The Performance of Privatized Utilities: Evidence from Latin America

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Abstract

This article analyzes the relative performance of recently privatized Latin American electricity distribution utilities. Empirical results show that privatized firms are more efficient in their use of labor and have higher labor productivity growth rates than public or cooperative companies. There is also evidence of increasing returns to scale.

JEL Classification: L94, O30.

Key Words: Ownership, Efficiency, Technical Change, Input Requirement Function.

I. Introduction

The Latin American electricity market has undergone a major transformation over the past 20 years. Reform in the region started in Chile, with the privatization of major electric utilities between 1986 and 1989. Argentina followed Chile's example in 1992; shortly thereafter Bolivia, Colombia, and Peru followed suit. During the second half of the 1990s, Panama, El Salvador, Guatemala, Nicaragua, Costa Rica, Honduras, and Brazil also adopted reforms. The main missing players in the process of transforming the electricity sectors have been Ecuador, Mexico, Paraguay, Uruguay, and Venezuela, although Ecuador, Mexico, and Venezuela recently initiated actions toward restructuring.

Reformers in the region have recognized that generation, transmission, and distribution each have different economic characteristics.[1] Generation is recognized as the one part of the chain where there are no significant economies or diseconomies of scale, while transmission and distribution are considered natural monopolies. The reforms entailed unbundling electricity generation, transmission, and distribution, and resulted in generally competitive generation markets, and maintained monopolies for transmission and distribution.[2] Whenever possible, reformers also broke up horizontally the former national distribution companies into several regional monopolies to reduce the strength of the residual monopolies.

Regional monopolies in distribution activities were generally auctioned to private operators and are subject to price and quality regulation. In most countries the reforms were associated with

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[1] In all countries of the region, except Colombia, the network and retail businesses are bundled with the distribution activities and only large consumers are free to buy energy from sources other than distributors.

[2] To reduce market power, restrictions on cross-ownership among different categories of companies were introduced in most countries in the region. For more about the reforms, see Dussan (1996); Rudnick (1998); Fischer and Serra (2000); Millan, Lora, and Micco (2001); Rudnick and Zolezzi (2001).

the adoption of incentive-based regulatory regimes.[3] As part of this incentive-based regulatory framework, most countries are planning to introduce some form of yardstick competition to stimulate efficiency of regional monopolies.[4]

Horizontal separation of distribution national monopolies into geographical monopolies can represent a loss in terms of economies of scale, which add to the increases in transaction costs and possible losses of economies of scale and scope due to the vertical separation of the generation, transmission, and distribution activities. The idea of the reformers was that these increases in transaction costs and possible losses of economies of scale and scope may be compensated by a greater efficiency induced by the introduction of private ownership, competition in generation, and yardstick competition in distribution. The result of this trade-off has to be solved empirically.

Many authors studying the impact of the reforms in the region document an increase in labor productivity in all the countries where restructuring and privatization has taken place (see Rudnick 1998; Fischer and Serra 2000; Rudnick and Zolezzi 2001). However, the results of these works rely on partial productivity ratios. In this paper I provide additional empirical evidence by using a more comprehensive labor requirement function approach to examine whether ownership or organization of the distribution companies has any systematic impact on labor productivity and technical change in Latin American during the period 1994-2001.

The paper also contributes to the empirical literature that links ownership and performance in electricity distribution (see Meyer 1975; Neuberg 1977; Veiderpass 1992; Hjalmarsson and

[3] Under incentive regulation the distribution company is the residual claimant on cost reductions giving powerful incentives to control costs (see Crew and Kleindorfer 1986; Laffont and Tirole 1993; Armstrong, Cowan, and Vickers 1994; Sappington 1994).

[4] Yardstick competition is a way of inducing competition by tying the reward a firm receives to its performance relative to comparable firms (Shleifer 1985).

Veiderpass 1992a, 1992b; Hougaard 1994; Pollitt 1995; Bagdadioglu et al. 1996; Kumbhakar and Hjalmarsson 1998).

II. Model Specification of Electricity Distribution

As observed by Kumbhakar and Hjalmarsson (1998), while productivity in electricity generation is to a large extent determined by technology, productivity in distribution is mainly determined by management and efficient labor use. Accordingly, this paper focuses on labor productivity. The concept of efficiency used here is labor use efficiency, according to which a firm is inefficient if, *ceteris paribus*, it uses more labor to produce a given bundle of outputs than an otherwise efficient firm would.

The electricity distribution model includes one endogenous input (the number of employees); three exogenous outputs (the number of final customers, the total energy supplied to final customers, and the service area); two exogenous inputs (transformer capacity and kilometers of distribution network); and two environmental or control variables (residential sales' share and GNP per capita).[5]

Because a finer disaggregation was not available, I use the number of employees as the measure of labor input. Ideally, labor input should be divided into various categories (unskilled labor, skilled labor, management). As Coelli et al. (2002) note, measuring labor in a single aggregate variable implicitly assumes uniform skills distributions across firms. This is usually a reasonable assumption within one country, but it could be problematic in cross-country

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[5] Jamasb and Pollitt (2001) review the frequency with which different input and output variables are used to model electricity distribution. They find that the most frequently used outputs are units of energy delivered, number of customers, and the size of the service area; the most widely used physical inputs are number of employees, transformer capacity, and network length. Some studies have used operating and capital costs as input variables. However, these data are not always available, and when they are, differences in accounting principles complicate their use in international comparisons.

comparisons. As discussed below, I try to control for the differences in skill distributions across countries by including GNP per capita as an environmental variable.

