ECONOMÍA

ISSN 0124-4396

SERIE DOCUMENTOS

BORRADORES
DE
INVESTIGACIÓN

No. 40, Enero de 2004

Performance and Efficiency in Colombia's Power Utilities: An Assessment of the 1994 Reform

Carlos Pombo

Rodrigo Taborda

UNIVERSIDAD DEL ROSARIO
Colegio Mayor de Nuestra Señora del Rosario - 1653

POMBO, Carlos

Performance and Efficiency in Colombia's Power Utilities : an Assessment of the 1994 Reform (Borradores de Investigación) / Carlos Pombo, Rodrigo Taborda. — Bogotá: Centro Editorial Universidad del Rosario, 2004.

31 p. : cuad., tab. –- (Economía. Serie Documentos, 40).

Incluye bibliografía.

ISSN: 0124-4396

PRIVATIZACIÓN DEL SECTOR ELÉCTRICO – COLOMBIA / REFORMA REGULATORIA DEL SECTOR ELÉCTRICO – COLOMBIA - 1994 / EMPRESAS ELÉCTRICAS – PRIVATIZACIÓN - COLOMBIA / I. Título / II. Taborda, Rodrigo.

Performance and Efficiency in Colombia's Power Utilities: An Assessment of the 1994 Reform

Carlos Pombo*
capombo@urosario.edu.co
Facultad de Economía
Universidad del Rosario
Calle 14 # 4 – 69 Bogotá, Colombia

Rodrigo Taborda
rtaborda@urosario.edu.co
Facultad de Economía
Universidad del Rosario
Calle 14 # 4 – 69 Bogotá, Colombia

Abstract

This paper describes the core features of the power sector 1994 regulatory reform and evaluates utility performance and efficiency before and after the reform. The performance analysis assesses the changes in means and medians of a series of profitability, efficiency, investment, sales of the privatized power holdings. Technical efficiency is estimated through DEA technique in a sample of 33 power thermal-plants that account for 85% of the thermal park and 12 distribution utilities. The sample units are plants that were active before the reform and new entrants that started business operations after the reform. The main outcomes show that efficiency scores have improved after the reform and that regulatory policy has had a positive effect on technical efficiency in thermal power generation. In contrasts the less efficient power distributors got worsened after the reform and were not able to undertake plant restructuring in order to catch up productive efficiency with respect to the best practice production frontier.

JEL Classification: L43, L51, L94,O3

Key Words: Privatization, industrial restructuring, Colombian power sector, regulatory reform

Resumen

El artículo describe las características centrales de la reforma regulatoria al sector eléctrico en 1994 y evalúa el desempeño y la eficiencia de las empresas públicas antes y después de la reforma. El análisis de desempeño evalúa los cambios en medias y medianas en ganancias, eficiencia, inversión y ventas de las empresas privatizadas en el sector. La eficiencia técnica es estimada mediante la técnica DEA en una muestra de 33 plantas térmicas de energía, que representan el 85% del parque térmico; y 12 empresas distribuidoras de energía. La muestra de plantas generadoras está compuesta por plantas que estaban activas antes de la reforma y plantas nuevas que entraron en operación después de la reforma. Los principales resultados muestran que la eficiencia mejoro después de la reforma y que la política regulatoria ha tenido un efecto positivo en la eficiencia de la generación térmica de energía. Por el contrario, las distribuidoras de energía menos eficientes empeoraron después de la reforma y no llevaron a cabo una reestructuración para alcanzar la eficiencia productiva respecto a las empresas que conforman la frontera de eficiencia en distribución de energía.

Clasificación JEL: L43, L51, L94, O3.

Palabras clave: privatización, reestructuración industrial, sector eléctrico colombiano, reforma regulatoria.

---

* Associate professor and director graduate studies, Department of Economics, Universidad del Rosario.
Financial support from the IDB's Latin American Research Network is gratefully acknowledged and Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología "Francisco José de Caldas" - COLCIENCIAS.

1. INTRODUCTION

The 1994 regulatory reform of the power sector in Colombia is one of first reforms in Latin America that introduced a market system for the wholesale electricity transactions and the first in implementing a bidding system for its pool in the region. In this sense, the reform deepened the Chilean as well as the Argentinean experiences, where wholesale electricity prices were based on declared costs rather than marginal supply prices.[1] The reform sought to introduce new competition and set up an independent regulatory system. In that sense, the main purpose was to set the basis for the expansion and diversification of power generation sources, improving both the sector's efficiency and its reliability. Political willingness to support this plan was important by 1992 because the country was in the middle of a generalized power shortage and rationing schedules.

The generating system had to be made less vulnerable to abnormal hydrological conditions (i.e., El Niño) and more reliant on thermal generation from either coal or natural gas. The reform focused to incentive utilities' 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 in Colombia split the traditional vertical monopoly structure of the power sector into four different activities: generation, transmission, distribution and commercialization of electricity; it also created the pool market for electricity with remarkable results in buyer's price hedging, efficiency improvements in power generation, and overall gain in system reliability due to firm entry during the last recorded 1996-1997 *El Niño* cycle. In addition the positive effect of the new regulation implied the setting up of a non-regulated market of large clients that boosted transactions of forward electricity contracts.

Regarding power transmission, new regulation handle this activity as a natural monopoly. The reform consolidated *Interconexión Eléctrica S.A (ISA)* as the country's power transmission company.[2] Power distributors as domiciliary public service providers face 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 as well as the determining the nature of pass through to final users. The second type of regulation concerns quality control, whereby companies are subject to sanctions if their service fails to meet minimum quality standards. The reform was designed to impact two types of final users. Residential users are mainly regulated consumers. Final prices for them are set by a markup formula. The reform

---

1 A complete presentation of the regulatory reform in Colombia is in Pombo (2001). Estache and Rodriguez-Pardina (1998) and Mendoça and Dahl (1999) outlines a general presentation of the process in Latin America. The study of the Guash and Spiller (1999) published by the World Bank is a comprehensive study regarding privatization, regulatory policy instruments, and contract designing for several Latin American countries and network industries. Nonetheless, for the power sector the Colombian experienced was tangentially mentioned in the study. On the other hand the IDB 2001 provides a short analysis the sustainability of the power sector reforms in Latin America. For an international review see Newbery (2000).

2 ISA is in fact the larger power transported for the Andean Region. ISA won in 2001 the concession for the construction of the northern Peru grid, and in 2002 entered in the Bolivian market. Today there is a fully regional interconnection with neighboring electricity systems of Ecuador and Venezuela.

also introduced the figure of non-regulated users. They are large clients, mainly commercial and industrial users. 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 it became a complementary policy within a broad deregulatory context.

This paper presents an ex-post performance analysis for the electric utilities based on three elements: i) an analysis of firm performance through the changes in means and medians of profitability, operating efficiency, labor, investment and sales indicators of the privatized power utilities ii) direct measures of productive efficiency scores through data envelope analysis programming (DEA) applied to thermal power plants as well as a sample of electricity distribution companies and, iii) a econometric analysis regarding the determinants and micro-fundamentals of the thermal plant efficiency scores.

The paper core objectives are two-fold. First it seeks to provide new empirical evidence regarding changes in electric utilities performance and productive efficiency derived from the 1994 regulatory reform. The results look to offer objective elements for ex-post policy evaluation regarding the benefits of market designing, promotion of market competition, and price and quality regulation. The results are also important for contrasting purposes were the Colombian experience has not been fully stressed in international studies despite of been the first pool based on a bidding procedure in Latin America. Second, the focus on the efficiency analysis completes previous results of recent studies regarding the power sector reform in Colombia.[3]

The paper structure is organized in four additional sections. Section 2 outlines the privatization and regulatory reform program undertook during the 1994-1998 period. Section 3 presents the results of changes in performance variables of the privatized power-holdings. It evaluates the null hypothesis of structural changes in indicators mean and medians outlines regarding firm profitability, efficiency, investment, payroll size, and sales. The analysis carried out takes into account industry-adjusted indicators by specific control group. Section 4 carries out a DEA plant efficiency measurement across thermal generation plants that counts for 85% of system thermal park, and a preliminary assessment of changes in productive efficiency for the larger power distribution companies after the reform. Section 5 performs the econometric analysis of the thermal plant efficiency, and Section 6 concludes.

2. INDUSTRY RESTRUCTURING AND PRIVATIZATION IN THE POWER SECTOR[4]

Regulatory reform in Colombia's electricity supply industry (ESI) is supported by the Electric Law (Law 143) and by the Domiciliary Public Services Law (Law 142) of July 1994. The reform changed the structure of the vertically integrated industry. The new regulatory institutions started to operate one year later. The reform's core elements followed the schemes adopted

---

[3] See Pombo (2001) for more details.

[4] For details regarding privatization in the real sector in Colombia see Pombo & Ramirez (2002).

in Great Britain concerning the separation of power activities and markets, the setting up of an electricity spot market or pool, and the development of a long-term contract market for electricity.[5] Law 143 created the Regulatory Commission for Energy and Gas [*Comisión de Regulación de Energía y Gas*, (CREG)] and rules regarding: i) the sector's planning and expansion plans, ii) the regulatory scheme, iii) power generation, iv) transmission and grid operation, v) grid access fees, vi) the rate-setting regime for electricity sales, vii) concession contracts, and vii) environmental issues.

The power sector reform sought to introduce new competition and set up an independent regulatory system. In that sense, the main purpose was to set the basis for the expansion and diversification of power generation sources, improving both the sector's efficiency and its reliability. Political willingness to support this plan was important by 1992 because the country was in the middle of a generalized power shortage and electricity rationing schedules were imposed. The generating system had to be made less vulnerable to abnormal hydrological conditions (i.e., El Niño) and more reliant on thermal generation from either coal or natural gas.

