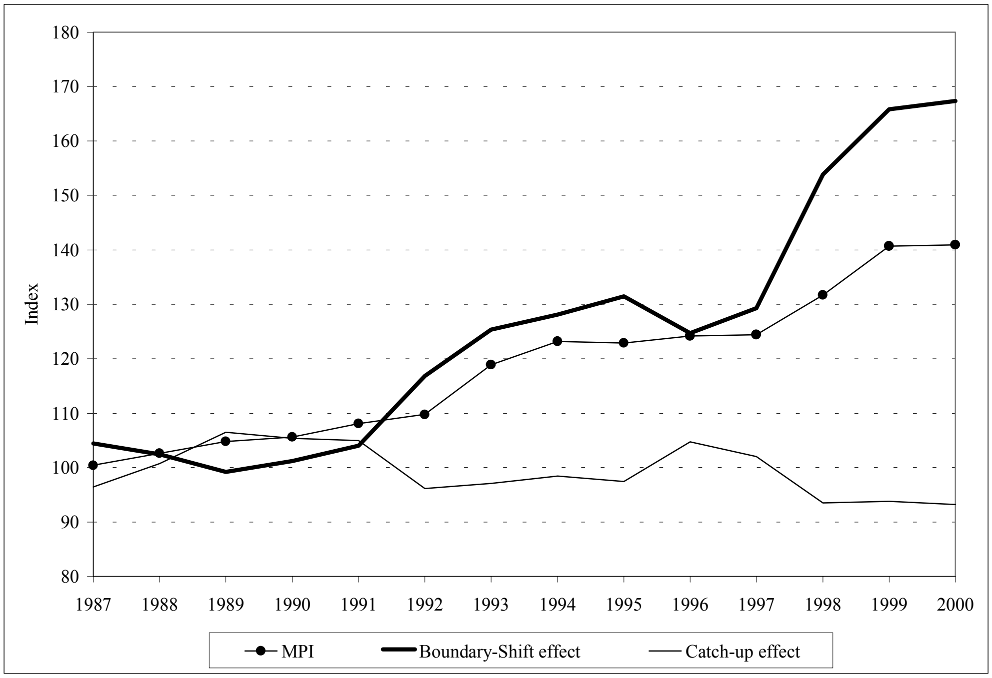
29 To the best of our knowledge there are no available studies using this procedure to assess the effectiveness of regulatory change on public utilities. For a discussion of choosing the window length in DEA, see Asmild, et al. (2004).

30 In other words, data is staked according to firm-year observations for each of one the 12 utilities before and after 1995, although the reform was introduced in 1994, we moved the breaking date to 1995 in order to allow for one year of accommodation in the behavior of the EDC and the implementation of the pool market for electricity.

FIGURE 4

MALMQUIST PRODUCTIVITY INDEX LEVELS (1986=100)



Source: Authors' calculations based on inputs/output and environmental variables dataset used in Table 7

TABLE 9

MANAGERIAL AND REGULATORY POLICY EFFICIENCY

	Policy inefficiency	
	1986-1994	1995-2001
CEDELCA	1.0000	0.9988
CEDENAR	1.0000	0.9976
CENS	0.9353	0.9733
CHEC	0.8782	0.9790
EEB	0.9638	0.9827
ELECTRICARIBE	0.9979	0.9998
ELECTROCOSTA	0.8590	0.9811
EMCALI	0.9293	0.9961
EPM	0.9561	0.9824
ESSA	0.8486	0.9775
HUILA	0.9991	1.0000
TOLIMA	0.9957	0.9871
Industry average	0.9469	0.9880

Source: Authors' calculations

Notes: scores are averages for policy groups by firm-year observations.