Given that most Latin American electricity distribution firms have the obligation to meet demand, I consider the amount of electricity supplied to final customers (in gigawatt hours, GWh) and the number of final customers served as exogenous outputs in electricity distribution.

I include service area (in square kilometers) as an output, since an increase in the service area either increases the use of resources or reduces the supply of other products (Førsund and Kittelsen 1998). Although there is an occasional redrawing of boundaries to merger and takeover, for practical purposes the firm has little direct control over the size of its service territory, and hence service area can be considered an exogenous variable.

As Kumbakhar and Hjalmarsson (1998) note, the extent to which distributors have control over the length of distribution lines is limited since the amount of capital in the form of network reflects geographical dispersion of customers rather than differences in productive efficiency. And this is also the case, to a lesser degree, for transformer capacity (in mega-volt-amper, MVA). Therefore, I treat distribution lines and transformer capacity as exogenous capital variables that represent the characteristics of the network.

The model also includes two environmental variables in order to capture external factors that might influence firms' performance and are not directly controllable by them. The proportion of total energy delivered that is distributed to residential customers captures the effect of delivering energy at different voltages required by different customers. It is included as an environmental variable, since the resources needed to deliver *E* units of medium voltage electricity to one customer are not the same as those needed to supply *E*/1,000 units of low voltage electricity to 1,000 households. GNP per capita (in purchasing power parity units) is included to control for differences in the socioeconomic environment in which firms operate in each country. It can capture, for example, differences in the quality of the labor input across countries.

The electricity distribution data used in this study include information on 94 Latin American firms between 1994 and 2001. The data were constructed on the basis of the Regional Electric Integration Commission (CIER) reports, which are based on surveys answered by the firms. Given the obvious danger that only the most successful utilities would answer the survey, I took great care to assemble the largest possible sample of firms, complementing CIER's reports with information provided by regulators and governmental agencies.

The sample is representative of the electricity distribution sector in the region. It covers the following countries: Argentina (34 firms that supply electricity to 83% of the total number of customers in the country), Bolivia (3, 34%), Brazil (4, 19%), Chile (3, 20%), Colombia (5, 34%), Costa Rica (8, 100%), Ecuador (13, 62%), Mexico (1, 79%), Panama (1, 62%), Paraguay (1, 100%), Peru (12, 99%), Uruguay (1, 100%), and Venezuela (8, 92%). Summary statistics of the unbalanced panel are presented in table 1. A total of 427 observations are available for estimation.

The purchasing power parity figures of GNP per capita were obtained from the World Bank database. I use purchasing power parity in order to correct for international differences in relative prices (for details, see the technical notes to the *World Development Reports*).[6]

The database also includes two ownership dummy variables: DP, which takes the value of one if the firm is private and zero otherwise, and DC, which takes the value of one if the firm is a cooperative and zero otherwise. Overall, 41 percent of the observations correspond to private firms (twelve public firms were privatized in the sample period) and 12 percent to cooperative ones. Since I only have data of cooperative firms for two countries, results involving cooperative firms must be taken with caution.

III. Econometric Model

The Average Labor Requirement Function

In order to estimate a parametric input requirement function, I first have to choose a functional form. I use a translog form since it is flexible and easy to calculate. A translog labor requirement function with three outputs, two fixed capital inputs, and two environmental variables, for a panel of $i = 1,...,N$ producers observed over $t = 1,...,T$ periods may be specified as

$$\begin{aligned} l^{i,t} = {} & \alpha_0 + \sum_{m=1}^{3} \varpi_m y_m^{i,t} + \frac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3} \varpi_{mn} y_m^{i,t} y_n^{i,t} + \sum_{k=1}^{2} \beta_k x_k^{i,t} + \frac{1}{2}\sum_{k=1}^{2}\sum_{j=1}^{2} \beta_{kj} x_k^{i,t} x_j^{i,t} + \sum_{k=1}^{2}\sum_{m=1}^{3} \delta_{km} x_k^{i,t} y_m^{i,t} \\ & + \sum_{h=1}^{2} \psi_h z_h^{i,t} + \theta_t t + \frac{1}{2}\theta_{tt} t^2 + \sum_{k=1}^{2} \xi_k x_k^{i,t} t + \sum_{m=1}^{3} \varsigma_m y_m^{i,t} t + \theta_1 tDP^{i,t} + \theta_2 tDC^{i,t} + \alpha_1 DP^{i,t} + \alpha_2 DC^{i,t} + v^{i,t} \end{aligned} \quad (1)$$

where l, y_1, y_2, y_3, x_1, x_2, z_1, and z_2 are the natural logarithms of labor, sales, customers, area, lines, transformer capacity, residential sales' share, and GNP per capita, and v is the random error term. The introduction of ownership dummies allows the technology of electricity distribution to differ with firm-ownership.

