Regulation of State-Owned and Privatized Utilities:

Ukraine Electricity Distribution Company Performance

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Both ownership and regulation affect the behavior of utility managers. Private ownership rewards managerial decisions that enhance shareholder value. Regulatory incentives reward behavior that affects profits and costs. An empirical analysis of 24 Ukraine electricity distribution companies from 1998 to 2002 indicates that privately owned firms do respond to incentives that add to net cash flows (associated with reducing commercial and non-commercial network losses). However, they also respond more aggressively than do state-owned distribution utilities to mark-up (cost-plus) regulatory incentives that increase shareholder value but decrease cost efficiency.

Keywords: Incentive regulation, state-owned and privatized utilities, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA)

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1. INTRODUCTION

Economists have analyzed the impact of regulation on the performance of electric utilities. In addition, they have explored the impact of privatization on managerial decision-making. This study links these lines of research in the context of a new regulatory authority in Ukraine and distribution utility privatizations starting in 1998. The empirical work has two objectives: (1) to evaluate the impact of Ukrainian regulatory incentives on utility performance and (2) to determine how ownership affects the behavior of these utilities. In this analysis of the relative efficiency of Ukrainian electricity distribution companies, privately owned firms are seen to behave in a manner consistent with that predicted by Boycko, Shleifer, Vishny (1996) in their theory of privatization. They state that the presence of private investors is "conducive to efficiency" (1996, 318).[1] However, their conclusion must be modified to take into account potentially perverse regulatory incentives that can lead to higher costs (and to higher profits) for privatized firms.

Megginson and Netter (2001) survey empirical studies on privatization. The mixed performance across sectors and countries (including transition economies) is described as follows: "The gains from privatization come from change in ownership combined with other reforms such as institutions to address incentives and contracting issues, hardened budget constraints, removal of barriers to entry, and an effective legal and regulatory framework" (2001, 364). Their concluding observations emphasize the need to analyze public policies that complement privatization initiatives (2001, 382).

This empirical study of twenty-four electric utilities in the Ukraine tests the extent to which privately owned firms respond to incentives in ways that are different from publicly owned firms. Two types of regulatory incentives are present: incentives that add to net cash flows (associated with reducing commercial and non-commercial distribution network losses) and incentives associated with cost-of-service regulation. This study examines managerial behavior in state-owned and privatized firms: in both cases, "insiders" (managers) have an information advantage over outsiders (investors, citizens, and the regulator). However, we find evidence that discretionary behavior by managers of both types of firms results in differential performance.

The unique problems faced by transition economies stem from the shocks associated with moving from a command-and-control economy to one in which market forces are allowed to allocate resources. In the case of natural monopolies, some form of regulatory oversight has emerged in most countries that were part of the former Soviet Union. The initial political problems associated with achieving financial sustainability for electricity that had previously been priced below cost has meant that regulation has tended to address short-term needs rather than seek long-term efficiency objectives. Thus, imperfect adjustments to historical shocks might explain weak sector performance. Such shocks are beyond the control of managers and regulators: the main strategic implication is that financial sustainability requires long-term policies that have the confidence of investors and customers.

Poor performance also might be caused by managerial slack and misconduct. If weak cost control can be attributed to self-serving managerial decisions, a logical remedy involves

[1] Shleifer's (1998) literature survey outlines the implications of state ownership when managers receive only a small fraction of the value they create. Private ownership improves incentives to cut costs due to improved contractual arrangements and reduced opportunities for political corruption. See also, Shleifer (1985).

creating improved procedures for corporate governance.[2] When managers lack good internal incentives, the shareholders (for privatized firms) or taxpayers (for government-owned firms) experience the destruction of value. In such situations, managers (as agents) are benefiting at the expense of owners and citizens. Privatization has been offered as a way to improve the design of internal incentives. Because of different internal incentives, privatized and state-owned distribution utilities are likely to respond differently to opportunities to improve cash flows.[3] Political considerations affect the objectives of the latter a greater degree than the objectives of a profit-maximizing private firm. However, even if internal incentives are strong, the policy environment can cause managers to waste resources if the regulatory incentives reward behavior that increases costs.

After briefly reviewing the forces that shaped the development of the Ukrainian electricity sector over the past decade, we present a stylized version of the regulatory constraint. We then investigate the performance of distribution utilities empirically and explain the results in terms of regulatory incentives and differential managerial behavior within state-owned and privatized firms. Refinement of regulatory incentives can improve sector performance—for the benefit of citizens and shareholders.

2. UKRAINIAN ELECTRICITY: SHOCKS, REFORMS, AND THE REGULATORY FRAMEWORK

Energy reform in Ukraine was initiated in 1992 under the severe economic crisis induced by the collapse of the Soviet Union. To ensure the continued development and financial sustainability of its electric power system, the Ukrainian government (with the support of international consultants) developed a model for electricity industry reform. The vertically integrated industry was restructured in 1994-96: unbundling generation, transmission, dispatch, distribution, and supply activities.[4]

The National Electricity Regulatory Commission (NERC) of the Ukraine was established by presidential decree in December 1994 as an independent regulator agency responsible for regulating prices of transmission and distribution activities, issuing and monitoring licenses for sector activities, reviewing electricity market operations, promoting competition in the electricity market, and protecting consumers against monopoly abuses. One potential abuse under inappropriate incentives is the use of excessive resources to produce a given level of electricity service. In anticipation of this problem, promoting efficiency is a statutory duty of the NERC,

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[2] La Porta et al. (2000, 4, 6) state, "Corporate governance is, to a large extent, a set of mechanisms through which outside investors protect themselves against expropriation by the insiders." For state-owned enterprises, citizens (like investors) are still vulnerable to managerial misbehavior that raises costs or reduces service quality. "When investor protection is very good, the most the insiders can do is over-pay themselves, put relatives in management, and undertake some wasteful projects."

[3] In their study of Ukraine (using data from 1998) Schnytzer and Andreyeva (2002, 83) conclude that "firms . . . behaved more as if they were still in a loosely reformed Soviet environment where exchange via interpersonal connections, rather than the price mechanism, determined the allocation of resources." The researchers did not focus on electricity; nevertheless, they found that soft budget constraints hurt economic performance of firms.

[4] Electricity is supplied to consumers by both regional electricity companies, RECs (regulated tariff suppliers—oblenergos) and unregulated (independent) tariff suppliers. According to the Electricity Law (1997) all non-residential customers are allowed to choose their electricity supplier. In practice, most customers are supplied by RECs.

which makes cost containment a key regulatory objective.[5] The National Electricity Regulatory Commission developed and introduced a variant of cost-plus regulation to set prices for distribution utilities.

2.1 Price Regulation and Targeted Line Losses

The introduction of price regulation for distribution and tariff supply services was complicated by the reform process. A total of 27 RECs were created in 1996 as a result of restructuring eight vertically integrated regional power associations. The regulator lacked reliable data on historical costs (Ryding 1998). Thus, the initial regulatory procedures could be viewed as ad hoc and based on the financial needs of individual systems and limited information/accounting systems rather than some comprehensive analysis of incentive effects. In May 1998, NERC adopted a price-setting methodology for electricity distribution and tariff supply companies, to be effective in January 1999. According to this methodology, the retail electricity price is calculated as:[6]

$$P_r = (P_{wem} / (1- k_l)) + T_d + T_s \qquad (1)$$

where P_r is the retail electricity price,

P_{wem} is the wholesale electricity price,

k_l is the allowed level of network losses (targeted line losses),

T_d is the electricity distribution tariff regulated by NERC, and

T_s is the electricity supply tariff regulated by NERC.