4. ECONOMETRIC ANALYSIS OF EFFICIENCY SCORES

This section reports the results of the econometric analysis performed on the DEA efficiency scores from the pooled DEA sample.[31] The analysis follows a limited dependent variable model given that the dependent variable under analysis is censored by construction. It takes positive values and is bounded at 1; that is, the efficient plants will record an efficiency score $-y_{it}-$ of one, otherwise, $0 \leq y_{it} < 1$. The baseline censored-model follows a linear specification:

$$y_{it} = \begin{cases} \mathbf{x'_{it}B} + e_{it} & 0 < y_{it} \leq 1 \\ 0 & otherwise \end{cases} \tag{5}$$

The residuals are I.I.D following a normal distribution with zero mean and constant variance. Equation (5) models efficiency scores as a function of utility characteristics, performance, environmental, ownership structure, and regulatory-related policy dummies. Plant characteristics include indicators of input-intensity given by sales in GWh to transformers or power lines length ratios, while the log of plant, property, and equipment (PPE) controls for plant size. Two variables controlling for plant efficiency were included. The first one is either the loss index or the industry-adjusted loss index. As mentioned before, this is a standard indicator for efficiency in power distribution. The greater are the power losses, the higher is the utility's technical inefficiency. The second variable is the log of sales to PPE ratio, which controls for utility capital productivity. Several performance variables were considered. Among them are variables on profitability and sales diversification given by the industrial-to-residential sales ratio.[32] The expected sign for those is positive since profitability channels new investment and leads to increases in industrial sales, which cover the utility against the risk of bad debtors within the residential sector in the regulated market. The indicators of covered urban area and number of subscribers per Km^2 control for market density. Those are environmental variables within the context of power distribution activity. The expected sign of these variables is positive because greater density allows the utility to exploit its network's economies of scale. A set of dummies completes the model. The dummies capture the implementation of regulatory reform, ownership structure, and business activity. As mentioned before, some power distribution companies are still integrated with power generation activities, while others became completely specialized after privatization.

Table 10 displays the main results regarding the determinants of DEA efficiency scores under constant return to scale assumption and scale efficiency defined in Equation 4. The first three columns depict the efficiency scores OLS regression pooled equations. The fifth column reports the Tobit pooled regression based on the specification of regression equation 3, which reports normal residuals with constant variances. This condition is fundamental for getting unbiased and efficient coefficients in the Tobit regressions. Regression equation 6 presents the Tobit-random

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[31] This is a "pooled DEA" instead of a "window DEA" analysis as the one presented in Section 3.2, we do so in order to allow comparable conclusions with the policy analysis presented en the previous section were time dimension was not used.

[32] One can argue that utilities are profitable due to the exercise of monopoly power. Nonetheless, under price-cap regulation profitability increases are sustained by efficiency gains.

effects panel specification, which controls for unobservable individual characteristics through the specific component vi of the residual, which is different for each individual (utility) in the panel.

The reading of those results is as follows. First, the model has a good fit explaining from 75% to 85% the efficiency scores. The independent variables are in all cases statistically significant and show the expected sign, except for the industry adjusted loss index.[33] Second, efficiency scores are positively related to input intensity and plant size indicators. In particular, a 10% increase in physical sales to transformers will raise efficiency scores on an average of 14%, while a 10% increase in the log of PPE will raise technical efficiency in 0.9%. Third, the effect of performance indicators is mixed. On one side, increases in utility capital return will boost efficiency. For instance, a 10% increase in operative income to net worth ratio will improve efficiency on average in 0.45%. On the other side, the industry-adjusted loss index displays the opposite sign.[34] This result might be influenced by the fact that some utilities that were considered as benchmarks did not show improvements in their power losses indices during the time span.[35] Fourth, density variables turned out to be significant. An increase in 100 Km2 in the urban area served will boost efficiency on average in 0.018%. Fifth, regulatory policy had positive effects on utility efficiency. Disregarding the estimation method the regression coefficients show on average an overall efficiency gain of 5%, the same type of result obtained in the policy efficiency exercise performed in previous section. In contrast, the business dummy that captures whether a utility is still integrated or fully specialized in power distribution, has a negative effect. The result is consistent across regressions. On average, there was an overall efficiency loss of 10% from not being fully specialized.

The scale efficiency regressions were not as robust as the efficiency scores ones. We were not able to find an equation without residuals with increasing variance. Therefore, we limited the analysis to OLS robust regression. The explanatory factors are almost the same as those just discussed. The model explains 78% of utility scale efficiency. Two additional variables turned out to be important. One is the loss index that shows up with the expected sign, 10% increase in power losses coefficient will deteriorate utility efficiency scale in 6.5%. The other is capital productivity, 10% increase in the log of sales to PPE ratio will raise scale efficiency in 0.9%. In sum, productive efficiency responds to the proposed model where micro variables seem very important in explaining its behavior, and understanding the role of regulatory policy and exogenous factors that currently have a direct effect on overall efficiency in urban power distribution.