In order to allow for the effect of time in a flexible manner, I include a second order polynomial in *t*, and the time term interacted with logs of outputs and network characteristics. I include the interaction variables between the ownership dummies and time in order to examine the differences in technical change by ownership type. Technical change (TC) is defined as

$$TC = -\frac{\partial l}{\partial t} = -\left[\theta_t + \theta_{tt} t + \sum_{m=1}^{3} \varsigma_m y_m^{i,t} + \sum_{k=1}^{2} \xi_k x_k^{i,t} + \theta_1 DP^{i,t} + \theta_2 DC^{i,t}\right],$$

so that a positive value of TC indicates technical progress (reduction in labor requirement to distribute a given bundle of outputs, given the network characteristics).

[6] See Temple (1999) for a discussion of why purchasing power parities have to be used for accurate cross-country comparisons of real incomes.

Traditionally, the level of output has been used to represent firm size. Recently, however, writers have begun to distinguish between firm size and level of output for industries in which services are provided over a network of geographically distributed points (see Caves, Christensen, and Tretheway 1984). Since I am interested in addressing the impact of mergers or horizontal separation of the distribution activities on the labor use the definition of firm size has to include both outputs and network characteristics. Thus, returns to scale (RTS) is defined from the combined effect of increases in outputs and in network characteristics. This definition is equivalent to the inverse of the sum of the elasticities of labor with respect to the 3 outputs and the 2 capital inputs:

$$RTS = 1/\left(\partial l/\partial y_1 + \partial l/\partial y_2 + \partial l/\partial y_3 + \partial l/\partial x_1 + \partial l/\partial x_2\right).$$

Returns to scale are said to be increasing, constant or decreasing when RTS is greater than one, equal to one, or less than one.[7]

The relative efficiency of firms in this model is based on the assumption that all firms in a particular ownership group are equally efficient.[8] Such a restrictive assumption is relaxed in the following stochastic frontier model.

<u>The Stochastic Labor Requirement Frontier Model</u>

In this section I consider a stochastic labor requirement model in which the basic technology is assumed to be the same for all firms irrespective of their ownerships. The stochastic frontier model is specified as

$$\begin{aligned} l^{i,t} = \alpha_0 &+ \sum_{m=1}^{3}\varpi_m y_m^{i,t} + \frac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3}\varpi_{mn} y_m^{i,t} y_n^{i,t} + \sum_{k=1}^{2}\beta_k x_k^{i,t} + \frac{1}{2}\sum_{k=1}^{2}\sum_{j=1}^{2}\beta_{kj} x_k^{i,t} x_j^{i,t} + \sum_{k=1}^{2}\sum_{m=1}^{3}\delta_{km} x_k^{i,t} y_m^{i,t} \\ &+ \sum_{h=1}^{2}\psi_h z_h^{i,t} + \theta_t t + \frac{1}{2}\theta_{tt} t^2 + \sum_{k=1}^{2}\xi_k x_k^{i,t} t + \sum_{m=1}^{3}\varsigma_m y_m^{i,t} t + \varepsilon^{i,t}. \end{aligned} \qquad (2)$$

[7] Notice that returns to scale should use GWh produced rather than sold. However, I only have data for the latter.

The composite error term $\varepsilon^{i,t} = v^{i,t} + u^{i,t}$ allows for inefficiency in labor use $\left(u^{i,t} \geq 0\right)$ and for noise $\left(v^{i,t}\right)$. The labor requirement frontier is given by equation (2) when $u = 0$. Thus, the frontier gives the minimum amount of labor required to produce a given level of outputs, *ceteris paribus*, and inefficiency can be interpreted as the percentage increase in labor for a firm that is not operating on the frontier.

Estimation of the parameters and firm-specific inefficiency in the above model requires distributional assumptions on the noise and inefficiency terms. The noise term is assumed to be independent and identically distributed $N\left(0, \sigma_v^2\right)$. The $u^{i,t}s$ are non-negative random variables, which are assumed to be independently distributed such that $u^{i,t}$ is the truncation (at zero) of the normal distribution with mean $\mu^{i,t}$ and variance σ_u^2. The $\mu^{i,t}$, which is assumed to be non-negative, is defined by

$$\mu^{i,t} = \lambda_0 + \lambda_1 t + \lambda_2 DP^{i,t} + \lambda_3 tDP^{i,t} + \lambda_4 DC^{i,t} + \lambda_5 tDC^{i,t}.$$ [9]

This specification allows mean inefficiency to vary across ownership types, and it also allows technical inefficiency to vary over time (catching-up effects).[10] Furthermore, it allows technical inefficiency change to depend on ownership type.

The technical efficiency of the *i*-th producer at time *t* is given by $TE^{i,t} = \exp\left(u^{i,t}\right)$. The prediction of the technical efficiencies is based on its conditional expectations (see Battese and Coelli 1993).

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[8] Differences in efficiency between, for example, private and public firms can be calculated from the derivative of the labor requirement frontier with respect to the private dummy.

[9] The distributional assumptions on the inefficiency effects permit the identification of the intercept parameters and the time trend in the stochastic frontier and the inefficiency model.

[10] See Battese and Coelli (1995) for a discussion on these types of models.