The allowed level of line losses (normative technical losses) is established in the retail electricity price and charged to all consumers. Reduction of losses below the allowable level gives the REC greater cash flows and excessive losses imply lower cash flows. Therefore, such a pricing methodology creates a very strong incentive for profit-maximizing companies to reduce electricity losses. For example, using numbers that are close to the actual tariffs and assuming no independent suppliers, assume k_l =15%, P_{wem}=\$20/MWh, T_d= \$5/MWh, T_s= \$1.5/MWh, and k_{actual} (actual level of network losses) is 20 percent. A REC's revenue (cash flow before subtracting operating costs) is equal to the difference between consumers' payments for electricity distributed and supplied and expenditures for purchasing electricity from the wholesale market.

The REC's revenue from distribution and supply activities R_a is equal to the following:

$$R_a =[P_{wem}/(1-k_1) + T_d + T_s]\times Q(1-k_{actual}) - P_{wem}\times Q \qquad (2)$$

where Q (electricity purchased by the REC from the wholesale market) is denoted in MWh. The cash flow loss is about 27 percent if the company's network losses are 20 percent when target losses are 15 percent.

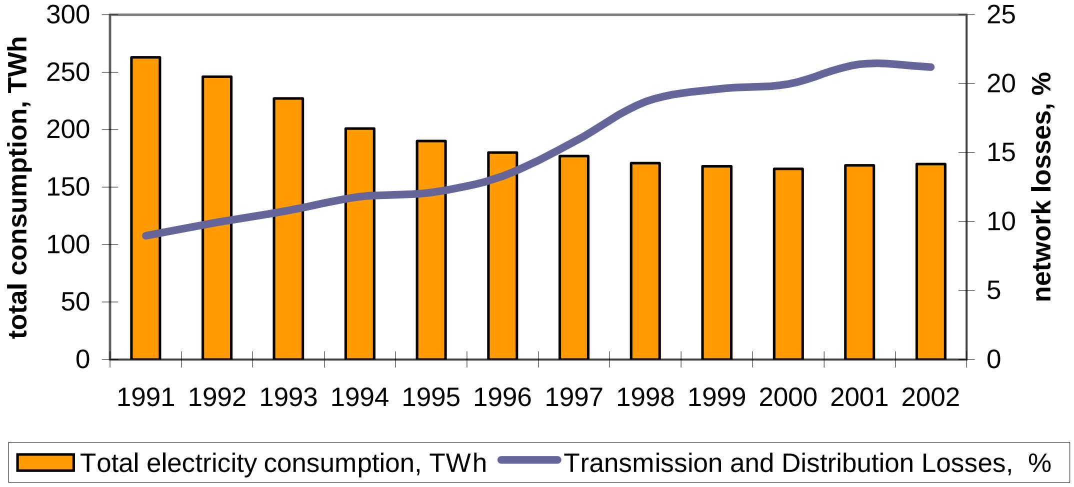
The targeted line losses incentive (equation 1) provides a strong reward for firms that successfully address the problem caused by under-loading, deferred maintenance, and commercial losses (non-payments and theft); these are the main reasons for a more than twofold

[5] Determining relative efficiency is a task taken on by regulators on a regular basis. A survey by Jamasb and Pollitt (2001) shows that more than twenty countries utilize benchmarking in regulation. They cite twenty-seven empirical studies that use comparative efficiency analysis to evaluate distribution utility performance.

[6] This simplified formula does not take into account two voltage classes.

growth of network losses, to over 20 percent of production (Figure 1). We now turn to the regulatory framework to explain both distribution network losses and incentives for cost-containment.

Figure 1: Electricity Consumption and Network Losses in Ukraine, 1991-2002



2.2. Mark-up (Cost-plus) Regulation

Price regulation for monopoly services (distribution and tariff supply) is based on regulatory approval of the unit costs of these services (T_d and T_s in Equation 1). In the development of distribution and supply tariffs, the REC submits data to NERC on elements of expenditures for the base period (year 1) and forecasts of expenditures and output (electricity distributed or supplied) for the projected period. The price-setting procedure takes one month and concludes with an open hearing where NERC determines and approves each element of expenditures, each element of returns (depreciation as a return of capital and some percentage of the book value of assets appropriate for repairs),[7] required revenue, and the tariff (average price is the required revenue divided by the projected output). Tax, depreciation and repair rates are specified by the law "On Levying Tax on Enterprise Profit." NERC approves tariffs that cover "justified" costs and provide a return (called a "profit") for each regulated company; NERC has significant discretion in determining the mark-up (a traditional measure of profit adequacy for soviet-type economies).

Profit is not related to return on assets for most Ukrainian energy companies, except for the six companies privatized in 2001. For these, the rate of return is 17 percent on rate base (where the rate base or asset value, A, equals the sale price at privatization plus additional investments less accumulated depreciation). For these firms, now there is at least a link between total returns (profit levels) and the value of assets. Recently, the government has tried to force state-owned companies to pay dividends to the state as a return on state investments in the development of energy companies.

A stylized version of the revenue requirement (RR) formula is shown below:

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[7] In the United States, accounting profit would be a return on assets or return on rate base. The mark-up involves an implicit return on investment (through the mark-up on the capital elements), but the formula also establishes incentives to increase operating expenses.

$$RR = \text{Projected Operational Costs} + \text{Projected Profit} \quad (3)$$

A standard measure of projected profit adequacy in the former Soviet Union is the mark-up. The mark-up, **m**, (so-called, "profitability") is expressed as:

$$\mathbf{m} = \text{Projected Profit} / \text{Projected Operational Costs, so} \quad (4)$$
$$\text{Projected Profit} = \mathbf{m} \times (\text{Projected Operational Costs}) \text{ and}$$
$$\mathbf{RR} = (\text{Projected Operational Costs}) \times \mathbf{(1 + m)}$$

The equation for projected operational costs is:
Projected *Operational* Costs = Projected Operating Costs + Depreciation + Repair Costs where Projected Operating Costs include cash outlays for raw materials, external services, labor (wages and fringe benefits, where social security is 38 percent of labor costs), and some other costs. Depreciation (**d**) and repair rates **(e)** are specified by the law "On Levying Tax on Enterprise Profit" as some percentage of asset value (A_0), so Depreciation = $d \times A_0$, Repair Costs = $e \times A_0$. Expressed as a formula, revenue requirements become:

$$RR = (OC + d \times A_0 + e \times A_0)(1 + m) = (OC + (d+e) \times A_0)(1+m), \quad (5)$$

where **m** is a mark-up on both operating costs and capital elements,
OC = projected operating costs
d is the depreciation rate (e.g., .10)
e is the approved repair rate (e.g., .05)
$\mathbf{A_0}$ is asset value for the current period

Based on (4), we see that mark-up on operating costs and capital elements is labeled "profit," but it clearly does not bear a strong link to the accounting returns on investment (accounting profits) that would be calculated in the West. The formula allows firms to secure higher revenue (through higher prices) if their operating costs are estimated to increase. The repair cost does not appear as a component of actual operating costs, but reflects some percentage of asset value. Thus, companies with more assets obtain more cash flows. If the REC forecasts an increase in operating costs of $100, the next period's allowed cash flow (revenue requirements) goes up by $100(1+m); if the REC bought $100 worth of equipment last period, it obtains $100(1+m)(d+e). During the period under study, RECs have had an incentive to increase operating costs by substituting expenses for capital investments—an "anti-Averch-Johnson effect".[8] Unless expenses are "disallowed," future revenue requirements increase with higher projected costs. Information asymmetries and tight review deadlines limit the extent of disallowances.