Diagram 1 synthesizes the post-reform power market structure by power activity: generation, transmission and distribution. There are several comments worth mentioning. First, the split among power activities implied the divestiture of the main power holdings that were vertically integrated monopolies. The same happened with the national grid company[*Interconexión Eléctrica S.A. (ISA*)], which had to sell all of its power generating units in 1995 and become an independent generator firm. The new regulatory framework seeks to promote market entry and competition among generators. They compete openly by sending their bids one day ahead to the pool. The sale price is based on an hour of use and it distinguishes between peak and off-peak hours. The National Dispatch Center, which is located at ISA's headquarters, combines information regarding the system's constraints, such as hydrological factors, reservoir levels, and transmission bottlenecks, with final commercial demand in order to determine the dispatch orders. Thus, the market price that the pool[6] sets is the highest marginal bid that clears the market each hour. Based on the above, the pool administrator runs the next-day merit order dispatches.[7] Financial transactions take place by direct purchases from the pool or through

---

5 The national grid company Interconexión ISA as the largest nationwide power generator and transporter of bulk electricity following the vertically integrated natural monopoly model. For more details, see World Bank (1991). A complete description of the regulatory reform in Colombia's power sector is in Pombo (2001b) and ISA reports. Historically, Colombia's power sector has been divided in five regional markets: Bogotá Power Company (EEB); the Atlantic Coast Regional Electric Corporation Eléctrica S.A (ISA) was founded in 1967. By that time, the sectoral development view was to consolidate (CORELCA), Public Enterprises of Medellín (EPM), Public Enterprises of Cali and the Cauca Valley Corporation (EMCALI and CVC), and the Colombian Power Institute (ICEL). So far, only two out of the five power distribution networks have been privatized. Nevertheless, one has to keep in mind that the city of Bogotá is still the largest shareholder of CODENSA, the power distribution utility founded after the EEB divestiture. Therefore, EPM, EMCALI, and ICEL still, as public utilities, cover 70% of the geographical areas that belong to the National Interconnected System. Hence, privatization and entry competition remain a pending and unfinished task for local power distribution.

6 The pool is locally known as the *Mercado de Energía Mayorista* (MEM).

7 The power market in Colombia parallels the British pool of the early 1990s. For more details on electricity markets and the British experience see the work of Armstrong, Cowan and Vickers (1994) and Newbery (2000). For Latin America good reviews are found in Spiller and Guash (1998), and the IDB 2001 annual report.

contracts signed directly between generators and final users. However, the pool administrator runs the invoicing generated by all financial agreements. That is, that office pays and collects bills derived from contracts.

Regarding power transmission, new regulation handle this activity as a natural monopoly. The reform consolidated ISA as the country's power transmission firm. In this sense, the regulator determines prices and guarantees access to the grid to all providers. This company is not allowed to have an equity share in either power generating or distributing companies. Power distributors as domiciliary public service providers face two types of regulation. The first one is price regulation. CREG currently sets the markup formula for distributors as well as the determining the nature of pass through to final users. With respect to the latter, 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.[8] Price regulation at this stage differs from most systems that have moved toward electricity markets that have adopted price-cap rules. The second type of regulation concerns quality control, whereby companies are subject to sanctions if their service fails to meet minimum quality standards. The reform was designed to impact two types of final users.

Residential users are mainly regulated consumers. Final prices for them are set by the markup formula, which includes past inflation. The reform also introduced the figure of non-regulated users. They are large clients, mainly commercial and industrial users. The minimum consumption to become a large client was set in 1995 in 2 Megawatts (MW) per month likewise the parameter used in England. This lower limit was reduced to 0.5 MW in 1997. A large client might enter into a purchase agreement contract with a power distributor, wholesale retailer or generator. This implies that these large consumers can hedge against pool price volatility, a sensitive variable especially in hydro-based systems. 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 it became a complementary policy within a broad deregulatory context.

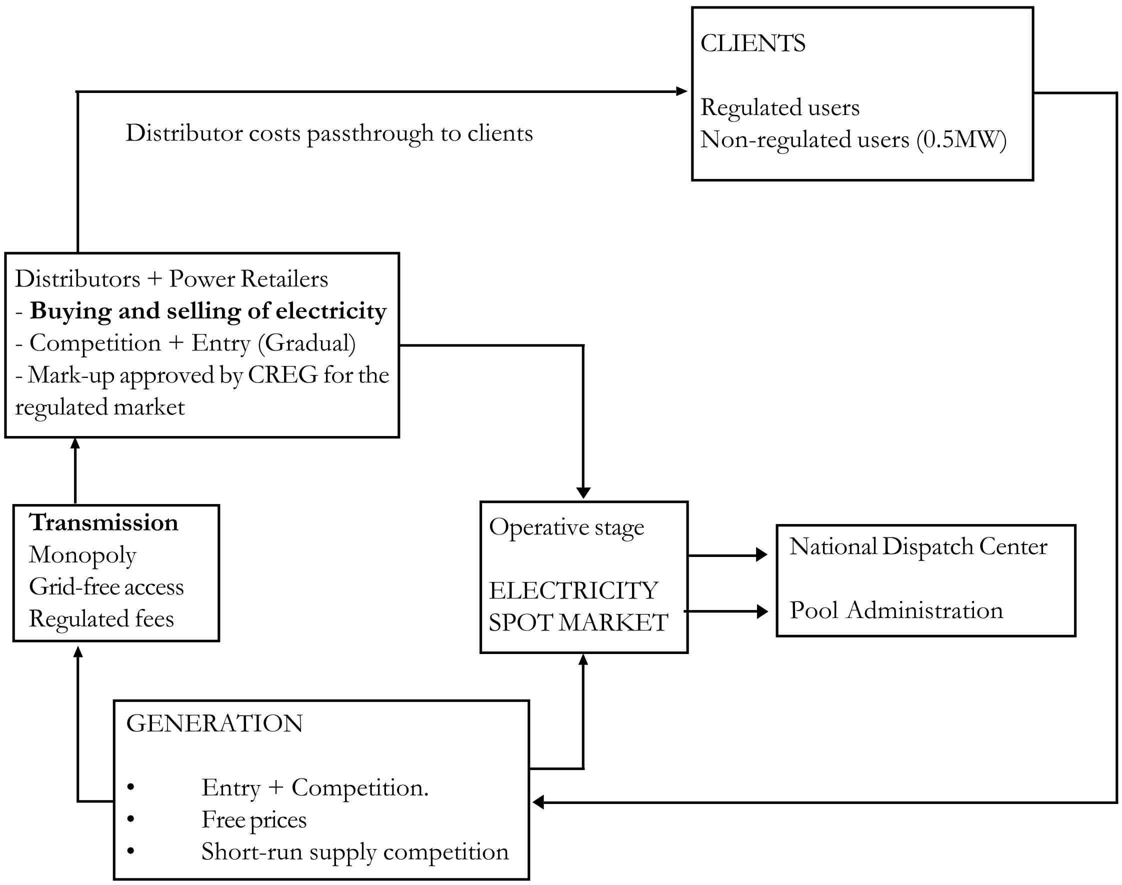
Table 1 describes the sales process in the power sector. It depicts the privatized utility, thermal plant or hydro unit, the capacity of each unit expressed in Megawatts, the sale amount in current US$, the power holding seller as well as the company buyer, and the last column it includes the buyer's country origin. Privatization in the power sector had two phases until 1998. The first one was the 1996–1997 privatization round, which focused on the sale of thermal plants and hydroelectric stations. Sales reached US$3.9 billion. This represented a 50% transfer of overall system generating capacity. The most important transaction was the sale of

[8] The last component is the analog for the Uplift component in Great Britain. For details on the Colombian and British formulas see Pombo (2001b).

48% of the Bogotá Power Company's net worth, which also included the transfer of the local distribution network and the regional grid. The buyers were two holding companies owned by ENDESA and CHILECTRA, Chile's largest power generators.

DIAGRAM 1

THE POWER MARKET STRUCTURE



Notes: This diagram shows the power sector structure after the regulatory reform and the relation among power activities. Non-regulated users are large clients (commercial, industrial users) whose minimum consumption is 0.5 megawatts (MW) of capacity per month. 1 MW of capacity = 1000 KWh.
Source: *Interconexión Eléctrica S.A -ISA-* report 1998.

The second phase of the privatization program took place in 1998 and focused on the capitalization and sale of the CORELCA holding, which covered Colombia's northern Atlantic region. The restructuring involved splitting the holding into several independent companies according to power activity: generation, transmission and distribution. The national grid company ISA bought 65% of the new transmission company's equity share. On the other hand, a holding company formed by American and Venezuelan utilities purchased a 65% equity share of the two distribution utilities founded after CORELCA's restructuring. Both transactions added up US$1.16 Billion. The following section will focus on the performance analysis of the privatized firms in manufacturing and power utilities in order to provide an assessment of their privatization and economic deregulation policies. In these two sectors, assets transfers accounted for 90% of the total privatization sales in the productive sector as of mid-1999.