IV. Empirical Results on Public versus Private Firms

In this section I compare private and public firms. In the following section I incorporate cooperative firms. Ordinary least squares estimates of the average labor requirement function model without including cooperative firms (375 observations) are reported in table 2. Since I divided the original data on inputs and outputs by their geometric means the first-order coefficients can be interpreted as elasticities evaluated at the sample mean. The time trend variable has also been mean-corrected.

The labor requirement function appears well behaved. The first-order output elasticities have the correct signs, since an increase in output levels is associated with an increase in the use of labor. Since a translog form is only local second-order approximation about a point of expansion the properties required from economic theory must be checked for every observation point, not just the sample mean. Non-decreasing in output levels is checked by calculating the labor elasticities with respect to output level Y_1, Y_2, and Y_3. The estimated labor elasticities with respect to GWh sold, number of customers, and service area are positive for 84%, 57%, and 70% of the observations.

The first-order output and network characteristics coefficients sum to 0.88, implying an approximate scale elasticity of 1.14 at the sample mean values. To assess the returns to scale characteristics of the industry in more detail, I evaluate returns to scale at every observation point. Inspection of the distribution of the scale elasticity reveals that 83% of the observations exhibits increasing returns to scale, 34% has scale elasticity greater than 1.2, 17% of the observations displays scale elasticity greater than 1.35, and 8% has scale elasticity greater than 1.5. I also calculate average returns to scale by firm size quartile, using the number of customers as the proxy of firm size.[11] Returns to scale are 1.38, 1.18, 1.08, and 1.05, for the first, second, third and fourth quartile. This suggests that gains are possible through increasing the size of the firms, especially in below average size firms.

The coefficients of the environmental variables are very small relative to their estimated standard errors. This implies that residential sales' share and GNP per capita are not significant to explain the use of labor by Latin American firms.

Formal tests of hypothesis associated with the translog average labor requirement model are reported in table 3.[12] The hypothesis that there is no technical change is rejected at the 1% level. The null hypothesis of neutral technical change is also rejected at the 1 percent level, even when I use the small sample correction to the likelihood ratio (LR) statistic proposed by Mizon (1977). The coefficient of the private dummy-time interaction is negative and significant at the 5% level suggesting that private firms have a higher annual rate of labor productivity growth than public firms (11% for privatized firms and 6% for public firms).

The private ownership effects are significantly different from zero at the 1 percent level. As shown in table 4, the derivative of the labor requirement function with respect to the private dummy is negative for all time periods implying that private firms are more labor-efficient than their public counterparts. The average reduction in the use of labor by private firms compared with otherwise similar public or cooperative firms ranges from 5% in 1994 to 40% in 2001.

Stochastic Labor Requirement Model

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[11] The first quartile consists of firms with less than 94,897 customers; the second between 95,185 and 221,910; the third between 224,149 and 562,491; and the fourth greater than 569,610.

[12] These tests are performed using a likelihood ratio (LR) statistic defined by $LR = 2(L_U - L_R)$, where L_R is the log likelihood of the restricted model and L_U is the log likelihood of the unrestricted model. Under the null hypothesis, LR is asymptotically distributed as a chi-square with degrees of freedom equal to the number of restrictions involved.

Maximum likelihood estimates of the stochastic labor requirement model are reported in table 5. To derive the likelihood function, I use the parameterization proposed by Battese and Corra (1977): $\gamma = \sigma_u^2 / \left(\sigma_v^2 + \sigma_u^2\right)$. All estimates were performed using the computer program FRONTIER 4.1 (Coelli 1996).

All first-order coefficients on outputs have the expected values regarding economic behavior, and the coefficients are high relative to their estimated standard errors. The estimated labor elasticities with respect to GWh sold, number of customers, and service area are positive for 83%, 62%, and 73% of the observations. The sum of the first-order output and network characteristics coefficients implies an approximate scale elasticity of 1.12 at the sample mean values. Inspection of the distribution of the scale elasticity reveals that 81% of the observations exhibits increasing returns to scale, 30% has scale elasticity greater than 1.2, 16% of the observations displays scale elasticity greater than 1.35, and 6% of the observations has scale elasticity greater than 1.5. Returns to scale are 1.35, 1.17, 1.07, and 1.04, for the first, second, third, and fourth quartile. The average rate of labor productivity growth is 12.9%.

The estimated coefficients and hypothesis tests in the inefficiency model are of particular interest here. Table 6 presents tests of various null hypotheses for the technical inefficiency effects model.

The first null hypothesis, $H_0 : \gamma = \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = 0$, which specifies that electricity distributors are fully technically efficient, is strongly rejected by the data, given the assumption of the translog labor requirement model.

The null hypothesis that specifies that the time effects are absent from the technical inefficiency effects model, $H_0 : \gamma = \lambda_1 = \lambda_3 = 0$, cannot be rejected at the 5% level. This suggests that there is no clear tendency for the least efficient units to catch-up with the more efficient ones.

The null hypothesis that there are no private ownership effects, $H_0 : \lambda_2 = \lambda_3 = 0$, is rejected at the 1% level. The coefficient of the private dummy is negative and the interaction between the private dummy and time is not significant. Together they suggest that private firms are more efficient and that this advantage is constant over time.