The mark-up (m) that constrains or limits "regulatory profit" is determined by NERC in a highly discretionary manner. For example, the mark-up can be set higher if projected equipment investments are particularly high. Note that assets include the value of past investments (less accumulated depreciation). However, working (circulating) capital is not taken into account in

[8] Both mark-up regulation and the rate-of-return regime applicable to the six companies privatized in 2001 forbid the reallocation of approved costs. For example, according to the ROR methodology, each company forecasts components of its operating expenditures for seven years, and all savings accrue to the firm. However, a company cannot spend more for one category (materials or equipment) and less for another (labor costs). Such rigidities will limit the achievement of allocative efficiencies in the future, since cost-effective substitution is not rewarded.

the formulae, so firms have an incentive to minimize their use of working capital. Most importantly, NERC can decide to increase m to ensure that cash flows are available for investments (capacity expansion and modernization) and dividends to shareholders. The variable used in the empirical work is Operational Cost = OC + d x A_o + e x A_o, where operating cost—OC—is the primary component.

2.3 Manipulating Regulatory Lag

In the License Conditions for distribution companies (adopted in 1996), the regulatory lag was four years. REC could ask NERC for a price review one year after the first price setting, but neither the company nor NERC could initiate a price review during the succeeding three years. However, the regulator could annually adjust prices for inflation. In principle, the regulatory lag provides incentives for companies to reduce operating costs and excessive capital outlays during the three years in which the price is in effect. If the company can reduce costs, the REC can earn more profits because of the fixed unit price. However, this provision was ignored in practice and was abolished by NERC in 2001. For example, in 2000, tariffs were reviewed on average 1.5 times a year for all companies; with an even higher rate (2.4 times) for privately-owned companies that were part of the Investment Pool. On average, during 1999-2002, each REC had 1.13 price reviews per annum (Table 1).

Table 1: Number of Price Reviews per Company

Distribution companies by ownership		Annual number of price reviews, 1999-2002				
		1999	2000	2001	2002	1999-2002
privatized by Investment Pool, 1998	total	8	12	2	4	26
	per company	1.6	2.4	0.4	0.8	1.3
privatized by VSE, 2001	total	6	7	4	4	21
	per company	1.5	1.75	1	1	1.31
privatized by AES, 2001	total	3	2	3	0	8
	per company	1.5	1	1.5	0	1
state owned	total	21	16	6	14	57
	per company	1.5	1.14	0.43	1	1.02
All Distribution companies	total	38	37	15	22	112
	per company	1.5	1.46	0.65	0.88	1.13

2.4 Inappropriate Affiliate Transactions

The regulatory framework described above does not provide incentives for controlling costs. The absence of a regulatory lag promotes higher expenditures for variable inputs by firms. Furthermore, if these transactions are with an affiliated organization, the (potentially excessive) outlays provide a mechanism for extracting cash flows from customers and transferring money to owners. For example, if software for a new billing system is purchased from a parent or related company, the costs are passed on to customers: any excessive outlays for the input benefit investors directly (through the high transfer prices) and indirectly (through the mark-up procedures). Because of the short period of time available for regulatory investigation (one month) NERC staff cannot check company performance in a thorough manner. Furthermore, the absence of consumer representation in regulatory proceedings suggests that the regulator receives information and pressure from regulated firms, without receiving adequate input from other affected parties.

2.5 Overall Price Constraints

Although there is no formal requirement that price not increase by a particular amount, NERC certainly tries to limit electricity price increases through tests of "reasonableness." For example, the mark-up can vary across firms. At times, NERC has approved a doubling of distribution tariffs, resulting in a 20-30 percent electricity price increase for end-users. However, the company must justify a tariff increase as reasonable during NERC open hearings, where interested parties like regional administrations also have input. The "reasonableness" judgment on this politically sensitive issue can be viewed as a "regulatory sustainability constraint." Thus, managers do not have unlimited discretion to waste resources or to transfer money to shareholders. Nevertheless, the short regulatory lag and mark-up (cost-plus) regulation are disincentives to cost containment.

3. MANAGERIAL BEHAVIOR: PUBLIC VS. PRIVATE OWNERSHIP

The dataset includes firms under public and private ownership. Generation and transmission companies are state-owned, but privatization of distribution companies has occurred in two waves. In the summer of 1998, a group of Ukrainian and offshore companies known as Investment Pool purchased shares in five of the 27 regional distribution/ supply companies through tender offers.[9] In April 2001, six other distribution companies were sold for $160 million (U.S.).[10] To facilitate privatization of the six distribution companies (and to provide better incentives for cost containment), NERC and the investors agreed to apply a rate-of-return (ROR) pricing methodology to the newly privatized companies. The empirical results presented below demonstrate the need for adopting a mechanism with improved incentives.

The agreement established a ROR of 17 percent on rate base (the selling price of the privatized companies and new capital investments) for seven years (2001-08). Operation and maintenance costs can be fixed for seven years to give an incentive for distribution companies to reduce their costs. This feature of the incentive mechanism was designed to decouple realized operating costs from allowed revenues. However, during the first year after price review (2002), companies tried to increase OM costs (operating cost plus maintenance) to establish a higher level of OM costs.

From 1998 through 2001, the unified regulatory regime (the 1998 pricing methodology) was applied to all the companies, both public and private. In 2002 the same regulatory regime was applied to 19 of the 24 companies in the sample (all state owned, 6 privatized in 1998, 1 privatized in 2001). The five companies privatized in 2001 were regulated according to new tariff setting rules (2001) but during the first year after price review (before fixing OM costs) the mechanism provided cost inflating incentives like former (1998) price setting methodology. Therefore we maintain that during 1998-2002, both types of firms were subject to identical regulatory incentives. As we shall see below, the empirical results indicate that privatized firms

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[9] These were: Sumyoblenergo, Prykarpattyaoblenergo, Chernigivoblenergo, Poltavaoblenergo and L'vivoblenergo. The Investment Pool also accumulated large stakes in these companies from the secondary market. A Ukrainian financial group represented by Finance and Credit Bank purchased shares in two other RECs: Lugans'koblenergo and Odesaoblenergo.

[10] Two of them were sold to the American utility AES, and the other four companies were sold to a utility from the Slovak Republic, VSE. AES Corporation (USA) bought Kyivoblenergo and Rivneoblenergo, and VSE (Slovakia) bought Zhytomyroblenergo, Khersonoblenergo, Kirovogradoblenergo and Sevastopol'energo. For more information on these privatizations, see IMEPOWER Investment Group (2002), *Privatization Overview*, http://www.imepower.com.

responded differentially to regulatory incentives in comparison with RECs that are still government-owned.