3. CHANGES IN PERFORMANCE OF THE PRIVATIZED POWER UTILITIES

The ex-post performance analysis in the power sector takes into account the effects of the 1994 reform on firm entry, market competition, and efficiency gains. In that sense, the analysis focuses on firm changes in means and medians of direct measures of profitability, efficiency, assets and investments, and sales of the privatized power holdings. The study sample covers the equity transfers in three out of five regional power systems where privatization took place, as described in Section 2. They are the former: i) Bogotá Power Company, ii) Cauca Valley Corporation (CVC) and iii) the *Corporación Regional de la Costa Atlántica* (CORELCA) holding. The control group is Public Enterprises of Medellín [*Empresas Públicas de Medellín (EPM)*], which is a municipally owned company and has been traditionally the most efficient public enterprise not only in power generation and distribution but also in other services such as water and telecommunications. All series since 1995 shared the assumption of the pre-reform electric holding structure in order to have comparable statistics. The dataset collects the historical financial reports for the privatized power holdings from several sources since 1983, which allowed us to replicate similar measures of profitability, efficiency, assets and investment, sales, and employment.

The performance analysis follows the approach of firm assessments used in privatization studies such as Megginson et al. (1994) and La Porta and López-de-Silanes (1999).[11] Tables 2 and 3 present the main results regarding the performance effects of the regulatory reform on the power holdings. Several facts are worth mentioning. First, the reform has had a direct and positive effect on utility operating efficiency. The average cost per unit dropped 45% at constant prices. The mean (median) of sales to PPE rose 17% (18%), while the mean (median) sales to employees rose 20.3% (15.7%). The same happened with the operating income to employee ratio where the mean (median) increase was 63% (48%) at constant prices after the reform. Changes are significant at the 5-percent level.

There are at least three important sources of these efficiency gains. First, utilities made an effort to reduce both power losses and the under-collecting problem in distribution. This was the case for the Bogotá Power Company in particular, which drastically reduced it power loss indices from 53% in 1985 to 22% in 1996. The same trend is observed for the other privatized holdings.[12] Second, the reform and privatization induced new investment in incumbent firms, in contrast to what was observed for manufacturing. All investment rates at least doubled on average. Notice that capital stock remains unchanged, but this is not statistically significant. Total assets usually have several biases depending on the depreciation schedules. For that rea-

---

[9] See Appendix 2 for a complete description of the power sector databases.

[10] See Pombo (2001b) for more details. The point here is that there are two sources of power losses. One is the technical loss due to the power losses in transmission necessary to maintain the system's stability. The non-technical loss is the difference between real consumption and invoicing. Cities such as Bogotá used to have power stealing, illegal connections, and adulterated meters among other irregularities.

TABLE 1
PRIVATIZATION IN THE POWER SECTOR: 1995-1998

Utility/Plant/Hydro	CapacityMW	Type	Sale US$ Mill.	Seller	Buyer	Buyer Share %	Investor Country Origin
Betania	500	Hydro	497	ICEL	ENDESA	100	Chile
Chivor	1,000	Hydro	645	ISA	CHILGENER	100	Chile
Tasajero	150	Termal-Coal	30	ICEL	Cooperative-Sector	58	Colombia
TermoCartagena	180	Termal-Coal	15	CORELCA	Electricidad-Caracas	15	Venezuela
					Cooperative-Sector	85	Colombia
EPSA-Gen	772	Hydro	535	CVC	Houston Industries	56	United States
	210	Termal-Gas					
ESPA-Distrib					Electricidad-Caracas		Venezuela
EEB-Gen	2,312	Hydro	810	EEB	Capital-Energia Holding1	48.5	Chile-Spain
	104	Termal-Coal			(EMGESA)		
EEB-Distrib			1,085	EEB	Luz-Bogotá Holding2 (CODENSA)	48.5	Chile-Spain
EEB-Trans.			141	EEB	Capital-Energía Holding1	5.5	Chile-Spain
			141	EEB	Luz-Bogotá Holding2 (EEB-Head Quaters)	5.5	Chile-Spain
CORELCA							
Electro Costa-Distrib				CORELCA	Houston Inc-Electricidad	65	USA-Ven
and					Caracas		
Electro Caribe-Distrib			980	CORELCA	Houston Inc-Electricidad Caracas	65	USA-Ven
Transelca-Transm			180.5	CORELCA	ISA	65	Colombia
Total Generation	5,228		2,532				
Total Distribution			2,065				
Total Transmission			462,5				
Total Privatization			5,060				

Notes on Table 1: This table describes the sales process in the power sector. It depicts the privatized utility, thermal plant or hydro unit, the capacity of each unit expressed in Megawatts, the sale amount in current US$, the power holding seller as well as the company buyer, and the last column it includes the buyer's country origin. Generating capacity is expressed in megawatts (MW). One MW of capacity = 1000 KWh. Sales are in millions of current US$. EEB = Empresa de Energía de Bogota; EPSA = Empresa del Pacifico S.A (formerly CVC); CVC = Corporación Autónoma del Cauca; ICEL = Instituto Colombiano de Energía Eléctrica; CORELCA = Corporación Eléctrica de la Costa Atlántica; ISA = Interconexión Eléctrica S.A.

[1]: Capital Energía = ENDESA (Chile) + ENDESA-Desarrollo (Spain)

[2]: Luz Bogota = CHILECTRA (Chile) + ENERSIS (Chile) + ENDESA-Desarrollo (Spain)

Sources: MME (1996) and (1998), reports to the Congress; ISA reports (1998, 1999).

TABLE 2

CHANGES IN PERFORMANCE: SAMPLE OF PRIVATIZED POWER UTILITIES AND PUBLIC ENTERPRISES OF MEDELLÍN

Variabe	N Before	N After	Mean Befote Median Before	Mean After Median After	t-stat z-stat
I. Profitability					
Operating Income/Sales	48	20	0.3208	0.1891	-3.093[a]
			0.3587	0.2262	2.410[b]
Net Income/Sales	48	20	0.1382	0.0882	-0.693
			0.1992	0.0998	0.794
Operating Income/PPE	48	20	0.0562	0.0288	-3.060[a]
			0.0556	0.0397	2.544b
Operating Income/Net-Worth	48	20	0.0997	0.0463	-3.155[a]
II.Operating efficiency					
Cost per unit	48	20	0.0292	0.0207	-1.790[b]
			0.0226	0.0194	1.561
Log (Sales/PPE)	48	20	1.2574	1.4289	3.260[a]
			1.2278	1.4101	-2.907[a]
Log (Sales/employees	48	20	2.0020	2.2035	4.469[a]
			2.0021	2.1578	-3.957[a]
Operating income/employees	48	20	112.82	183.91	4.367[a]
			105.54	156.68	-4.321[a]
III. Labor					
Log (Employees)	48	20	3.4354	3.3987	-0.4701
			3.5205	3.4255	0.8080
IV. Assets and Investment					
Log (PEE)	48	20	4.1807	4.1733	-0.1135
			4.1513	4.1509	0.1750
Investment/salesd	48	8	0.0039	0.0066	1.9950[b]
			0.0033	0.0063	-1.1710
Investment/employeesd	48	8	0.4869	0.8374	1.6493[c]
			0.2721	0.6909	-1.5220
Investment/PPEd	48	8	0.0742	0.1579	3.1909[a]
			0.0647	0.1521	-1.9900b
Log (PPE/total amployees)	48	20	0.7453	0.7746	0.4286
			0.7817	0.7960	-0.2690
V. Output					
Log (Sales)	48	20	5.4382	5.6023	2.5933[a]
			5.4771	5.6886	-2.6250[a]

Notes on Table 2: This table presents raw results for 3 privatized power holdings and Public Enterprises of Medellin. The dataset is a balanced panel by construction and the sample size (N) refers to firm-year observations for two times periods: i) before the regulatory reform a = 1983-1994 and ii) the post-reform years = 1995-1999. The maximum number of firm-year observations before the reform is 40, and 20 after the reform. The table reports for each empirical proxy the number of usable observations, the mean, and the median values before and after the sector regulatory reform (1995), and the t-stat and z-stat (Mann-Whitney non-parametric rank sum) as the test for significance of the change in mean and median values. Value variables before transformations in logs are in millions of pesos at 1995 prices. Definitions of each variable as well as details on Colombia's power sector datasets and definitions can be found in Appendices 1 and 2.
a = significant at 0.01; b = significant at 0.05; significant at 0.1; d = post-reform period = 1995–1996 due to availability of appropriate data.

son a more accurate indicator is the current investment rates. Notice that in most cases the changes in performance of operating efficiency and investment-adjusted indicators are not statistically significant with respect to their control group. The reading of such a result is that, despite efforts made by the newly privatized and divested electric holdings, these were not enough to surpass EPM's efficiency changes.

Third, employment cuts were not as significant. The four electric holdings had on average 13,300 employees before the reform. This number only decreased to 11,600 employees during the 1995–1999 period. Thus, the observed 23% real increase in labor productivity was due to the increase in sales rather than drastic employment cuts. In fact, the mean (median) of sales increased by 16.4% (21.1%). One must keep in mind that the 1994 reform adopted a mixed model for the provision of electricity, given the appropriate signals to private investors in undertaking long-lasting efforts. This new investment implied that firms received embodied efficiency gains. This point becomes clear with the evolution of thermal capacity as depicted in Figure 1, which clearly shows sharp increases in thermal capacity and a doubling during the 1990s.