In terms of the estimated level of labor-efficiency, there is an advantage to privatized firms. The mean efficiency index for private firms is 89%, and this is significantly higher, at the 1% level, than the average figure of 73% for public firms.

V. Cooperatives

In this section I include cooperative firms in the analysis.[13] Ordinary least squares estimates of the model in equation (1) are reported in table 2.

The first-order output elasticities have the correct signs. Again, I check the sign of the output elasticities at every observation point. The estimated labor elasticities with respect to GWh sold, number of customers, and service area are positive for 91%, 60%, and 64% of the observations.

The first order-output and network characteristics coefficients sum to 0.88, implying an approximate scale elasticity of 1.13 at the sample mean values. Inspection of the distribution of the scale elasticity reveals that 94% of the observations exhibits increasing returns to scale, 23% has scale elasticity greater than 1.2, only 2% of the observations displays scale elasticity greater than 1.35, and no-one has an elasticity greater than 1.5. I also estimate average returns to scale by

[13] As Hollas and Stansell (1988) note, in the debate about the link between ownership type and efficiency an entire class of firms, the cooperatives, has been virtually ignored in the literature. Cooperatives are privately owned but presumably lack the profit maximization motive attached to private firms. A characteristic of the not-for-profit firm is that no one can claim the right to appropriate the residual. In this sense, the cooperative firms share with public firms the property that their members cannot sell their interest in the firm.

firm size quartile.[14] Returns to scale are 1.15, 1.12, 1.11, and 1.18, for the first, second, third and fourth quartile.

Formal tests of hypothesis associated with this model are given in table 3. I reject the hypothesis that there is no technical change at the 1 percent level. I also reject the null of neutral technical change at the 1 percent level.

The coefficient of the interaction variable between time and the cooperative dummy is not significantly different from zero at any of the usual levels of confidence, suggesting that labor productivity growth in cooperative and public firms is not significantly different (an annual rate about 4%). The coefficient of the private dummy-time interaction is negative and significant at the 1 percent level suggesting that private firms have higher rates of labor productivity growth than private and cooperative firms (about 10%).

The derivative of the labor requirement function with respect to the private dummy is negative for all time periods, and the private ownership effects are significantly different from zero at the 1 percent level. I cannot reject the hypothesis of absence of cooperative ownership effects.

These results suggest that public and cooperative firms are not significantly different in terms of their efficiency levels, and that private firms are more efficient than their public and cooperative counterparts. As shown in table 4, the average reduction in the use of labor by private firms compare with otherwise similar public and cooperative firms ranges from 32% in 1994 to more than 75% in 2001.

To check the robustness of these results, I use a subset of firms in the sample that have no experienced any within-firm variations in ownership over the sample period, that is, where the ownership type is constant. As Ehrlich et al. (1994) point out, such a sub-sample guarantees that

[14] The first quartile consists of firms with less than 60,581 customers; the second between 62,239 and 161,685; the

the time-ownership interactions account only for between-firm variations in ownership, which are more likely to yield a long-run effect of ownership on productivity growth.

Estimates of this restricted sample model are presented in the last two columns in table 2. The results are similar to the ones reported above. The average reduction in the use of labor by private firms compare with otherwise similar public and cooperative firms ranges from 26% in 1994 to 56% in 2001. This implies that productivity increases are not just short run effects after the privatization, and gives additional support to the conclusion that private firms are not only more efficient than public and cooperative firms but also that they have higher rates of labor productivity change.

The Stochastic Model

Maximum likelihood estimates of the stochastic labor requirement model including cooperatives are presented in table 5. All the first-order output elasticities have the expected positive signs. The estimated labor elasticities with respect to GWh sold, number of customers, and service area are positive for 89%, 63%, and 59% of the observations. The sum of the first-order output and network characteristics coefficients implies an approximate scale elasticity of 1.15 at the sample mean values. Inspection of the distribution of the scale elasticity reveals that 95% of the observations exhibits increasing returns to scale, 28% has scale elasticity greater than 1.2, 2% of the observations displays scale elasticity greater than 1.35, and no-one has an elasticity greater than 1.5. Returns to scale are 1.15, 1.14, 1.13, and 1.19, for the first, second, third, and fourth quartile.The average rate of labor productivity growth is 7.81%.

Tests of various null hypotheses for the technical inefficiency effects model are presented in table 6. The first null hypothesis, $H_0: \gamma = \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$, which specifies that electricity distributors are fully technically efficient, is strongly rejected by the data. The null

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third between 164,826 and 477,844; and the fourth greater than 484,384.

hypothesis that specifies that the time effects are absent from the technical inefficiency effects model, $H_0 : \gamma = \lambda_1 = \lambda_3 = \lambda_5 = 0$, cannot be rejected. This suggests that inefficiency is constant over time, the same result as in Section IV.

The null hypothesis that there are no cooperative ownership effects, $H_0 : \lambda_4 = \lambda_5 = 0$, cannot be rejected at the usual levels of confidence, suggesting that public and cooperative firms do not differ in their labor-efficiency levels. The null hypothesis that there are no private ownership effects, $H_0 : \lambda_2 = \lambda_3 = 0$, is rejected at the 1% level. Since the derivative of the inefficiency effect with respect to the private dummy is negative in all time periods, there is evidence that private utilities are more efficient than public and cooperative firms.