3.1 Evaluating REC Performance

The purposes of this study are to identify the impacts of regulatory incentives and to determine whether public and private RECs have responded differently to the same set of incentives. In addition, we examine relative performance of RECs under both ownership types. Efficiency measurement methods can be subdivided into parametric and non-parametric methods. Parametric methods of efficiency analysis rely on specified functional forms of production or cost functions; they utilize econometric techniques. Typical parametric methods include regression analysis and stochastic frontier analysis. Non-parametric methods use mathematical programming techniques and do not require specification of production or cost functions. Data Envelopment Analysis (DEA) is a non-parametric method that evaluates performance relative to the frontier.

3.2 Methodology: DEA Models

DEA facilitates the estimation of the relative efficiency of regulated companies in Ukraine, given the incentives employed during 1998-2002. DEA is appropriate for evaluating RECs that perform "similar tasks" and for which measurements of inputs and outputs are available. DEA's strength is in simultaneously considering multiple inputs and outputs without need for a prior assignment of weight. The technique also has its limitations: As the number of variables in a DEA model increases, more firms tend to be on the efficiency frontier: a firm is likely to be using relatively less of a particular input or producing more of a particular output, which places it near or on the multidimensional frontier (Rossi and Ruzzier (2000)). Irastorza (2003) has also criticized DEA for its sensitivity to inclusion or exclusion of variables.

Another limitation of the non-parametric approach is that in original DEA models, the statistical properties of efficiency scores could not be quantified.[11] A way around this problem in the empirical work is given by the bootstrapping methodology proposed in Simar and Wilson (1998a, 1998b, 1999a, 1999b). Bootstrap techniques are well suited for producing confidence intervals around the estimated individual efficiency and bias corrected estimates. Nevertheless, since DEA uses a linear programming model to analyze the observed data, it does not require the specification of a functional form to be fitted, which avoids the danger of fitting the wrong functional form. To check the robustness of our results, we also examine relative performance using a more traditional cost function model.

4. MODEL SPECIFICATIONS AND DATA

4.1 Description of Sample and DEA Models

The sample consists of 24 RECs, 1998-2002.[12] According to a recent survey by Jamasb and Pollitt (2001), frontier analysis models for electricity distribution companies most frequently use the following as outputs: electricity delivered, number of customers and size of service area.

[11] The Charnes, Cooper, Rhodes (CCR) DEA model (Charnes et al. 1978) is employed in this study. For an introduction to the basic models and theoretical extensions, readers are referred to Charnes et al. (1994), or Cooper et al. (2000).

[12] Two city power companies have been excluded to make the sample more homogeneous. A third company was excluded because of bankruptcy proceedings. There are some missing data in year 1998, so the dataset is an unbalanced panel.

The most frequently used inputs are operating costs, number of employees, transformer capacity, and network length. The analysis presented here attempts to obtain a reasonable balance between simplicity and realism in model specification (Table 2). Model 1 (DEA1) is the basic specification, similar to empirical studies conducted by IPART (1999) and by Carrington et al (2002). Model 1 identifies real cost inefficiency of privatized companies under poor regulatory incentives. Model 2 (DEA2) incorporates network losses into the analysis. This model recognizes RECs that improve performance (efficiency scores) by decreasing network losses. It still penalizes firms that increase expenditures (which are passed on to consumers under cost-plus regulation). Thus, DEA2 can be viewed as an auxiliary model for evaluating current regulatory incentives and for developing more efficient regulatory schemes.[13]

Table 2: DEA Model Specification

	Model 1	Model 2
Inputs		Electricity input, MWh
	Operational costs, 1000 UAH	Operational costs, 1000 UAH
	Network length, 1000 km	Network length, 1000 km
Outputs	Number of Customers	Number of Customers
	Electricity Delivered, MWh	Electricity Delivered, MWh

4.2 Inputs

Following studies by Jamasb and Pollitt (2001, 2003), we first consider a basic model with two inputs and two outputs (electricity delivered and number of customers). The inputs are network length and "operational costs" – operating costs plus capital elements (depreciation and repair costs). Using operational costs (a monetary measure) has both strengths and weaknesses in efficiency studies. For example in their review of potential drawbacks of using OPEX, Rossi and Ruzzier (2000) identified several problems, but most of them are applicable to cross-national studies (different accounting rules, different input prices).[14] Because of these problems, most cross country empirical studies, such as the one by Estache et al (2004), use only physical inputs and outputs.

[13] There are two orientations of DEA models—input and output. In an input orientation model, inputs are minimized at given outputs. In an output orientation model, output is maximized at given inputs. The input DEA results are presented in the study because they are more intuitive, especially for the readers who are not familiar with DEA techniques. In the output orientation DEA model, the efficiency value range between [1, ∞). The smaller the efficiency value, the more efficient is the firm, with the most efficient firms having an efficiency value of 1. However, both two orientations will give us exactly the same ranking. If θ^* represents the input-oriented efficiency score of specific DMU, and ϕ^* is his output-oriented efficiency score, $\theta^* = \frac{1}{\phi^*}$ (Cooper et al. 2000). Therefore, using input DEA does not generate inconsistencies in our later test of robustness which compares scores with those obtained for stochastic production frontier models.

[14] In cross-national studies, different companies may apply different accounting rules, and therefore include some cost items in OPEX that other firms do not consider. This problem is not relevant for the current Ukraine study. Distribution companies in Ukraine are required to use the same methods for calculating their operational costs (described above).

However, it is not always possible or desirable to use only physical inputs and outputs. For example, it is very difficult to identify and collect the information about different inputs comprising non-labor OPEX. This category includes a wide range of inputs, from paper clips to computers. In addition, it is difficult for information on physical inputs to account for quality and composition of the inputs—for example, the mix of technical and non-technical staff given the same number of employees, or different materials used to upgrade or maintain the networks. Finally, the assumption that all the companies face similar input prices is reasonable for the Ukraine. Thus, like many other single country DEA studies, we utilize operational expenditures as an input.

According to Carrington et al (2002), there are two reasons to use the network length as a measure of physical capital. First, networks are the major capital component of distribution companies. Second, the information on network length is likely to be accurate because distributors collect this information to monitor and report their performance. While there is no consensus on whether network length is an input or an output (IPART 1999), the majority of empirical studies use network length as a proxy of the capital input. The debate is based, in part, on the use of operation costs per network kilometer as a partial measure of efficiency, and in part on a concern that distributors with larger networks will be penalized in the evaluation of relative efficiency.[15]

4.3 Outputs

The two outputs employed in the study (electricity delivered and number of customers) are the most commonly used outputs in electricity distribution studies. The electricity delivered reflects the degree to which the distributor is meeting its objective of providing a flow of energy to customers: greater delivery requires more inputs. The number of customers is a direct measure of the service coverage, with higher numbers requiring more inputs (for billing and network maintenance).

Quality of service is another potential output since a firm can always lower its costs by reducing its service quality. Coelli et al. (2002) note that typical quality measures in developed countries include average length of supply interruption per customer per year, delays, waiting times for service connections, and average time to restore supply after interruptions. Incorporating quality into the present analysis would require a more comprehensive data collection effort, but future research should certainly explore whether service quality might alter the conclusions of this study by affecting performance comparisons.