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[33] In addition there is no collinearity problem across regressors according to the mean of the variance inflation factor (VIF) statistic.

[34] The adjusted index says that if there is an improvement in reducing the non-technical losses with respect to the control group (EPM) it has to converge to 1. If the adjusted index increases means that power losses worsen relative to EPM's.

[35] This is the case of ELECTRICARIBE, CEDENAR, y TOLIMA.

TABLE 10

EFFICIENCY SCORES AND PLANT SCALE DETERMINANTS

Variable	OLS Pooled				Tobit -Pooled	Tobit-Panel-RE
	ES-CRTS	ES-CRTS	ES-CRTS	Scale efficiency[1]	ES-CRTS	ES-CRTS
	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5	Eq 6
Sales-GWh / Transf	1.2458 [a]	1.4584 [a]	1.403 [a]	1.0415 [a]	1.7976 [a]	0.4966 [a]
	(0.0913)	(0.0686)	(0.0714)	(0.0561)	(0.1117)	(0.0893)
Sales-GWh / Lines	0.2878 [a]	0.2115 [a]	0.2305 [a]		0.202 [a]	0.2135 [a]
	(0.2878)	(0.0248)	(0.0257)		(0.0307)	(0.0181)
Subcribers per Km2	7.3E-05 [a]					
	(9.1E-06)					
Urban Area (Km2)		2.04E-05 [a]	1.72E-05 [a]	1.56E-05 [a]	2.14E-05 [a]	
		(2.9E-06)	(3.1E-06)	(1.97E-06)	(3.82E-06)	
Ind-sales / Res-sales	0.1106 [b]					
	(0.0517)					
Log PPE		0.0938 [a]	0.0983 [a]	0.1062 [a]	0.1056 [a]	0.0783 [a]
		(0.0079)	(0.0081)	(0.0066)	(0.0091)	(0.0057)
Log (sales/PPE)				0.0908 [a]		
				(0.0312)		
Oper-Income / Net Worth	0.0246 [c]	0.0218 [c]	0.026 [b]		0.0433 [b]	0.0372 [a]
	(0.0142)	(0.0124)	(0.0124)		(0.0198)	(0.0114)
Loss Index				-0.6448 [a]		
				(0.1411)		
Loss Index-ad	0.1072 [a]		0.0456 [a]		0.0483 [a]	0.0391 [a]
	(0.0234)		(0.0187)		(0.0213)	(0.0122)
Dummy Regulation	0.0549 [b]	0.0601 [a]	0.0534 [a]	0.0595 [a]	0.0663 [a]	0.0563 [a]
	(0.0218)	(0.0162)	(0.0164)	(0.0150)	(0.1844)	(0.0111)
Dummy Business	-0.1384 [a]	-0.1123 [a]	-0.1251 [a]		-0.1172 [a]	-0.0662 [a]
	(0.0226)	(0.0195)	(0.0200)		(0.0221)	(0.0133)
Constant	0.1647	-0.8199	-0.9357	-0.529	-1.0798	-0.50338
Sigma					0.1100	
Num Obs	192	192	192	192	192	192
R^2-OLS	0.7659	0.8552	0.8597	0.7788		
Mean VIF	1.50	1.46	1.61	1.59		
F-test	74.8	155.2	140.2	108.6		
	[0.0000]	[0.0000]	[0.0000]	[0.0000]		
LR-Chi2(k-1)					372.2	
					[0.0000]	
Uncensored Obs					146	
Censored Obs					46	
Wald-Chi2(k-1)						704.7
						[0.0000]
Num of groups						12
Obs per Group: (Min, Max)						16,16
Cook-Weisberg -OLS	5.66	2.71	1.30	36.02		
	[0.0174]	[0.0996]	[0.2540]	[0.0000]		
Breuch Pagan -OLS	28.3	6.45	3.52	43.68		
	[0.0000]	[0.2643]	[0.7409]	[0.0000]		
swilk -OLS	2.86	1.49	1.15	0.934		
	[0.0021]	[0.0669]	[0.1251]	[0.1751]		
LR Test on s^m=0						130.2
Chi2(1)						[0.0000]

Notes: 1/ = White-Hubert robust standard errors; 2/= Weighted data. Analytical weights using residuals OLS equation

Std errors appear in parentheses, and p-values in square brackets; a= significat at 1%, b= significant at 5%, c= significat at 10%

Series definitions are in explained in Appendix 3 and in the text.