In term of the estimated level of labor-efficiency the mean efficiency index for private firms is 91%, and this is significantly higher at the 1% level than the average figure of 73% for public and cooperative firms.

VI. Conclusions

In this paper I have focused on the relative performance of recently privatized Latin American electricity distribution utilities. I examine labor productivity and technical change for private, public, and cooperative firms, and also returns to scale.

The following main conclusions can be drawn from the empirical results: (i) privatized firms are more labor-efficient than their public or cooperative counterparts; (ii) there is evidence of labor productivity growth during the period; (iii) the rate of labor productivity growth is higher for privatized firms, and is not significantly different between cooperative and public companies; and (iv) there are increasing returns to scale in electricity distribution in Latin America.

Together (i) and (ii) imply that even if more efficient firms were privatized first, privatization would have a positive dynamic effect.

The results support recent theoretical work that argues that public firms are inefficient because politicians force them to pursue political goals such as excess employment (Boycko, Shleifer, and Vishny 1996; Shleifer 1998). The findings are also consistent with a substantial body of empirical work showing that privatization of public firms leads to significant improvements in productivity as employment is reduced and efficiency rises toward private standards (Megginson, Nash, and van Randenborgh 1994; La Porta and Lopez-de-Silanes 1997), and with the widespread perception that state-owned electricity distributors in Latin America are attractive places to provide employment for political reasons (Joskow 2000).

The presence of increasing returns to scale suggests that the gains derived from increases in labor productivity after the reforms may be outweighed by losses due to the horizontal separation of the former distribution national monopolies.

I want to note, however, some caveats in the interpretation of the results. First, privatization always involves changes in ownership and regulation, since the alternative to state ownership is rarely purely private, unregulated firms. Therefore, the persistence differences in labor-efficiency in favor of private firms have to be interpreted as an indicator of the impact on efficiency of the joint introduction of private ownership and incentive regulation after the reforms.

Second, in the early stage of the reforms the governments will wish to demonstrate its success by showing that it leads to higher efficiency. To do so it is likely to choose firms who are already operating efficiently, so that when privatized they provide an example of high efficiency compared with their public sector counterparts. Thus, if a positive link is found between private ownership and efficiency, it is difficult to establish the direction of causality. This should not be surprising: establishing causality is not a trivial problem as information on the counterfactual situation of what would have happened had the firms not being privatized is inherently unavailable. In this paper I try to address this problem by estimating both labor productivity levels and labor productivity change.

Third, the lack of control of quality standards in the econometric model would overestimate the efficiency of private utilities if they were providing a bundle of output of inferior quality.[15] As note by Holmstrom and Milgrom (1991, 1994), providing an agent with strong incentives to pursue one objective, such as cost reductions, can lead to his shirking on other objectives, such as quality. To avoid this problem, very strict quality requirements were incorporated as part of the reforms, with penalties for not fulfilling the requirements. As Fischer and Serra (2000) document, fines for bad service were increased considerably since the reforms. As a result, the reform processes produce a notable improvement in the quality of service (Rudnick and Zolezzi 2001), which in fact could lead to a bias in the other way.

Fourth, in this paper I assume that, given the capital inputs, the firm minimizes the labor input in order to produce the given bundle of outputs. This assumption might not be valid for public firms, which might have employment targets. As Stigler (1976) note, the imposition of an arbitrary set of goals upon firms which in fact have other goals may lead to the fallacious conclusion that the latter firms are inefficient. This has important policy consequences, since if public firms' inefficiencies are a by-product of government-imposed social objectives, the benefits from these social goals might outweigh the cost of inefficiency. This is an interesting topic for further research.

[15] Unfortunately, collecting comparable supply reliability data is generally difficult because of variations in the definitions of the measures used, in particular, variations across firms in different countries.

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Table 1: Sample Summary Statistics

Variable	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Outputs:				
Sales (in GWh)	4,995	19,750	11	175,498
Number of customers	735,186	2,373,884	3,847	19,760,000
Service area (in km^2)	94,451	276,790	59	1,889,910
Inputs:				
Distribution lines (in km)	25,158	82,206	245	595,170
Transformer capacity (in MVA)	1,534	4,123	7	33,078
Number of employees	1,794	5,438	12	41,063
Environmental variables:				
Residential sales / sales	0.41	0.11	0.11	0.97
GNP per capita (in PPP units)	7,557	2,916	2,193	12,890