The second model has the same outputs, but considers three inputs: purchased electricity, operational costs, and network length. The additional input in DEA2, power purchased from wholesale market, captures the role of network losses since it is equal to electricity delivered plus network losses.[16]

[15] In order to test the robustness of our results to alternative model specifications, both model 1 and model 2 were re-specified with network length as an output. The results are robust to alternative specifications: for example, in DEA1, state-owned enterprises are more cost-efficient than privatized firms. The latter have higher average efficiency scores than state-owned companies do under both specifications of DEA2. In addition, the firm-specific efficiency scores under the input and output specifications are highly correlated with each other. Thus, the basic patterns reported here are similar under both specifications; to conserve space, we report the results with network length as an input.

[16] The data for DEA analysis were collected by using a NERC questionnaire mailed to distribution companies. Operational cost data were adjusted for inflation to the 2002 level by using National Bank of Ukraine statistics on the Consumer Price Index. In another (less comprehensive) study, Gazizullin (2003) utilized DEA for Ukraine

Thus, two DEA models are used in the study: Model 1 (two inputs and two outputs) and complementary Model 2 (three inputs and two outputs). Summary statistics of the unbalanced panel are presented in Table 3. The sample includes a wide range of RECs, so to confirm the DEA results, we also utilized a more traditional cost model with two environmental variables—customer density and customer mix, in line with the approach proposed by Rossi and Ruzzier (2000). This analysis is presented in Section 5.

Table 3 : Sample Summary Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Outputs				
Electricity Delivered (in GWh)	4192.481	5452.013	774.617	24199.451
Number of customers	698700.243	365959.584	331509	1938162
Inputs				
Network Length(in km)	38298.354	12843.137	17110	74132
Operation Cost (thousand UAH)	64376.016	40046.441	12465.774	198762.664
Electricity Purchased (in GWh)	5217.932	6127.998	1225.623	26989.308
Environmental variables				
Customer number /network length	17.725	3.694	13.023	26.344
Residential customers /Total customers	0.968	0.020	0.918	0.992

4.4 DEA Results and Interpretation

The constant returns to scale (CRS) annual efficiency scores are presented for model 1 in Table 4.[17] The 24 firms fall into three categories:

State-owned companies:	numbered 101-114
Companies privatized in 1998:	numbered 201-205 (highlighted in Table 4)
Companies privatized in 2001:	numbered 301-305

Estache et al. (2004) reviewed different ways to deal with panel data within the context of DEA. One approach involves computing a frontier for each period and comparing these cross-sectional studies. In this way, one calculates the efficiency of each firm relative to the frontier in each period. Another approach involves treating the panel as a single cross-section (each firm in each period being considered as an independent observation), pooling the observations altogether.[18]

RECs, using similar models. His results are consistent with those reported here, although he did not test for robustness, nor did he analyze the effects of the regulatory incentives.

[17] The conclusions are similar if a variable returns to scale DEA model is utilized.

[18] The same basic results are obtained if a frontier is computed for each period. Similarly, the results are robust to the alternative specification of variable returns to scale (VRS). The correlation between CRS and VRS efficiency

Under this methodology, a single frontier is computed, and the relative efficiency of each firm in each period is calculated by reference to this single frontier. To consider changes in efficiency scores during 1998-2002, five years of data were pooled for the DEA to obtain a unified efficiency frontier for five years. A firm on the frontier is denoted as having a score of 1.

Table 4: Efficiency Scores for Model 1 and Pooled Data (Companies Privatized in 1998 by Investment Pool Are Marked)

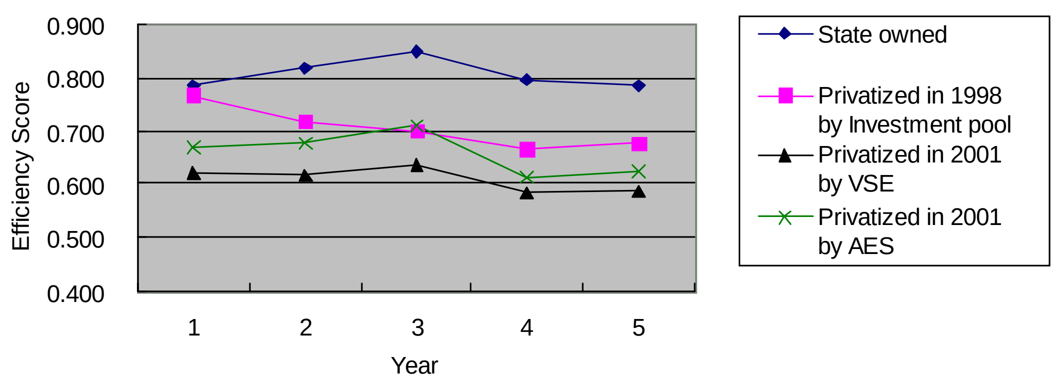
1998		1999		2000		2001		2002	
Company	CRS	Company	CRS	Company	CRS	Company	CRS	Company	CRS
104	1.00000	103	1.00000	114	1.00000	103	1.00000	104	0.998813
201	0.93116	104	0.98365	104	0.99514	104	1.00000	103	0.994625
111	0.89645	109	0.95587	103	0.99511	111	0.95263	111	0.942829
105	0.89378	114	0.95461	109	0.98248	114	0.92983	114	0.901612
203	0.84314	201	0.90969	111	0.96838	105	0.87084	105	0.879043
106	0.83575	111	0.88311	105	0.94194	201	0.86211	201	0.858994
109	0.81124	105	0.87572	106	0.92220	109	0.83902	109	0.832794
202	0.78469	203	0.82742	201	0.88570	101	0.81323	106	0.753957
101	0.74927	106	0.82015	101	0.82665	106	0.75365	101	0.749471
110	0.74211	110	0.79612	203	0.79394	203	0.73179	107	0.742676
107	0.72523	101	0.75686	110	0.76725	107	0.71383	203	0.716167
113	0.71828	113	0.71899	302	0.74500	112	0.69023	108	0.689151
302	0.69642	112	0.71568	107	0.72071	110	0.66753	302	0.664934
204	0.67782	107	0.71056	113	0.71893	302	0.65732	112	0.648461
108	0.63784	302	0.70990	112	0.69707	108	0.65188	204	0.640215
304	0.63744	204	0.66036	108	0.68333	204	0.64305	110	0.636678
102	0.63225	108	0.64895	304	0.67445	113	0.63962	113	0.633429
301	0.61839	304	0.64494	305	0.65254	305	0.62000	305	0.608269
205	0.59052	102	0.63164	102	0.64372	102	0.59579	205	0.602659
		305	0.61865	301	0.63492	301	0.58907	102	0.594937
		301	0.61833	204	0.62949	304	0.56969	301	0.594513
		303	0.60755	303	0.61465	205	0.55596	304	0.584625
		202	0.60462	205	0.60683	303	0.54045	303	0.558181
		205	0.59107	202	0.57813	202	0.53653	202	0.557255
Average	0.75904		0.76018		0.77827		0.72600		0.72435

scores of model 1 is 0.966 and the correlation between CRS and VRS efficiency scores of model 2 is 0.921. Both of these models are significant at the 0.01 level. And the results are also robust to the ownership of the firms.