V. Conclusions

This paper has conducted an in-depth study of utility performance and technical efficiency trends for a time span long enough to test performance, efficiency and productivity benefits in power distribution of the 1994 reform in Colombia. Based on a sample of 12 utilities covering the largest cities of the country and a time span of 16 years, the findings suggest that the recent evolution in urban power distribution has improved during the post-reform years. The performance exercise reported a recovery in profitability rates. This is partly explained by gains in labor and capital productivity across companies, but higher residential tariffs also unbound utility financial constraints. This result contradicts in some sense the public version of a structural financial crisis within power utilities. Nonetheless, the companies that are facing financial problems respond to their own particular reasons.[36]

The efficiency analysis yields important outcomes. On one hand, the results of efficiency trends across power distributors did not boost efficiency within the inefficient power distributors. Moreover, they became less efficient after 1995. However, the efficient distributors, which are the larger utilities, remain on the best practice frontier. This trend is confirmed with the Malmquist productivity indices. Efficiency gains relied on the boundary shifts rather than efficiency catch up across utilities below the frontier. This implies that those plants are away from the benchmark's Pareto efficient inputs allocation. The benefits of the reform are also observed after disentangling managerial from policy efficiency. The inefficiency in the post-reform period, after have eliminated any managerial inefficiency in each policy group, is dramatically lower than pre-reform period.

Finally the econometric exercise provides evidence regarding the determinants of efficiency scores. They are influenced by firm characteristics such as plant size and factor intensities. Market density has a positive effect on utility productive efficiency. Regulatory policy has had positive effects on power distribution efficiency according to the regression equations. This regulation dummy turned out to be a robust regressor that on average implied an efficiency gain of 5% after the reform. This finding is consistent and goes in the same direction with previous results of efficiency analysis in power generation for the case of Colombia reported in Pombo and Ramírez (2003). The policy implications of the above results lie on the fact that ownership does not guarantee itself efficiency improvements. The ownership dummy turned out to be a non-significant explanatory variable. This finding is consistent with results found in other case studies where there is no evidence of positive impact of private ownership in plant efficiency in power generation and distribution, such as those reported in Pollit (1995).

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[36] For instance, Pombo and Ramírez (2003) document that profitability indicators did not increase among the privatized power holdings keeping the pre-reform structure of integrated utilities in power generation, distribution and in lesser degree transmission. The study concludes that such outcome is consequence of open market competition in power generation. The former ICEL subsidiaries and EMCALI were not included in the above mentioned-study.

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APPENDIX 1

TABLE A1.1

DEFINITIONS OF PERFORMANCE INDICATORS

Variable	Description
Profitability	
Net Income / Sales	Net income is equal to sales minus financial expenses plus other income. Sales are equal to the value of services sold.
Operating income / PPE	Operating income equals sales. PPE stands for the value of the company fixed assets.
Operating income / Net Worth	Operating income equals sales. Net worth is total assets plus additional income from shareholders and past income.
Operating Efficiency	
Log (sales/PPE)	Sales are equal to the value of services sold. PPE stands for the value of the company fixed assets.
Log (sales / employees)	Sales are equal to the value of services sold. Labor is the number of employees in distribution.
Labor	
Log (employees)	Labor stands for the number of employees in distribution.
Assets	
Log (PPE)	PPE stands for the value of the company fixed assets.
Log (PPE / Employees)	PPE stands for the value of the company fixed assets. Labor stands for the number of employees in distribution.
Output	
Log (Sales)	Value of electric energy sold to total users.
Log (Sales residential)	GWh sold to residential users
Log (Sales total)	GWh sold to total users (residential, industrial, commerce and government)
Loss index	Percentage energy losses. Percentage of GWh entered in the grid system which did not reach final users for technical or billing reasons.
Tariffs	
Residential tariffs	Energy price of sale to final residential users
Industry tariffs	Energy price of sale to final industry users.