The new regulation has used two instruments to provide incentives to market entry. One is the design of capacity charges by which the regulator guarantees a minimum return on the installed capacity. The second instrument is the power purchase agreements (PPAs). These are long-term contracts through which generators hedge against unexpected changes in demand and distributors hedge against system constraints. One type of PPA initially implemented in Colombia is to *pay what is generated*, which involves an advance purchase of plant capacity. Most thermal generators are marginal producers whose objective is to generate a hedge for the system. In fact, the thermal park had 63 plants with an effective capacity of 3,800 MW in 1998, which represents a 32% share. Among them 21 started commercial operations after 1993 and 16 are privately owned. This is not a coincidence since the government had already undertaken an emergency expansion plan to overcome the 1992 power generation crisis.[11] Thus, fixed investment in thermal generation has played a central role in improving system reliability as well as promoting market entry in power generation.

The behavior of profitability indicators, however, did not mirror the efficiency gains. Notice the striking result that all profitability indicators, adjusted and unadjusted, dropped after the regulatory reform. The mean (median) of operating income to sales ratio was 32.1% (35.8%) before the reform for the study sample. The indicator fell to 18.9% (22.6%) during the post-reform years. Operating income to PPE or Net Worth, as indicators of firms' profit rates of gross and net fixed assets respectively, were reduced by close to one half. The above changes are significant at the 5-percent level. The adjusted indicators show the same behavior. That is, the privatized holdings lost relative profitability with respect to their control group.

The conventional wisdom would say that any gains in input productivity must have a direct impact on firm profitability rates if and only if there are not drastic changes in market compe-

---

[11] An analysis of the 1992 blackout is in Pombo (2001). The official version of the blackout causes and policy measures is in the 1993 Ministry of Mining report to the Congress.

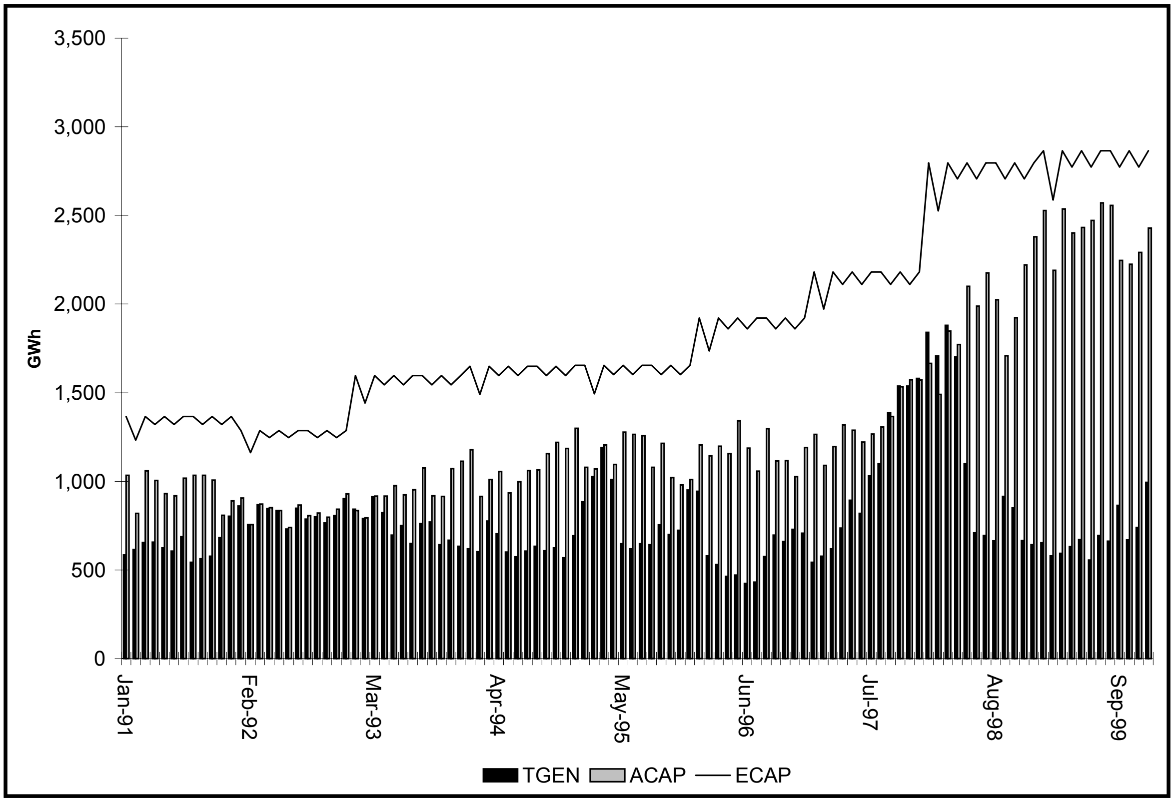
TABLE 3
INDUSTRY-ADJUSTED CHANGES IN PERFORMANCE PRIVATIZED POWER UTILITIES

Variable	N Befote	N After	Mean Before	Mean After	t-stat z-stat
I. Profitability					
Operating Income/Sales	36	15	0.7122	0.4088	-2.308[b]
			0.8264	0.6109	1.757[c]
Net Income/Sales	36	15	0.1677	0.0504	-0.341
			0.1949	-0.0076	0.537
Operating Income/PPE	36	15	0.7458	0.3206	-2.018[b]
			0.6933	0.4037	2.293[b]
Operating Income/Net-Worth	36	15	0.7647	0.3152	-1.996[b]
			0.7559	0.3729	1.736[c]
Mean Tariff	26	6	1.7088	1.0469	-2.032[b]
			1.4213	1.0296	1.977[b]
II. Operating efficciency					
Cost per unit	36	15	0.5101	0.6649	1.242
			0.4162	0.5036	-1.137
Log (Sales/PPE)	36	15	1.0055	1.0488	0.828
			0.9663	0.9989	-1.116
Log (Sales/employees)	36	15	1.0296	0.9910	-1.394
			1.0324	0.9955	1.220
Operating income/employees	36	15	1.2877	1.1073	-1.142
			1.2240	1.0026	1.199
III. Labor					
Log (Employees)	36	15	1.0013	0.9974	0.128
			1.0477	0.9974	-0.475
IV. Assets and Investment					
Log (PEE)	36	15	1.0133	0.9763	-1.826[b]
			1.0031	0.9593	2.150[b]
Investment/Salesd	36	6	1.1585	1.0014	-0.371
			0.9723	0.9074	0.539
Investment/employeesd	36	6	1.6667	0.6618	-1.350
			0.8622	0.3741	1.546
Investment/PPEd	36	6	1.2120	1.0372	-0.411
			1.0115	1.4047	0.108
Log (PPE/employees)	36	15	1.0733	0.9021	-1.386
			1.2772	0.9431	1.530
V. Output					
Log (Sales)	36	15	1.0115	0.9937	1.225
			1.0361	1.0081	-1.199

Notes on Table 3: This table presents the industry-adjusted results for 3 privatized power holdings. Performance proxies are adjusted relative to Public Enterprises of Medellín. The dataset is a balanced panel by construction and the sample size (N) refers to firm-year observations for two times periods: i) before the regulatory reform = 1983-1994; and ii) the post-reform years = 1995-1999. The maximum number of firm-year observations before the reform is 36, and 15 after the reform for each adjusted variable. The table reports for each empirical proxy the number of usable observations, the mean, and the median values before and after the sector regulatory reform (1995), and the t-stat and z-stat (Mann-Whitney non-parametric rank sum) as the test for significance of the change in mean and median values. Definitions of each variable as well as details on Colombia's power sector datasets and definitions can be found in Appendices 1 and 2 a = significant at 0.01; b = significant at 0.05; significant at 0.1; d = post-reform period = 1995–1996 due to availability of appropriate data.

tition. The 1994 regulatory reform implied more competition within the market in power generation and distribution. First, ownership composition changed drastically within the first five years after the regulatory reform, which has induced a balanced distribution of the power gen-

FIGURE 1.
THERMAL CAPACITY VS. GENERATION (GWH)



Notes en Figure 1: TGEN = thermal generation, ACAP = available capacity, ECAP = effective capacity.
Source: *Interconexión Eléctrica S.A* -ISA- (1998, 1999)

erating capacity between public and private utilities. By 1998 public utilities counted for 42% of the power generating capacity while private and mixed-capital utilities held a 58% share. The largest generator has a 21% market share.[12] This outcome contrasts with the initial divestiture in the UK where the CEGB was split into a duopoly for non-nuclear generation, and in Chile where the three largest power generators control 85% of the market.

On the power distribution side, privatized utilities dropped their final rates after 1995 and have converged to EPM's final-user rates. The relative rate for regulated users dropped from

[12] See Pombo (2001) for more details. The National Interconnected System was formed by 33 hydro centrals plus 63 thermal plants distributed among 26 power companies in 1998. EMGESA, the largest generator, was founded after the Bogotá Power Company divestiture. On the other hand, no single power generator can have more than ¼ of system's generating capacity (Law 143).

1.70 to 1.04 after the reform. If one takes into account the non-regulated electricity market, the drop must be even greater. Table 4 summarizes the main variables of the wholesale electricity market. Two facts are noteworthy. First, the evolution of electricity spot prices suggests that buyers—power distributors—have effectively hedged against pool price volatility. Real contract prices dropped 42% from 1996 to 2000. That outcome is important since contracts have a 75% market share in bulk electricity. Another important outcome is that market deregulation has sharply increased the number of non-regulated users, most of which are large industrial and commercial clients. In fact, the definition of "large customer" has changed over time. It began with a minimum individual consumption of 2.5 MW/month and has gradually decreased. The current level is at 0.1 MW/month, implying that non-regulated demand doubles during the analyzed period and accounts for 25% of today's commercial demand for electricity. There was an additional factor that contributed to narrowing gross and net utility profits. There was a sharp increase in financial costs during the first half of the 1990s. The four regional markets under study had on average a 90% real increase in their financial costs relative to the average of the 1980s. The Bogotá Power Company faced most of the indebtedness burden because of the over-costs generated by the five-year delay in the startup of the *Guavio* hydroelectric plant.