The results for DEA model 1 presented in Table 4 suggest that state-owned companies are significantly more efficient than privatized companies. In each year of the period 1999-2002, the most efficient RECs tend to be state-owned companies. Furthermore, the RECs with the lowest efficiency are privatized firms. Thus, model 1 produces a pattern of weak relative performance for privatized RECs (summarized in Table 5). For example, using DEA1, the five RECs privatized in 1998 (Investment Pool companies) have an average efficiency score of .705 for the period, while the publicly owned RECs have an average score of .806. Figure 2 depicts a general downward trend from 2000 to 2002 for all RECs, but Investment Pool companies have the greatest decline of efficiency scores following privatization in 1998. Similarly, companies privatized in 2001 have sharp drops in their efficiency scores after privatization. This outcome runs counter to expectations regarding the efficiency impacts of privatization.[19]

To understand why model 1 provides an unexpected view of relative performance, we utilize DEA model 2 which takes network losses into account by adding a third input (electricity purchased by the REC). For Ukraine, as well as for most transitional and developing countries, commercial and technical losses are a significant source of net revenue losses. As a result of high network losses (beyond the targets), distribution companies will have inadequate revenue to cover all reasonable costs that are allowed by the regulator. The result is that such companies have actual operational costs that are lower than required for long term sustainability. For example, company 104, which had a high efficiency score in DEA1, is identified as far less efficient in DEA2. One explanation is that it has not had funds for maintaining network equipment and for cutting network losses. Reductions in such losses are evidence of improved efficiency, associated with value maximization. As shown in Tables 6 and 7, relative efficiency scores have changed significantly with the incorporation network losses into the DEA.

Figure 2: Dynamics of efficiency scores for state owned and privatized companies. Model 1 (1998-2002)



[19] We argue that regulatory incentives explain this outcome. Kumbhakar and Hjalmarsson (1998) explore some of the implications of yardstick comparisons in the context of incentive mechanisms and corporate governance.

Table 5: Summary Statistics by Ownership for DEA Model 1 Efficiency Scores

Companies	Summary	1998	1999	2000	2001	2002
State owned	MEAN	**0.786**	**0.818**	**0.847**	**0.794**	**0.786**
	SD	0.114	0.126	0.137	0.140	0.139
	Max	1.000	1.000	1.000	1.000	0.999
	Min	0.632	0.632	0.644	0.596	0.595
	N	11	14	14	14	14
Privatized in 1998 by Investment pool	MEAN	**0.765**	**0.719**	**0.699**	**0.666**	**0.675**
	SD	0.134	0.142	0.134	0.134	0.118
	Max	0.931	0.910	0.886	0.862	0.859
	Min	0.591	0.591	0.578	0.537	0.557
	N	5	5	5	5	5
Privatized in 2001 by VSE	MEAN	**0.618**	**0.615**	**0.634**	**0.583**	**0.587**
	SD	0.000	0.006	0.019	0.040	0.026
	Max	0.618	0.619	0.653	0.620	0.608
	Min	0.618	0.608	0.615	0.540	0.558
	N	1	3	3	3	3
Privatized in 2001 by AES	MEAN	**0.667**	**0.677**	**0.710**	**0.614**	**0.625**
	SD	0.042	0.046	0.050	0.062	0.057
	Max	0.696	0.710	0.745	0.657	0.665
	Min	0.637	0.645	0.674	0.570	0.585
	N	2	2	2	2	2

Model 2 includes purchased electricity as an input, so higher network losses result in lower efficiency scores. DEA model 2 (pooled data) yields results different from those obtained with model 1 (see Table 5); nevertheless, the average annual efficiency scores for all groups are very close. The lowest efficiency score for DEA2 is .74, compared with .56 for DEA1.[20] Table 6 shows that the average efficiency scores of the companies privatized in 1998 (.952) exceed those of state-owned RECs (.893). The efficiency scores of the state-owned companies dropped rapidly in 2000-01. By comparison, the efficiency scores of the privatized companies dropped only a little and recovered to the same level as before, which suggests that their performance is more stable, as managers could adapt to exogenous shocks.[21]

[20] State-owned company 103 is still one of the most efficient companies during this period using DEA2. However, the measured performance of the companies privatized in 1998 improves significantly. REC 205 was one of the top three companies in the four consecutive years. In year 2002, the top three companies are from the group privatized in 1998.

[21] Clear conclusions cannot be drawn for privatized firms that had only one year to adapt to regulatory incentives under new ownership. Companies privatized by AES in 2001 had increases in their efficiency scores after privatization. However, companies privatized by VSE in 2001 had decreases in their efficiency scores after privatization.

Table 6: Efficiency Scores for Model 2 (pooled data)
(Companies Privatized in 1998 by Investment Pool Are Highlighted)

1998		1999		2000		2001		2002	
Company	CRS	Company	CRS	Company	CRS	Company	CRS	Company	CRS
205	1.00000	103	1.00000	114	1.00000	103	1.00000	205	1.00000
106	0.97606	114	1.00000	205	1.00000	205	0.99504	202	0.99565
202	0.97235	205	0.99036	103	0.99813	202	0.97809	204	0.99423
204	0.94645	202	0.97296	110	0.99421	101	0.97062	103	0.99160
104	0.93449	106	0.95695	202	0.97473	114	0.96061	110	0.99006
301	0.93073	303	0.95557	104	0.95339	110	0.95495	114	0.95881
110	0.92487	203	0.95189	101	0.95229	204	0.95465	101	0.95156
304	0.92479	112	0.94598	203	0.94768	104	0.93448	304	0.93908
302	0.92425	204	0.94549	106	0.93843	106	0.91633	106	0.93323
203	0.91397	104	0.93522	204	0.93298	203	0.91430	301	0.92622
101	0.90446	110	0.93520	112	0.93292	304	0.91078	104	0.92258
113	0.90352	304	0.92680	111	0.93141	301	0.90986	203	0.92079
111	0.89258	302	0.91673	304	0.92920	112	0.89209	201	0.89601
201	0.88602	201	0.91499	302	0.92729	303	0.88714	113	0.89426
102	0.86321	111	0.90904	201	0.92012	201	0.88582	112	0.88684
107	0.81128	113	0.89854	301	0.90699	113	0.88189	302	0.87886
109	0.79653	101	0.89544	113	0.90027	302	0.85657	303	0.87723
108	0.79309	109	0.89361	102	0.89644	305	0.85370	102	0.85012
105	0.73855	301	0.88148	303	0.87311	111	0.85154	105	0.84012
		102	0.85328	109	0.87208	102	0.84498	111	0.82387
		107	0.81478	107	0.81458	108	0.78494	109	0.81204
		108	0.76340	105	0.80968	109	0.78121	108	0.78660
		305	0.76204	108	0.80704	105	0.78001	305	0.78434
		105	0.74093	305	0.79937	107	0.75869	107	0.74697
Average Score									
	0.89670		0.90670		0.91718		0.89410		0.90004

Table 7: Summary Statistics by Ownership for DEA Model 2 Efficiency Scores (pooled data)