APPENDIX 2

INPUT ESTIMATION IN POWER DISTRIBUTION

The original data provided by CREG on distribution net length and number of transformers was incomplete (including data only for 1999, 2000 and 2001) and slightly inconsistent (in some cases from year 2000 to 2001 the variables decreased instead of increase or remain constant, a technical situation difficult to conceal in the electric energy distribution industry). Given that the goal of the study is to compare information on distribution facilities before and after the 1994 regulatory reform and that the rest of the information collected ranged from 1985 - 2001, we estimated in sample information for distribution net length and number of transformers from econometric estimation on the available data for net and transformers.

The procedure for estimation of the missing data is based on determinants of the data originally reported on net length and number of transformers, then from the parameters found an in-sample backward forecasting is applied, in the cases were unreliable results were obtained, no change was applied on the data and the last observation obtained was left for the previous year. Table A2.1, shows the original information provided by CREG, the final data obtained is available upon request.

TABLE A2.1.
ORIGINAL INFORMATION PROVIDED BY CREG

Firm	Year	Transformers (number of)	Transmission net length (Km)
CVC (VALLE)	2000	18470	7421
CVC (VALLE)	2001	19881	7425
CAQUETA	2001	1806	1543
CEDELCA	2000	8330	4780
CEDELCA	2001	8302	5181
CEDENAR	2000	758	2538
CEDENAR	2001	758	2538
CENS	2000	4586	1361
CENS	2001	8123	1430
CHEC	2000	14691	7596
CHEC	2001	15856	8198
CHOCO	2001	909	798
EADE	2001	14903	13353
EDEQuindio	2001	5783	2231
EEB	2001	48546	17098
EPM_solo	2000	39460.0	5035.0
EPM_solo	2001	43019.0	5040.0
EMCALI	1999	15506	2187
EMCALI	2000	15376	2183
EPP	2000	4268	435
EPP	2001	4281	436
EPSA	2000	18470	7421
EPSA	2001	19881	7425
ESSA	2001	17290	9576
HUILA	2001	6227	3731
TOLIMA	2001	2022	804
ELECTRICARIBE	2000	21105.0	6011.0
ELECTRICARIBE	2001	21105.0	5968.0
ELECTROCOSTA	2000	11843.0	9628.0
ELECTROCOSTA	2001	11843.0	9628.0

TABLE A2.2

REGRESSION USED TO ESTIMATE DISTRIBUTION NET LENGTH

Dependent variable: Km of distribution net	OLS
Total users	0.0103
	(.0024)
Employees	5.4411
	(1.7857)
Region Real GDP percapita	4562.1330
	(1199.965)
Region population	-0.0026
	(.0006)
Area served (km2)	-1.4108
	(.4277)
Share of Industrial demand on total demand	-14279.4500
	(6097.868)
Heteroschedasticity test Cook-Weisberg Ho: Constant variance (probability)	0.7554[a]
RESET specification test. Ho: model has no omitted variables (Probability)	0.0301 [a]
Prueba Normalidad: Skewness / Kurtosis (Probability)	0.4081 [a]
R2	0.93
F test for general significance.	43
Observations	25
Notes: a. Results obtained from same model with constant	

TABLE A2.3

REGRESSION USED TO ESTIMATE NUMBER OF TRANSFORMERS

Dependent variable: Transformers number	OLS
Consumer demand (GWh)	4.6089
	(1.8984)
Distribution net (km)	0.7689
	(.2732)
Total users	0.0171
	(.0075)
stock_m2_lic_const	-0.0001
	(.0001)
Region population	-0.0034
	(.0015)
Area served (km2)	0.5563
	(.2491)
Stock_licencias_usuarios	161.0899
	(85.818)
Heteroschedasticity test Cook-Weisberg Ho: Constant variance (probability)	0.0971[a]
RESET specification test. Ho: model has no omitted variables (Probability)	0.8939 [a]
Prueba Normalidad: Skewness / Kurtosis (Probability)	0.4107 [a]
R2	0.98
F test for general significance.	132
Observations	22
Notes: a. Results obtained from same model with constant	