Table 2: Average Labor Requirement Function

		Without cooperatives		With cooperatives			
				Full sample		Restricted sample	
	Variable	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
	Intercept	0.0643	0.6782	-0.3029	0.6229	-0.5054	0.6805
Outputs	Ln Y_1	0.4355	0.1006	0.4241	0.0970	0.4012	0.1060
	Ln Y_2	0.1490	0.1162	0.1898	0.1124	0.2904	0.1242
	Ln Y_3	0.0783	0.0239	0.0603	0.0221	0.0759	0.0236
	$(\text{Ln } Y_1)^2$	0.5930	0.3185	0.7594	0.2984	0.7418	0.3175
	$(\text{Ln } Y_2)^2$	0.0282	0.4219	-0.4752	0.3690	-1.0771	0.4456
	$(\text{Ln } Y_3)^2$	-0.0424	0.0241	-0.0251	0.0215	-0.0471	0.0251
	(Ln Y_1)(Ln Y_2)	-0.4633	0.2471	-0.2514	0.2268	-0.2464	0.2505
	(Ln Y_1)(Ln Y_3)	-0.0829	0.0804	0.0105	0.0718	0.0386	0.0757
	(Ln Y_2)(Ln Y_3)	0.2415	0.0780	0.1474	0.0563	0.0658	0.0672
Inputs	Ln X_1	0.0805	0.0749	0.1340	0.0704	0.1201	0.0745
	Ln X_2	0.1346	0.0808	0.0745	0.0772	0.0148	0.0875
	$(\text{Ln } X_1)^2$	0.2474	0.1897	0.2528	0.1722	-0.0129	0.1906
	$(\text{Ln } X_2)^2$	-0.2094	0.2481	-0.1931	0.2399	-0.4519	0.2832
	(Ln X_1)(Ln X_2)	0.0079	0.1955	0.0738	0.1801	-0.0366	0.2005
Inputs-outputs	(Ln X_1)(Ln Y_1)	-0.0101	0.2090	-0.2139	0.1940	-0.3274	0.2042
	(Ln X_1)(Ln Y_2)	-0.3105	0.2506	-0.1127	0.2187	0.2933	0.2653
	(Ln X_1)(Ln Y3)	-0.0858	0.0615	-0.0896	0.0545	-0.0222	0.0601
	(Ln X_2)(Ln Y_1)	-0.3145	0.2567	-0.4207	0.2414	-0.3785	0.2607
	(Ln X_2)(Ln Y_2)	0.7447	0.3340	0.7169	0.2995	1.0391	0.3339
	(Ln X_2)(Ln Y_3)	0.0104	0.0701	-0.0205	0.0658	-0.0051	0.0730
Control variables	Ln Z_1	-0.1971	0.1179	-0.3471	0.1037	-0.4329	0.1137
	Ln Z_2	-0.0072	0.0750	0.0189	0.0699	0.0370	0.0766
Technical change	Time	-0.0603	0.0165	-0.0410	0.0171	-0.0444	0.0182
	$(\text{Time})^2$	0.0116	0.0114	0.0093	0.0105	0.0062	0.0112
	Time* Ln Y_1	0.1037	0.0359	0.0774	0.0341	0.0887	0.0353
	Time* Ln Y_2	-0.1946	0.0409	-0.1685	0.0385	-0.1915	0.0414
	Time* Ln Y_3	-0.0283	0.0096	-0.0247	0.0088	-0.0263	0.0095
	Time* Ln X_1	0.1347	0.0300	0.1084	0.0272	0.1197	0.0292
	Time* Ln X_2	-0.0262	0.0337	0.0012	0.0311	0.0042	0.0328
	Time*DP	-0.0504	0.0254	-0.0639	0.0246	-0.0432	0.0268
	Time*DC			0.0120	0.0466	0.0171	0.0477
Dummies	DP	-0.2418	0.0662	-0.2602	0.0637	-0.2192	0.0758
	DC			-0.2622	0.1520	-0.2072	0.1574
Log likelihood		-217.773		-243.29		-210.06	

Note: Dependent variable: number of employees, in logs. Inputs: kilometers of net (X_1), transformer capacity (X_2). Outputs: sales (Y_1), number of customers (Y_2), service area (Y_3). Environmental variables: residential sales' share (Z_1), GNP per capita (Z_2). Ownership dummies: private firms (DP) and cooperative firms (DC).

Table 3: Specification Tests

Null hypothesis	Test statistic	Small sample statistic[a]
Without cooperatives		
$H_0: \theta_t = \theta_{tt} = \theta_1 = \xi_1 = \xi_2 = \varsigma_1 = \varsigma_2 = \varsigma_3 = 0$	78.87***	72.78***
$H_0: \xi_1 = \xi_2 = \varsigma_1 = \varsigma_2 = \varsigma_3 = 0$	29.20***	26.82***
$H_0: \theta_1 = \alpha_1 = 0$	20.94***	19.15***
$H_0: \theta_1 = 0$	4.30**	3.93**
With cooperatives		
$H_0: \theta_t = \theta_{tt} = \theta_1 = \theta_2 = \xi_1 = \xi_2 = \varsigma_1 = \varsigma_2 = \varsigma_3 = 0$	79.96***	74.25***
$H_0: \xi_1 = \xi_2 = \varsigma_1 = \varsigma_2 = \varsigma_3 = 0$	24.02***	22.19***
$H_0: \theta_1 = \alpha_1 = 0$	26.29***	24.19***
$H_0: \theta_1 = 0$	7.27***	6.68***
$H_0: \theta_2 = \alpha_2 = 0$	3.24	2.99
$H_0: \theta_2 = 0$	0.07	0.07

*The null hypothesis is rejected at the 10% level.
**The null hypothesis is rejected at the 5% level.
***The null hypothesis is rejected at the 1% level.
[a] Small sample correction of the likelihood ratio test proposed by Mizon (1977).