TABLE 4

MARKET EFFICIENCY VARIABLES - ANNUAL AVERAGES

Date	Mean Spot Price US$/KWh	Mean PPAs Price US$/KWh	Spot price Index Dic98 =100	PPAs price IndexDic98=100	Commercial Demand GWh	Non Regulated Demand GWh	Regulated Demand GWh	Non Regulated Demand Share	Non Regulated Users Number
1996	0.0084	0.0348	52.8	125.0	3,329.6	454.5	2,875.0	0.1365	11.2
1997	0.0548	0.0321	342.7	115.2	3,410.1	453.9	2,956.2	0.1336	95.3
1998	0.0374	0.0288	233.7	103.4	3,452.5	659.5	2,793.0	0.1910	678.8
1999	0.0159	0.0220	99.3	79.1	3,316.5	676.1	2,640.4	0.2038	891.6
2000	0.0204	0.0203	127.7	72.9	3,387.3	843.7	2,543.6	0.2489	2,377.0

Sources: *Interconexión Eléctrica S.A* (ISA) (1998, 1999) and *Mercado de Energía Mayorista (MEM)* requested files.
Notes on Table 4: This table shows the main variables of the wholesale electricity market. The spot price indicates the pool daily prices and the PPA or purchase power agreements are forward contracts of electricity prices and dispatched quantities. Both are market prices. Final residential and small commercial users, whose price formula is set by the regulatory commission, form the regulated demand. Non-regulated users are large clients who underwrite purchase contracts with power generators and distributors. The commercial demand is equal to the sum of the regulated and non-regulated demand. The last column reports the average of large clients that are registered in the electricity market for a given year. Prices per-kilowatt is in US$ at 1998 prices. Value series were deflated by US CPI. KWh = kilowatt per hour, GWh = gigawatts per hour = 1 million of kilowatts per hour.

4. PRODUCTIVE EFFICIENCY OF THERMAL PLANTS AND POWER DISTRIBUTION COMPANIES

The main result of the previous section was that the 1994 regulatory reform indeed induced power firms to achieve improvements in performance due to market competition and new market conditions, to put forth effort on the distribution side to pin down the non-technical power losses, and to undertake new investments in power generating capacity. This section presents the measurement of productive efficiency trough DEA methodology at plant-level for a sample of thermal electricity generation plants and distribution firms. Fifty-five thermal plants belonging to the interconnected system are the thermal park since 1995. But only 32 units have been active, showing a permanent or temporary production within a specific year. Because of changes in the statistical sources, the dataset has been divided in two samples. The first sample records about 33 thermal plants from 1988–1994—that is, the pre-reform years. The second one records 32 thermal units for the post-reform years (1995–2000).

The basic intuition that one must recall 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 one unit of a 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 one unit of output, we are able to say that the plant is inefficient to the best practice isoquant. *Data Envelope Analysis* (DEA) allows us to calculate a measure of plant technical efficiency. In particular, DEA uses a sequence of linear programs to construct a transformation frontier to compute efficiency measures relative to this reference technology. 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, which is a isoquant made up of 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, one says that is technically efficient. If the score is less than 1 then the plant is inefficient. For instance if plant B has a score 0.8 and plant A has a score of 1, then plant B is 20% inefficient relative to the production frontier. That is if plant B uses its inputs as plant A, then she would increase its output in 20%. The above measurement is called as *non-parametric input-oriented* efficiency scores.[13]

The measurement of the efficiency scores requires information of inputs and output for each thermal unit. Plant inputs are capital (or capacity in MW), labor (number of employees), and fuel consumption (coal, gas, fuel oil, and diesel oil). All fuels must have a common measure unit, such as BTUs or T-Calories.[14] Output is given in millions of KWh (GWh). Information for power generation, consumption by type of fuel and capacity at plant-level is available by crossing the different datasets before and after 1994.

Labor input is not directly observable for most units. There are two reasons for that problem. One is that before privatization thermal units were vertically integrated with power utilities, thus payroll series were recorded following accounting criteria. Power companies kept labor records to fulfill the requirements of financial reporting. Second, there was no regulator requesting information by power activity. Labor statistics after 1996 have improved sharply since the regulator (Superintendent of Domiciliary Public Services) has been in charge of the

---

13 The literature of DEA as well as their applications is extensive. The following references provide a good introduction and reviews on the topic: Coelli, *et al.* (1998) and Thanassoulis (2002).

14 BTUs stands for British thermal unit; the basic conversion factors are: 1 kWh = 3,412.1 BTUs; 1 GWh = 0.86 T-Calories; 1 MW of Capacity = 1,000 KWh.

SIVICO database. Labor series by power company are broken down by occupational categories, sectoral activities (i.e. generation, transmission, and distribution), and by type of power generation. In addition, after privatization the plants that were sold became new utilities. This allowed for making direct inferences of labor input (number of employees) by thermal substations. Fixed coefficients of labor to capacity were assumed based on the information sent by power generators in order to complete labor series before 1995.[15]

Table 5 displays the results of the efficiency frontier measurement exercise on 42 thermal plants that were active as marginal producers before and after the 1995 regulatory reform. The first three columns depict the plant name, startup year and plant capacity in megawatts (MW). All thermal units before the reform belonged to one out of the five electric holdings in the country as described in section 2. The fourth column indicates the ownership status by the year 2000, that is if whether the thermal unit belong to a public, private or a mixed-capital electric utility. The next four columns describe the efficiency scores before and after the 1994 reform. The table presents two types of scores. The first one is the variable SCORE that uses MW of capacity as total capital input. The second one the variable SCORE1, which capacity is adjusted by its effective utilization and this is the definition of capital input used in these estimations. The reason to perform such adjustment is that most thermal units are marginal producers. The base system in Colombia is hydro. The efficiency measures are under constant return to scale assumption, that is the value of total output is equal total input spending and therefore the sum of inputs weights is equal to 1.[16]

The exercise provides empirical evidence regarding the post-effects of the 1994 regulatory reform for power generation. First, entry in new generating capacity took place since 1993. One must recall that Colombia was in a middle of rationing power schedule and the government undertook an emergency plan. Among the several measures one was the overhaul of the largest thermal plants in the country. The reform, as mentioned, provided incentives to expand the power generating capacity in thermal generation. The new plants that entered in the system are in bold in the table. One sees that they are among the most efficient. Their efficiency score is greater that 0.8 once capital-input is corrected by capacity utilization. The second implication is that the most efficient plants before the reform are no longer after the reform. Nonetheless, this result is smoothed if one contrasts the adjusted scores by capacity that is the SCORE1 variable. Because entrants are pushing plant efficiency meaning that they are in the production frontier.

Changes in technical efficiency are measured by a downward shift on an isoquant. In this sense, the measurements show that the best practice frontier has moved after the reform. If there were no the case one would expect no change in plant efficiency between periods. Thus, this shift in the efficiency frontier imply an efficiency gain due to entry and new gas-based and combined-cycle technologies. Entrants are more efficient relative to incumbent plants and became benchmark technologies. Therefore, there is a positive evidence in support that overall thermal generation was able decrease the input to output ratios.

---

15 Appendix 2 describes the methodology and the contents of the power sector databases. The request for labor series was made through the Colombian Power Generator Association (ACOLGEN). SIVICO stands for *Sistema de Vigilancia y Control*.

16 The classical applications of DEA are under CRTS, because it is assumed that plants are operating at an optimal scale. In other words, average productivity is independent of output scale.

4.1 Efficiency measurement in power distribution

The productive efficiency in power distribution companies completes the measurement exercise. Along with the assessment for thermal plants efficiency, both exercises offers a comprehensive analysis of plant efficiency changes due to the new regulation. Efficiency measurement for power distribution through non-parametric linear programming DEA is not as straightforward than power generation, regarding definitions of what really constitutes an input or output variables. There are several studies on efficiency and performance in energy distribution systems. Filippini &Wild (2001), estimate econometrically cost functions for electricity distribution in Switzerland. Hjalmarsson & Veiderpass (1992) use DEA technique to estimate Malmquist index measures of productivity growth. Miliotis (1992), Bagdadioglu, Waddams & Weyman (1996), and Pacudan & Guzman (2002) perform DEA analysis to asses effects of policy and ownership in efficiency for Greece, Turkey and Philippines respectively.

Looking for an appropriate definition of a DEA model for power distribution we have classified the variables into inputs, outputs and environmental. The dual classification input/output/environmental of some variables comes along with a suitable characterization of the *decision-making-unit* (DMU) functions, if we take transformers and distribution power lines network simply as inputs, they are variables "under" control of the utility or the DMU which is the proper name in DEA literature. Nonetheless, the decision of input demand are endogenous to environmental variables such as: extension, topography, population density, urban migration where all together will determine for instance DMU's new investments in power lines network, substations and transformers.

Several definitions of a proper DEA model for electricity distribution can be formulated, ranging from the whole consideration of inputs/outputs/environmental variables of Table 6, to simply define as input the number of employees and output the number of customers, leaving the remaining variables aside or out of control of the DMU (environmental variables). Thanassoulis (2001) discusses the selection of variables and the definition of the input/output/environmental. In particular, he stresses that there must be some prior knowledge regarding DMU's operational characteristics, with the purpose of put a weight and rank variables by their importance into the efficiency scores measures. DEA itself imposes a constraint in the formulation of a final model where multiple inputs and outputs can bring most of the DMU's into the frontier leaving few for efficiency evaluation. Therefore, adopting a restricted model for efficiency assessment reduces the trade-off between relative efficiency and number of inputs. Table 6 depicts the study restricted-model for a given power distribution utility input/output/environmental variables.