Companies	Summary	1998	1999	2000	2001	2002
State owned	MEAN	**0.874**	**0.896**	**0.918**	**0.887**	**0.891**
	SD	0.073	0.082	0.069	0.079	0.077
	Max	0.976	1.000	1.000	1.000	0.992
	Min	0.739	0.741	0.807	0.759	0.747
	N	10	13	13	13	13
Privatized in 1998 by Investment pool	MEAN	**0.944**	**0.955**	**0.955**	**0.946**	**0.961**
	SD	0.045	0.029	0.032	0.045	0.049
	Max	1.000	0.990	1.000	0.995	1.000
	Min	0.886	0.915	0.920	0.886	0.896
	N	5	5	5	5	5
Privatized in 2001 by VSE	MEAN	**0.931**	**0.866**	**0.860**	**0.884**	**0.863**
	SD	0	0.098	0.055	0.028	0.072
	Max	0.931	0.956	0.907	0.910	0.926
	Min	0.931	0.762	0.799	0.854	0.784
	N	1	3	3	3	3
Privatized in 2001 by AES	MEAN	**0.925**	**0.922**	**0.928**	**0.884**	**0.909**
	SD	0.0004	0.007	0.001	0.038	0.043
	Max	0.925	0.927	0.929	0.911	0.939
	Min	0.924	0.917	0.927	0.857	0.879
	N	2	2	2	2	2

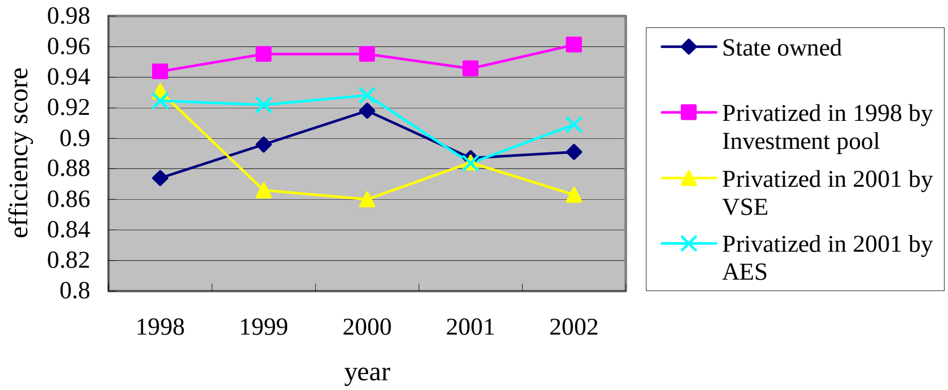
Note that even in model 2, companies did not improve their efficiency scores substantially after privatization. There are two potential reasons for this pattern. First, they began with relatively high performance, so it may not have been easy for them to improve operating efficiency and reduce network losses. A second explanation is that increases in operating expenses allowed regulated profit-maximizing firms to increase cash flows. Because of flaws in regulatory incentives (cost-plus mark-up regulation with short regulatory lags), managers of companies privatized in 1998 more than doubled operational costs per kWh delivered (Table 8). However, some of excessive earnings were applied to the reduction of network losses which had offsetting impacts on efficiency scores measured in DEA2 (Figure 3).

Table 8: Operational Costs per kWh Delivered (UAH/MWh)

	1998	2002
Privatized in1998	16.6	37.9
Public 1998-2002	17.9	25.2

The dramatic difference is also captured in model 1, where operational costs are one of the two inputs—leading to relatively low efficiency scores under DEA1. However, model 2 includes purchased electricity as an input; privatized RECs were able to significantly reduce network losses—raising their efficiency scores relative to those RECs that remained publicly owned over this period.

Figure 3: Dynamics of efficiency scores for state owned and privatized companies. Model 2 (1998-2002)



What might explain the differential responses of privatized and public firms to regulatory incentives? If a government-owned REC reduces network losses, the enhanced cash flows do not benefit managers unless there is a strong governance system that rewards improved performance. In the case of privately owned RECs, those cash flows go directly to the bottom line: investors are pleased and managers are rewarded. However, increases in expenses also benefit investors under mark-up regulation. Managers are attuned to internal rewards associated with reductions of network losses and (acceptable) increases in operating expenses. Thus, managers of privatized firms can devote resources to convincing NERC of REC cash flow needs, justified by increases in operational costs. In the absence of careful regulatory benchmarking or cost disallowances, managers do not have incentives to hold down operational costs.

In model 1, privatized distribution companies in Ukraine appear to be less efficient than state-owned companies. One explanation is that the regulator approves revenues for all companies sufficient to cover all "reasonable" expenditures, but private companies earn excessive revenues associated with excessive costs. Alternatively, it is possible that both state and private companies may be allowed inadequate revenues to provide services and maintain network quality, but private companies, with stronger internal incentives, are more successful in justifying higher revenue requirements.

Thus, managers of the private companies incur higher operational costs with mark-up regulation, short review lags, and lack of consumer participation in the regulatory process. Such managers may understand the regulatory environment better than the managers of state-owned enterprises, or the latter may face greater local political pressure to keep prices (and therefore costs) down. So when we consider the operational costs as the only controllable input, the state-owned companies' efficiency scores are significantly higher than those of private companies. However, managers of the private companies have more incentives to enhance profits and have been more successful at reducing network losses, which directly increases the cash flow of the companies under the binding constraint for allowed level of network losses (each company has a specific normative loss target that depends on topology of networks, electricity flows, etc.). Managers of state-owned enterprises may be more susceptible to "looking the other way" when confronting the issue of electricity theft or nonpayment, depending on the governance procedures and benchmarking utilized by government bureaucrats. This factor offsets the impact of their greater cost efficiency (from model 1). When we include network losses (model 2), the efficiency values of the private companies are better than those of the state-owned companies.

5. TESTING THE ROBUSTNESS OF THE CONCLUSIONS TO MODEL SPECIFICATION

To make informed decisions regarding electricity distribution companies, regulators need accurate information about the likely effects of their decisions on firm performance. The two nonparametric DEA models (Section 4) are unlikely to be totally persuasive regarding the impacts of incentives. This section presents a stochastic frontier analysis (SFA) to derive alternative indicators of REC technical efficiency. We test whether REC efficiency is sensitive to the choice of the scorecard methodologies and to the inclusion of environmental variables.[22]

5.1 Stochastic Frontier Analysis

An advantage of the SFA analysis is that it attempts to account for the effects of noisy data. Compared with DEA and regression analysis, deviations are attributed to the inefficiency. The disadvantage of SFA is that it assumes specific distributions for the random shock and inefficiency. A production frontier model can be written as:

$$y_i = f(x_i;\beta)\cdot TE_i \quad \text{, where} \tag{6}$$

y_i is the scalar output of producer i, i=1,…, N,
$f(x_i;\beta)$ is the production frontier, where x_i is a vector of K inputs used by producer i,
β is a vector of technology parameters to be estimated,
TE_i is the output-oriented technical efficiency of producer i.