Table 4: Derivative of the Labor Requirement Function with Respect to the Private Dummy

Year	Estimates without cooperatives	Estimates with cooperatives	
		Full Sample	Restricted sample
1994	-0.050	-0.324	-0.262
1995	-0.101	-0.388	-0.306
1996	-0.151	-0.452	-0.349
1997	-0.202	-0.516	-0.392
1998	-0.252	-0.580	-0.435
1999	-0.302	-0.644	-0.478
2000	-0.353	-0.707	-0.522
2001	-0.403	-0.771	-0.565

Table 5: Stochastic Labor Requirement Function

		Without cooperatives		With cooperatives	
	Variable	Coefficient	Standard error	Coefficient	Standard error
	Intercept	0.0912	0.6789	-0.7790	0.6169
Outputs	Ln Y_1	0.4180	0.0965	0.4116	0.0932
	Ln Y_2	0.2132	0.1131	0.2403	0.1012
	Ln Y_3	0.0825	0.0228	0.0466	0.0220
	$(\text{Ln } Y_1)^2$	0.6716	0.3029	0.8401	0.2830
	$(\text{Ln } Y_2)^2$	-0.1550	0.4142	-0.5552	0.3475
	$(\text{Ln } Y_3)^2$	-0.0342	0.0236	-0.0148	0.0204
	(Ln Y_1)(Ln Y_2)	-0.5099	0.2391	-0.2148	0.2283
	(Ln Y_1)(Ln Y_3)	-0.0519	0.0774	0.0272	0.0684
	(Ln Y_2)(Ln Y_3)	0.2027	0.0760	0.1598	0.0531
Inputs	Ln X_1	0.0453	0.0729	0.1140	0.0671
	Ln X_2	0.1303	0.0767	0.0590	0.0722
	$(\text{Ln } X_1)^2$	0.2453	0.1843	0.3317	0.1674
	$(\text{Ln } X_2)^2$	-0.2204	0.2318	-0.1420	0.2225
	(Ln X_1)(Ln X_2)	-0.0410	0.1902	0.0756	0.1702
Inputs-outputs	(Ln X_1)(Ln Y_1)	-0.0435	0.2015	-0.2627	0.1888
	(Ln X_1)(Ln Y_2)	-0.1891	0.2462	-0.0952	0.2079
	(Ln X_1)(Ln Y3)	-0.0903	0.0601	-0.1269	0.0533
	(Ln X_2)(Ln Y_1)	-0.3450	0.2456	-0.4720	0.2276
	(Ln X_2)(Ln Y_2)	0.8545	0.3170	0.7067	0.2832
	(Ln X_2)(Ln Y3)	0.0055	0.0686	-0.0310	0.0622
Control variables	Ln Z_1	-0.2004	0.1121	-0.3722	0.0986
	Ln Z_2	-0.0472	0.0743	0.0277	0.0669
Technical change	Time	-0.1290	0.0248	-0.0781	0.0183
	$(\text{Time})^2$	-0.0039	0.0181	0.0081	0.0106
	Time* Ln Y_1	0.1051	0.0352	0.0747	0.0333
	Time* Ln Y_2	-0.1831	0.0402	-0.1749	0.0356
	Time* Ln Y_3	-0.0254	0.0090	-0.0261	0.0083
	Time* Ln X_1	0.1204	0.0293	0.1090	0.0251
	Time* Ln X_2	-0.0263	0.0326	0.0058	0.0296
	Technical inefficiency model				
	Intercept	-0.1130	0.3024	0.1926	0.3012
	Time	0.2080	0.1156	0.0861	0.0670
	DP	-1.6445	0.7522	-1.6380	2.0221
	Time*DP	0.2435	0.3390	-0.3329	0.4492
	DC			-1.5147	1.9866
	Time*DC			0.1887	0.4644
	γ	0.5025	0.1933	0.4644	0.2150
	Log likelihood	-216.37		-241.71	

Table 6: Specification Tests of the Technical Inefficiency Effects Model

Null hypothesis	Test statistic[a]	Small sample statistic[B]
Without cooperatives		
$H_0 : \gamma = \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = 0$	23.74***	21.56***
$H_0 : \gamma = \lambda_1 = \lambda_3 = 0$	5.96*	5.39*
$H_0 : \gamma = \lambda_2 = \lambda_3 = 0$	15.74***	14.22***
With cooperatives		
$H_0 : \gamma = \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$	31.48***	28.86***
$H_0 : \gamma = \lambda_1 = \lambda_3 = \lambda_5 = 0$	6.48*	5.91
$H_0 : \gamma = \lambda_2 = \lambda_3 = 0$	22.85***	20.82***
$H_0 : \gamma = \lambda_4 = \lambda_5 = 0$	4.93*	4.49

*The null hypothesis is rejected at the 10% level.
**The null hypothesis is rejected at the 5% level.
***The null hypothesis is rejected at the 1% level.
[a] Critical values are obtained from the appropriate chi-square distribution, except for the tests of hypotheses involving $\gamma = 0$ (Kodde and Palm 1986, Table 1).
[b] Small sample correction of the likelihood ratio test proposed by Mizon (1977).