The dataset collects information of 12 power distribution companies that belonged to the five electric systems in the country that cover the larger 15 urban cities in the country.[17] Ten utilities were power distributors before the 1994 reform and still as regional power distribution companies. The reminder two companies are vertically integrated utilities in power generation

[17] See appendix 2 for details on the data sources and utility names.

TABLE 5
THERMAL PLANTS DEA EFFICIENCY SCORES

DMU	Plant Name	Plant Startup	Cap MW	Owner ship	Score before	Score after	Score1 before	Score1 after	Relative Effic.	Relative Effic.1
1	Barranca 1	1982	13	Public	0.7859	0.5932	0.7859	0.7939	-	+
2	Barranca 2	1982	13	Public	0.7203	0.5932	0.7448	0.7702	-	+
3	Barranca 3	1972	66	Public	0.8798	0.6404	0.8798	0.8211	-	-
4	Barranca 4	1983	32	Public	0.6625	0.6118	0.6625	0.8110	-	+
5	Barranca 5	1983	21	Public	0.7023	0.6176	0.7023	0.8217	-	+
6	Bquilla 1	1980	58	Public	0.9211	.	0.9139	.		
7	Bquilla 3	1980	66	Private	1.0000	0.6624	1.0000	0.7156	-	+
8	Bquilla 4	1980	69	Private	0.9699	0.7439	0.9803	1.0000	-	+
9	Cartagena 1	1980	66	Private	0.8677	0.6428	1.0000	0.7447	-	-
10	Cartagena 2	1980	54	Private	0.7932	0.6515	0.7437	0.8274	-	+
11	Cartagena 3	1980	67	Private	0.8712	0.6815	0.8603	0.8245	-	-
12	Chinu 4	1982	14	Public	0.4242	.	0.7097	.		
13	Cospique 1	1960	4	Public	0.9086	.	1.0000	.		
14	Cospique 2	1960	4	Public	0.7277	.	1.0000	.		
15	Cospique 3	1967	8	Public	1.0000	.	0.9722	.		
16	Cospique 4	1966	9	Public	1.0000	.	0.7791	.		
17	Cospique 5	1965	12	Public	0.4487	.	0.8584	.		
18	Flores 1	**1993**	152	Private	0.9881	1.0000	0.9881	1.0000	+	+
19	Guajira 1	1987	160	Public	1.0000	0.8563	1.0000	0.7743	-	-
20	Guajira 2	1987	160	Public	1.0000	0.8374	1.0000	0.8915	-	-
21	Paipa 1	1963	31	Public	0.4048	0.4977	0.3208	0.8859	+	+
22	Paipa 2	1975	74	Public	0.7307	0.3794	0.4755	0.7891	-	+
23	Paipa 3	1978	74	Public	0.6331	0.4154	0.3874	0.7735	-	+
24	Palenque 3-4	1972	15	Public	0.8780	0.4586	1.0000	0.8011	-	-
25	Palenque 5	1985	21	Public	0.6706	.	0.6706	.	.	.
26	Proeléctrica 1	**1993**	46	Private	**0.9993**	**0.9695**	**0.9993**	**0.8857**	-	-
27	Proeléctrica 2	**1993**	46	Private	**1.0000**	**0.9695**	**1.0000**	**0.9654**	-	-
28	Tasajeo	1985	163	Private	1.000	0.6755	1.0000	0.8241	-	-
29	Tibú 1	1965	6	Public	0.1669	.	0.3157			
30	Tibú 2	1965	6	Public	0.1632	.	0.8026			
31	Zipa 2-3	1976	104	Mixed	0.4904	0.8888	0.4213	0.6721	+	+
32	ZIPA 3	1976	66	Mixed	.	0.2235	.	0.8021	.	.
33	Zipa 4	1981	66	Mixed	0.4626	0.1879	0.4601	0.6797	-	+
34	Zipa 5	1985	66	Mixed	0.2692	0.3213	0.3042	0.8655	+	+
35	Flores 2	**1996**	100	Private	.	**0.9199**	.	**0.9205**		
36	Flores 3	**1998**	152	Private	.	**1.0000**	.	**1.0000**		
37	Merilectrica	**1998**	157	Private	.	**0.7887**	.	**0.9273**		
38	Tebsa B1	**1998**	768	Private	.	**1.0000**	.	**0.9141**		
39	Termocentro 1	**1997**	99	Public	.	**0.9160**	.	**1.0000**		
40	Dorada 1	**1997**	52	Public	.	**0.2554**	.	**0.8010**		
41	Sierra 1	**1998**	150	Public	.	**0.1442**	.	**0.8564**		
42	Termovalle 1	**1998**	214	Private	.	**0.8237**	.	**0.8858**		
						Total Decrease (plants)			**19**	**12**
						Share Capacity			**35.3%**	**24.6%**

Sources: Own estimations based on EMS 1.3 software written by Scheel (2000).

Notes on Table 5: All thermal units before the reform belonged to one out of the five electric holdings in the country as described in section 2. The fourth column indicates the ownership status by the year 2000, that is if whether the thermal unit belong to a public, private or a mixed-capital electric utility. The next four columns describe the efficiency scores before and after the 1994 reform. The table presents two types of scores. The first one is the variable SCORE

Notes on Table 5 (cont.)

scores before and after the 1994 reform. The table presents two types of scores. The first one is the variable SCORE that uses MW of capacity as total capital input. The second one the variable SCORE1, which capacity is adjusted by its effective utilization and this is the definition of capital input used in these estimations. The reason to perform such adjustment is that most thermal units are marginal producers. In Colombia the base system is hydro. The efficiency measures are under constant return to scale assumption, that is the value of total output is equal total input spending and therefore the sum of inputs weights is equal to 1. DMU = Decision-making unit; Input1: Capacity in MW; Input2: Labor in Number of Employees; Input3: Fuels, standardized in T-Calories; Output = electricity generation in gigawatts. Periods: Before Reform 1988–1994; After Reform: 1995–2000; Input-Output variables are annual averages.

and distribution. On the other hand, three of these com=panies have privatized their distribution network as explained in section 2.[18]

TABLE 6
RESTRICTED-MODEL FOR DEA ESTIMATIONS IN POWER DISTRIBUTION

	Input	Output
Discretionary variable	Employees distribution commercialization Transformers Power Lines	Total Sales (GWh) Total Customers
Environmental	Regional Real GDP per.capita National installed capacity in electricity generation	Urban area served

Table 7 summarizes the results of the efficiency scores of the chosen restricted-model. It also decomposes technical inefficiency into plant Variable Return to Scale (VRTS) and Scale Efficiency (SE). One must recall that the expected technology in power distribution is a fixed coefficient constant return to scale (CRTS) according to the traditional peak-load model (Steiner 1957). However, this decomposition arises when one suspects that firms are not operating at an optimal scale due to power transmission, financial or other market constraints.[19] In particular, it can be shown that

Technical Efficiency (CRTS) = [Pure Technical Efficiency (VRTS) x *Scale Efficiency]* (1)

where scale efficiency < 1.

Table 7 highlights the efficiency scores across power distributors. Under the assumption of CRTS we show that six out of the twelve electricity distribution firms are totally efficient for our time span. The lowest efficiency score correspond 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 getting internal scale economies by means of a increase in sales,

[18] One must recall that the 1994 reform did not mandate to divest between generation and distribution. What the reform forbids is for new enterprises to have two or more power activities, and no one must have investments in power transmission. The integrated utilities are Public Enterprises of Medellín (EPM), and Caldas Hydro Company (CHEC). Regarding Bogotá Power Company (EEB) the dataset was chained keeping the pre-reform stricture to make compatible the time series. On the other hand, the privatized distribution networks are represented for ELECTROCOSTA and ELECTRICARIBE, utilities that arose from the divestiture of CORELCA holding, and CODENSA that as explained in section 2 arose from the divestiture of EEB. For a complete description of the power sector in Colombia before the 1994 reform is in Pombo (2001).

[19] This decomposition is originally due to Banker, Charnes and Cooper (1984).

customers or in area served. Two utilities present serious inefficiencies in power distribution according to the scale efficiency component [CEDELCA (68.4) and Huila (86%)]. Moreover their efficiency scores worsened after the reform. These utilities show on average permanent financial and operating over-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.[20]

The next section turns to modeling efficiency and profitability as functions of plant characteristics, ownership structure, and regulatory policy variables for the former IFI firms and the sample of thermal plants, with the purpose of shedding light on the determinants of those performance variables.

TABLE 7

DEA EFFICIENCY SCORES - POWER DISTRIBUTION COMPANIES

DMU	1986-1987	1988-1989	1990-1991	1992-1993	1994-1995	1996-1997	1998-1999	2000-2001
Constant Returns to Scale								
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	069	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: Own calculations based on FEN-SIVICO datasets.

20 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. On the other hand the pool's administrator has penalized with stopping or rationing

5. THERMAL POWER PLANTS: STATISTICAL ANALYSIS OF EFFICIENCY SCORES

This section reports the results of an econometric analysis of thermal power plant DEA efficiency scores. The exercise follows a limited dependent variable model because the dependent variable under analysis is censored by construction. It takes positive values and is bounded at 1.00; thus, the efficient plants will record an efficiency score $-y_{it}-$ of one. Otherwise, $0 \leq y_{it} < 1$. The sample might also be truncated because there is knowledge of independent variables if only y_{it} is observed. This is particularly important for marginal power producers when the thermal plants are shut down by maintenance, transmission, and generation constraints because there is no power dispatch.