APPENDIX 3

TABLE A3.1
LIST OF ACRONYMS

CHB	Central Hidroeléctrica de Betania
CHEC	Central Hidroeléctrica de Caldas
CEDELCA	Centrales Electricas del Cauca S.A.
CEDENAR	Centrales Eléctricas de Nariño S.A.
CENS	Centrales Eléctricas del Norte de Santander SA
CORELCA	Corporación Eléctrica de la Costa Atlántica
CREG	Comisión de Regulación de Energía y Gas
CVC	Corporación Autónoma del Cauca
ELECTROCOSTA	Electrificadora de la Costa S.A. ESP
ELECTRICARIBE	Electrificadora del Caribe S.A ESP
EMCALI	Empresas Municipales de Cali
EPM	Empresas Públicas de Medellín
EPSA	Empresa de Energía Pacifico S.A.
ESSA	Electrificadora de Santander S.A.
EEB	Empresa de Energía de Bogotá
DNP	Departamento Nacional de Planeación
FEN	Financiera Eléctrica Nacional
HUILA	Electrificadora del Huila S.A.
ICEL	Instituto Colombiano de Energía Eléctrica
ISA	Interconexión Eléctrica SA
MME	Ministerio de Minas y Energía
TOLIMA	Electrificadora del Tolima S.A.
SSPD	Superintendencia de Servicios Públicos Domiciliarios
UPME	Unidad de Planeación Minero Energética

TABLE A3.2

REGRESSION EQUATIONS EXPLANATORY VARIABLES

Independent variable	Definition
Log (S / L)	Logarithm of value of sales over number of employees on electricity distribution.
Log (S-GWh / Transf)	Logarithm of sales in GWh over number of transformers on the system.
Log (S-GWh / Net)	Logarithm of sales in GWh over kilometers of distribution net.
Users / Km2	Total users over squared kilometers of area served.
Ind-sales / Res-sales	Industrial sales in GWh over residential sales in GWh.
Log (Local GDP pc)	Logarithm of local GDP per-cápita.
Sales / Users	Total sales in GWh over total of users.
Net Income / Sales	Net Income over value of sales
Net Income / Net Worth	Net Income over net worth
Regulatory Change	Dummy on regulatory reform. 1986-95 = 0; 1996 - 2001 = 1.
Ownr	Dummy on ownership after regulatory reform. Private = 1; Public = 0.
Structure	Dummy for bussines activities: Integrated utility = 1, Fully specialized in distribution = 0

THE POWER SECTOR DATASETS

Power sector statistics in Colombia are split among the following institutions:

i) The National Grid Company (Interconexión Eléctrica S.A); ii) the Mining and Energy Planning Unit (UPME); iii) the Electricity and Gas Regulatory Commission (CREG); iii) the National Planning Department (DNP); and iv) the Superintendent of Domiciliary Public Services (SSPD). As a result, each source has a different format and contents.

The information is sorted out either by plant, utilities, regional electricity markets, regional geographical provinces, or simply at a countrywide aggregate level. The Table A2.1 describes the contents of the collected datasets.

TABLE A3.3

COLOMBIA – POWER SECTOR STATISTICS – DATA SET DESCRIPTION

ISA-Reports	Operative Reports of the National Interconnected System
(1995-1999)	- Hydrology
	- Grid Constraints
	- Generation
	- Demand
	- Available effective capacity
	The Electricity Spot Market Report
	- Pool's prices & contacts
	- Total traded amount (GWh)
	- Pool's marginal supply prices by type of generation
SIVICO (1997-1999)	The following data available by utility level:
Source: SSPD	Financial Statements
	- Income statement
	- Balance sheet
	Labor Statistics
	- number of employees by sector's activity
	- number of employees by occupational category
	- number of employees by type of generation
	Market composition by type of users
	- consumption
	- invoicing
	- number of subscribers
	- average tariffs by users
	Results and Performance control process indicators
	- quality service indicators
	- spending & indebtedness indicators
SIEE (1070-1998)	The Economic and Energetic Information System is a dataset that covers the Latin American Economies Energetic Statistics
Source: OLADE	The SIEE sections are:
	- prices
	- demand and supply
	- energetic Equipment
	- environmental impact
	- economic + energetic indicators
	-world-wide energetic statistics
FEN (1983-1994)	The power sector historical financial data. The database offers a summary by power company of
	- income statements
	- balance sheets
	- other variables: purchase + sales of bulk electricity;
	available capacity; power losses
SINSE (1970-1994)	The power sector national system is a comprehensive database. The data is available by utility and regional market.
Source: MME	The SINSE chapters are
	- energetic balances
	- generation and Electricity Demand
	- number and type of subcribers
	- average tariffs by users