The baseline censored-model follows a linear specification:

$$y_{it} = \begin{cases} \mathbf{x'_{it}B} + e_{it} & 0 < y_{it} \leq 1 \\ 0 & otherwise \end{cases} \tag{2}$$

and the residuals are I.I.D following a normal distribution with zero mean and constant variance.

Equation (2) models efficiency scores as a function of plant characteristics, ownership structure, and regulatory related policy dummies. Plant characteristics include plant age, capital-labor ratio, technology type, and load factor. Controlling for the load factor indicates how marginal a given producer is.[21] A dummy that takes the value of 1 for all private plants captures ownership. The regulatory dummy tries to capture the effect of large customer definition. Thus, for each plant that dummy takes a value of one after 1998 (when the lower limit for large clients was set in 0.5 MW/month, which implied a jump from 100 to 900 non-regulated users on average). The dataset includes all observed records from each one of the 33 active thermal plants during the 1995-2000 period. Therefore, the dataset is an unbalanced panel with 166 observations.

Table 8 displays the *Tobit* regressions. The dependent variable in the first two equations is SCORE1, which represent plant efficiency scores measured under the assumptions of constant return to scale (CRTS), convex technology and plant generating capacity or capital input is adjusted by its effective utilization. This adjustment normalizes plant capacity by load factor, which means that all producers are treated as if they were off-peak generators. The dependent variable of the third equation is SCORE2 by which the measure of plant efficiency relaxes the assumption of CRTS. The reading of those results is as follows. First, the equations exhibit

---

power delivery to distributors since 2000 because of their contract indebtedness with power generators. such as CHEC with power generators since 2000. The last important transaction in the sector was EPM's purchase of CHEC. We do not present further analysis of the financial situation of the regional power distributors because it need more research and it is beyond the scope of this paper.

21 The definition of load factor for this exercise is: $LF = \frac{GWh}{K*(365*24)/1000} = \frac{GWh}{K*8.76}$

high quality of fit reported by the R^2 of the OLS regressions.[22] In particular, the overall effect of the plant characteristics, ownership structure, and regulatory policy dummy explain 90% of

TABLE 8
THERMAL PLANTS EFFICIENCY SCORES DETERMINANTS

	Eq 1 Pooled Tobit	Eq 2 Pooled Tobit	Eq 3 Pooled Tobit
	Dependent Variables		
Independent Variables	Score 1	Score 1	Score 2
Ajusted Capacity	-0.0004[c]		
	(0.0002)		
Age	-0.0155[a]	-0.0175[a]	-0.0183[a]
	(0.0018)	(0.0018)	(0.0029)
Age-scuared	0.0004[a]	0.0005[a]	0.0005[a]
	(6E-04)	(6E-05)	(9.5E-05)
Load Factor	0.4169[a]	0.3700[a]	0.1128[a]
	(0.0445)	(0.031)	(0.0428)
Load Factor-squared	-5.1005[a]	-4.5298[a]	
	(1.207)	(1.125)	
Capital-Labor ratio	0.0010		
	(0.0006)		
Dummy Gas	0.3653[a]	0.3704[a]	0.3960[a]
	(0.0118)	(0.0122)	(0.0196)
Dummy Combine Cycle	0.1431		
	(0.0923)		
Dummy Private Ownership	0.0323[a]		
	(0.0116)		
Dummy Public Ownership		-0.0423[a]	
		(0.0117)	
Dummy Regulatory Policy	0.0201[c]	0.0229[b]	0.0432[b]
	(0.0108)	(0.0112)	(0.1762)
Constant	0.4098[a]	0.4593[a]	0.5020[a]
	(0.0206)	(0.0208)	(0.0315)
Sigma	0.0660	0.0691	0.1122
Regression Statistics			
R2-OLS	0.9104	0.9074	0.775
Uncensored Obs	155	156	152
Censored Obs	7	10	14
LR-Chi(k-1)	377.3	379.5	228.9
	[0.0000]	[0.0000]	[0.0000]
Tests Residuals			
Cook-Weisberg - OLS	0.00	0.04	2.46
	[0.9924]	[0.8445]	[0.1168]
Breuch Pagan - OLS	6.87		
	[0.4416]		
Ramsey-RESET - OLS	1.83	0.59	0.28
	[0.1439]	[0.6225]	[0.8391]
Swilk - OLS	4.99	4.67	3.35
	[0.0000]	[0.0000]	[0.0004]

Notes on Table 8: This table reports results from TOBIT regressions for an unbalanced panel of 33 thermal plants for the 1995-2000 period. The total number of observations is 166. The dependent variables are: (1) SCORE1 -plant efficiency scores measured under the assumptions of constant return to scale (CRTS), convex technology and capital input is adjusted by its effective utilization, and (2) SCORE2 -plant efficiency scores measured under the assumptions

[22] In general, the variables included in the Tobit regressions are robust. Residuals are homoskedastic according to the reported OLS tests. The residuals are not normal, which is associated with the distribution Kurtosis. The distribution of the residuals is symmetric.

Notes on Table 8 (cont.)

of variable return to scale (VRTS), convex technology and capital input is adjusted by its effective utilization. The independent variables are: (1) plant generating capacity in (MW) adjusted by utilization rates, (2) plant age, (3) plant age squared, (4) load factor, (5) the squared of load factor, (6) plant capital-labor ratio, (7) gas technology - a dummy that takes the value of one if plant technology is gas based and zero otherwise, (8) combined cycle - a dummy that takes the value of one if plant technology is gas based and zero otherwise, (9) private - a dummy that takes the value of one if plant is privately owned and zero otherwise, (10) public - a dummy that takes the value of one if plant is publicly owned and zero otherwise, and (11) regulation - a dummy that takes the value of one for the years that the definition of a large client was set to a minimum consumption of 0.5 MW per month.
Standard errors appear in parentheses, and p-values in square brackets.
a = Significant at 0.01; b = significant at 0.05; c = significant at 0.1.

the efficiency scores once capital input is adjusted by capacity utilization, and explains 78% when the assumption of constant returns to scale is relaxed. Second, dummy variables for technology are robust and statistically significant in all equations. This implies that new gas-based technologies improve system efficiency, since they save on fuel consumption. Entrants played a central role in this particular issue. Third, the load factor is positively related, meaning that there is an effective reduction in the power losses associated with the frequent and costly plant start-ups. However, the square of the variable is negatively related, showing that there are decreasing returns to scale at full plant capacity.

Fourth, plant age is negatively related, meaning that older plants lose relative efficiency. Nonetheless, there are positive learning effects that partially offset plant aging, given the behavior of the square of the age variable. For instance, the accumulated efficiency loss after 10 years is 17%, but the learning effect represents a 4.5% efficiency gain. Fifth, regulatory policy has had positive effects. The regression coefficients indicate on avreage ot the three equations an overall efficiency gain of 2.8%. Sixth, the exercise is not conclusive regarding if there are structural differences in productive efficiency due to ownership. The private ownership dummy turned out not to be significant once capital input was corrected for capacity utilization and the assumption of CRTS was relaxed (Eq. 3). This result is in line with other studies. The study of Pollit (1995) reports statistically insignificant regression coefficients for his ownership dummy. Those regressions are based on a cross-sectional dataset of 768 thermal power plants for 14 countries.

6. Conclusions

The performance and efficiency analysis of the power sector yielded important outcomes after the 1994 sectoral reform. The general trends of electricity contract prices, the evolution of plant entry in thermal generation, and the increasing share of non-regulated users in commercial demand suggest that the regulatory reform has been effective in promoting market competition and system efficiency. The performance analysis shows as in the case of IFI firms that the 1994 regulatory reform and the privatization program had on one side a positive impact on electric utilities efficiency, but on the other a negative impact on profitability.

The sources of efficiency gains are explained by market competition in power generation, the reduction of the non-technical power losses in distribution, and the new investment in thermal capacity in gas-based technologies. The measurement of efficiency scores by thermal units reinforces the evidence in favor of the existence of an overall gain in system efficiency and reliability. In contrast, the results of efficiency trends across power distributors are not conclusive. The reform 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. Financial, managerial and demand constraints seems to be the sources the inability of getting an overall efficiency gain through an industry catching up effect in power distribution. Hence, disentangle the above elements needs further research.

Regulatory policy has had positive effects on plant efficiency based on the econometric results. The increasing number of non-regulated users has led generators to offer more competitive prices in order to ensure generation on contract bases. Consistent with other studies we found no evidence of positive impact in efficiency due to private ownership of electric utilities. Instead, regulation and market reform pin down the positive change in technical efficiency across thermal units.

On the other hand, the results of the reform on utilities' profitability are opposite to the expected direction. This outcome is partially explained by industry regulatory reform that introduced market competition in generation. This implied to utilities to face a price cap or an upper limit that limited their capacity to get extra-profits through power generation. In fact, the wholesale electricity market in Colombia is one of the most competitive given the number of power generators relative to the in the market size. Two additional facts were pointed out. First, power holdings faced financial over costs due to the increase in their external debt service and delays in startup in some hydro units at the beginning of the 90s. Second, power distributors have decreased real tariffs to final users. This is a consequence of the existence of a non-regulated market that has introduced competition in the market of forward contracts.

REFERENCES

Armstrong, M., S. Cowan, et al. (1997). Regulatory Reform: Economic Analysis and British Experience. Cambridge, Massachusetts, MIT Press.

Bagdadioglu, N., C. Waddams, et al. (1996). "Efficiency and Ownership in Electricity Distribution: A Non-Parametric Model of the Turkish Experience." *Energy Economics* **18**: 1-23

Banker, R., A. Charnes, et al. (1984). "Some Models for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis." Management Science **30**: 1078-1092.

Charnes, A., W. Cooper, et al. (1978). "Measuring the efficiency of decision making units." European Journal of Operational Research **2**: 429-444.

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

Estanche, A. and M. Rodriguez-Pardina (1998). Light and Lightning at the End of the Public Tunnel: The Reform of the Electricity Sector in the Southern Cone. Policy Research Working Papers - World Bank**:** 22

Filippini, M., J. Wild, et al. (2001). Scale and Cost Efficiency in the Swiss Electricity Distribution Industry: Evidence from a Frontier Cost Approach. Centre for Energy Policy and Economics -CEPE- Working Paper.

Guash, J. and P. Spiller (1999). Managing the Regulatory Process: Designs, Concept, Issues, and the Latin American Story. Washington, The World Bank.

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

Interconexión Eléctrica S.A. (ISA). 1998, 1999. Informes de gestión. On CD. Medellín, Colombia.

La Porta, R. and F. López-de-Silanes (1999). "The Benefits of Privatization: Evidence from Mexico." Quarterly Journal of Economics **114**(4): 1193-1242.

Megginson, W., R. Nash, et al. (1994). "The Financial and Operating Performance of Newly Privatized Firms: An International Empirical Analysis." The Journal of Finance **49**(2): 403-451.

Mendoça A., and C. Dahl, (1999) 'The Brazilian Electrical System Reform' Energy Policy **27**: 73-83

Miliotis, P. (1992). "Data Envelopment Analysis Applied to Electricity Distribution Districts." Journal of Operational Research Society **43**(5): 549-555.

Ministerio de Minas y Energía (MME). 1993, 1994, 1996, 1998. Memorias al Congreso Nacional. Bogotá, Colombia: Imprenta Nacional.

Newbery, D. (2000). Privatization, Restructuring, and Regulation of Network Utilities. Cambridge, MIT Press.

Pacudan, R. and E. de Guzman (2002). "Impact of Energy Efficiency Policy to Productive Efficiency of Electricity Distribution Industry in the Philippines." Energy Economics **24**: 41-54.

Pollit, M. (1995). Ownership and Performance in Electric Utilities: The International Evidence on Privatization and Efficiency. Oxford, Oxford University Press.

Pombo, C (2001) "Regulatory reform in Colombia´s electric utilities", Quarterly Review of Economics and Finance **41**: 683-711

Pombo, C. and M. Ramírez (2002). Privatization in Colombia: A Plant Performance Analysis. Borradores de Investigación - Facultad de Economía - Universidad del Rosario**:** 53.

Scheel, H. 2000. EMS: Efficiency Measurement System User's Manual. Available at http://www.wiso.uni-dortmund.de/lsfg/or/scheel/ems/.

Thanassoulis, E. (2001). Introduction to the Theory and Application of Data Envelopment Analysis. Norwell, Kluwer Academic Press.

World Bank. (1991). "Colombia: The Power Sector and the World Bank 1970–1987" In: Evaluación del Sector Eléctrico Colombiano. Bogotá, Colombia: Ministerio de Minas.

APPENDIX 1. THE PERFORMANCE INDICATORS

Variable	Description
Cost per unit	The ratio of cost of sales to net sales. Cost of sales is equal to the direct expenses involved in the production of a good. This includes raw materials expenditures plus the compensation paid to blue-collar workers. Sales are equal to the total value of products and services sold nationally and internationally.
Log (Sales/employees)	The log of the ratio of sales to total number of employees. Sales are equal to the total value of products and services sold nationally and internationally. Employees correspond to the total number of paid workers who depend directly on the company.
Log (Sales / PPE)	The log of the ratio of sales to property, plant and equipment. Sales are equal to the total value of products and services sold nationally and internationally. Property, plant and equipment is equal to the value of utility's fixed assets adjusted for inflation
Operating income / Sales	The ratio of operating income to sales. Operating income is equal to sales minus cost of sales and minus depreciation. Sales are equal to the total value of products and services sold nationally and internationally.
Net income / Sales	The ratio of net income to sales. Net income is equal to operating income minus interest expenses and net taxes paid. Sales are equal value of products and services sold domestically and internationally
Operating income / PPE	The ratio of operating income to PPE. Operating income is equal to sales minus cost of sales and minus depreciation. Property, plant and equipment (PPE) is equal to the value of utility's fixed assets adjusted for inflation.
Operating income / employees	The ratio of operating income to employees. Operating income is equal to sales minus cost of sales and minus depreciation. Employees correspond to he total number of workers who depend directly on the company
Log (Employees)	The log of total number of employees. Employees correspond to he total number of workers who depend directly on the company.
Log (PPE)	The log of property, plan and equipment. PPE is equal to the value of utility's fixed assets adjusted for inflation.
Investment/sales	The ratio of investment to sales. Investment is equal to the value of expenditure to acquire capital assets. Sales are equal value of products and services sold domestically and internationally.
Investment / employees	The ratio of investment to employees. Investment is equal to the value of expenditure to acquire capital assets. Employees correspond to he total number of workers who depend directly on the company
Log (PPE/employees)	The log of PPE to total employees. PPE is equal to the value of utility's fixed assets adjusted for inflation. Employees correspond to he total number of workers who depend directly on the company
Log (Sales)	The log of sales. Sales are equal value of products and services sold domestically and internationally

APPENDIX 2. 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

THE POWER SECTOR DATASETS

At present, the 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

TABLE A2.1

COLOMBIA – POWER SECTOR STATISTICS – DESCRIPTION OF THE DATASETS

DATA SOURCES	CONTENTS
ISA Reports (1995-1999)	Operative Reports of the National Interconnected System - Hydrology - Grid Constraints - Generation - Demand - Available effective capacity The Electricity Spot Market Report - Pool's prices and contacts - Total traded amount (GWh) - Pool's marginal supply prices by type of generation
SIVICO 1997-1999 Source: SSPD	The following data are available by utility level: 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 and indebtedness indicators
SIEE 1970-1998 Source: OLADE	The Energy and Economic Information System is a dataset covering the Latin American economies' energy-related statistics. The SIEE sections are: - Prices - Demand and supply - Energy-related equipment - Environmental impact - Economic + energy indicators - World-wide energy statistics
FEN 1983-1994 Source: FEN	The power sector historical financial data compiled by the Financiera Electrica Nacional (FEN). 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 Source: MME	The power sector national system is a comprehensive database. The data are available by utility and regional market. The SINSE chapters are - Energy balances - Generation and electricity demand - Number and type of subcribers - Average tariffs by users

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.

Besides the above datasets there were direct requests to ISA for the monthly indicators of the Mercado de Energia Mayorista (MEM) starting in July 1995, and the Thermal Park Dataset. The crossing of information among ISA's thermal park dataset, SIVICO, and SINSE allowed us to collect the input-output variables by thermal unit that are depicted in Table A4.2.

In order to make direct inferences of labor input by plant *after* 1996, a survey was carried out among the members of the Colombian Generators Association (ACOLGEN). The collected information allowed for distinguishing benchmarks of capacity-labor ratios, which under normal assumptions of putty-clay technology that coefficient to be turns out a constant parameter. The data provided by the power utilities along with SIVICO allowed us to identify the number of employees by thermal plants for the period 1996–1999 given the reported capacity per unit.

TABLE A2.2

THERMAL PLANTS - INPUT AND OUTPUT VARIABLES

Sample	Variables
1988-1994	Generation (GWh)
	Gross Capacity (MW)
	Net Capacity (MW)
	Coal (tons)
	Fuel Oil (gls)
	Diesel Oil (gls)
	Gas (ft3)
1995-1999	Generation (GWh)
	Effective Capacity (MW)
	Labor (Number of employees)*
	Heat Rate

Sources: SINSE, ISA, SIVICO

Notes: * Since 1996. Labor information is recorded by power utility and industry activity: generation, transmission and distribution (SIVICO).

The estimated benchmark labor to capacity ratios by occupational category for a base-technology thermal plant were:

0.036597 (Directives); 0.151852 (Administrative), and 0.527731(Operative)

For the 1988–1994 period the FEN books recorded some physical variables per power utility, among them the permanent employment series. Thus, the inference of labor series by the thermal units followed a constant distributing capacity assumption, that is:

Thermal Unit Labor (L_1) = (Max Theoretical Thermal Plant Unit Capacity (GWh) / Utility Available Capacity (GWh)) * Total Permanent Utility Employees

Other formulas were used in order to generate alternative labor series by thermal plants. One was based on power generation:

Thermal Unit Labor (L_2) = (Thermal Plant Generation (GWh) / Utility Available Capacity in GWh) * Total Permanent Utility Employees

Then an adjusted L_2 series was generated under the assumption:

$$(\frac{L}{MW})_{Thermal} = (\frac{L}{MW})_{Hydro} /(1+x) \text{; where: } x = avg\frac{MgP_{hydro}}{MgP_{thermal}} \text{; and}$$

Rationing Price: $MgP_{hydro} > MgP_{thermal} = 1.8$;

Without Rationing: $MgP_{hydro} < MgP_{thermal} = 0.6$

The above coefficients are observed parameters. L_1 and L_2 were used as the labor input series in the estimation of plant efficiency scores.