In econometric models, production frontiers are generally characterized as smooth, continuous, differentiable, quasi-concave production transformations. The above model (6) is classified as *deterministic frontier model* which attributes to technical inefficiency the entire shortfall of observed output y_i from maximum feasible output. The stochastic production frontier incorporates producer-specific random shocks into the analysis, as shown in equation 7.

$$y_i = f(x_i;\beta)\cdot \exp\{v_i\}\cdot TE_i \tag{7}$$

[22] Another way to compare the performance between groups is proposed by Brockett and Golany (1996). It is possible that one of the groups, say private, attracts a larger proportion of efficient managers than the other group, which makes the private group more efficient. In order to adjust for the managerial efficiency differences while evaluating the group efficiency between the two groups, they propose a four step procedure: First, separate all DMUs into two groups (private and state-owned in this case). Second, in each group, adjust the inefficient DMUs to their "level if efficient" value by projecting each DMU onto the efficiency frontier of its group. Third, run a pooled DEA with all the adjusted DMUs. Fourth, apply Mann-Whitney rank test to the result of the third step to test the null hypothesis that the two groups have the same distribution of efficiency values within the pooled DEA set. The implicit assumption of this method is that all the private (and state-owned) firms will be at the same efficiency level within their own group if we exclude the manager/human resource allocation problem. Although this is a very strong assumption, we followed the procedure and rejected the null hypothesis at 0.001 level (Z = -5.836).

where $f(x_i;\beta)\cdot\exp\{v_i\}$ is the stochastic production frontier. The producer-specific part, $\exp\{v_i\}$, captures the effects of random shocks on each producer.

$$TE_i = \frac{y_i}{f(x_i;\beta)\cdot\exp\{v_i\}} \tag{8}$$

In this case, y_i achieves its maximum feasible output $f(x_i;\beta)\cdot\exp\{v_i\}$ if and only if $TE_i=1$. Otherwise, $TE_i<1$ provides a measure of the shortfall of observed output y_i from maximum feasible output in an environment characterized by stochastic element $\exp\{v_i\}$.

Equation (8) can be rewritten as

$$y_i = f(x_i;\beta)\cdot\exp\{v_i\}\cdot\exp\{-u_i\} \tag{9}$$

$TE_i = \exp\{-u_i\}$. Since $TE_i<1$, we have $u_i>0$.

Utilizing the Log-linear Cobb-Douglas functional form, (9) can be written as:

$$Y_i = \ln y_i = \beta_o + \sum_n \beta_n \ln x_{ni} + v_i - u_i = \beta_o + \sum_n \beta_n \ln x_{ni} + \varepsilon_i \tag{10}$$

In a more general form, the model can be expressed as:

$$y_i = f(x_i;\beta) + v_i - u_i = f(x_i;\beta) + \varepsilon_i \qquad ,i=1,...,N, \tag{11}$$

where Y_i is the logarithm of the production of the i-th firm in (10);

x_i is a k×1 vector of (transformations of the) input quantities of the i-th firm;

β is a vector of unknown parameters;

v_i ~ iid $N(0,\sigma_v^2)$;

u_i ~ iid $N^+(0,\sigma_u^2)$ (half normal model);

u_i ~ iid $N^+(\mu,\sigma_u^2)$ (truncated normal model); and

v_i and u_i are distributed independently of each other, and of the independent variables.

The half normal stochastic frontier model and the more general truncated normal stochastic frontier model are both employed in this research to avoid arbitrary selection of a specific distribution function. Kumbhakar and Lovell (2000) go into more detail regarding the elements of this Maximum likelihood estimation procedure, developing an expression for the conditional expectation. Thus, we are able to obtain a prediction of the technical efficiency of each utility.

The unbalanced panel was used in the SFA. Battese and Coelli （1995) proposed time-variant models to deal with the panel data in the SFA. However, as Coelli et al. (2002) point out, the time-varying efficiency model restricts the technical efficiency of all firms to follow the same trend direction. However, it is unlikely that efficiency is either increasing over time or decreasing over time for each of the firms in the Ukraine. Following Coelli et al. (2002) and Estache, Rossi and Ruzzier (2000), we add a time term in the production function to represent the technical change. The SFA version of model 2[23] can be expressed as following:

$$\ln Edel = \beta_0 + \beta_1 \ln OPEX + \beta_2 \ln NetLength + \beta_3 \ln Einput + \alpha t + v_i - u_i \qquad (12)$$

where:
Edel: Electricity delivered
OPEX: Operational Cost
NetLength: Length of the network
Einput: Electricity Purchased

Since the results for the Half Normal and more general Truncated Normal models are highly correlated (correlation>0.98), we only report Half normal model in this study (Table 9):

Table 9: Stochastic Frontier Model

Stoc.Frontier half normal model					Number of obs=115	
					Wald chis(4)=20797.4	
Log Likelihood=122.163					Prob>chi2=0.000	
logEdeliver	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
LogEpurchased	1.005	0.011	90.180	0.000	0.983	1.027
LogNetlength	0.037	0.048	0.760	0.446	-0.058	0.131
LogOPEX	0.062	0.032	1.970	0.048	0.000	0.124
t	-0.015	0.006	-2.590	0.010	-0.027	-0.004
_cons	-1.269	0.275	-4.610	0.000	-1.808	-0.729
/lnsig2v	-7.974	0.902	-8.840	0.000	-9.741	-6.206
/lnsig2u	-3.773	0.173	-21.840	0.000	-4.111	-3.434
sigma_v	0.019	0.008	0.008	0.045		
sigma_u	0.152	0.013	0.128	0.180		
sigma2	0.023	0.004	0.016	0.031		
lambda	8.171	0.019	8.134	8.207		
Likelihood-ratio test of sigma_u=0:			chibar2(01)=7.01 Prob>=chibar(2)=0.004			

The relative importance of inefficiency is measured by $\lambda = \sigma_u / \sigma_v$. Here, $\lambda = 8.17$, which implies that inefficiency is the main source of the deviations from predicted outputs. We also see that the null hypothesis σ_U=0 is rejected at the level p=0.01. Most signs of the control variables are consistent with our expectation. As expected, electricity purchased has positive and significant impact on electricity delivered. The sign of network length is positive but not significant. The estimated sign of the operational cost (OPEX) coefficient is consistent with

[23] To check the robustness of the DEA Model 1 results Tsaplin et al. (2004) employed a log-linear model to estimate a SFA cost function with neutral technological change. As with DEA Model 1, state-owned companies appeared to be more cost efficient than privatized ones. We do not summarize those results here since our focus is on the more comprehensive DEA Model 2.

expectations. Higher OPEX indicates higher REC variable costs (proportional to electricity delivered), increases in capital elements (depreciation and repair), and expenditures on network loss reduction. Thus, OPEX exerts a positive and significant impact on electricity delivered. The time variable, t, reveals a negative time trend.

5.2 Accounting for the Operating Environment in SFA

As noted earlier, the sample turns out not to be very homogeneous, so we construct another model to test the robustness of including the environmental variables. According to Rossi and Ruzzier (2000), a frontier model has two parts: the "core" of the model and the environmental variables. Environmental variables capture external factors that influence the firm's efficiency, yet are not directly under the control of managers. IPART (1999) identified frequently used environmental factors, including customer density, customer mix, demand pattens (peak vs. average), energy density, overhead/underground network mix, supply reliability, climate and the regulatory environment (including institutional and historical factors). Due to limited data availability, only two environmental variables are introduced: customer density (customer number over network length) and customer mix (residential customers over total number of customers).

Consumer density is expected to have a positive coefficient. Higher customer density is associated with higher electricity consumption and delivery. The highest level of electricity losses is in rural, forest, and mountain regions with low customer density. In general the majority of theft and non-payment is in low density rural regions.

The second environmental variable, customer mix, captures the effect of delivering energy at different voltages required by different customers. A higher percentage of residential customers is expected to reduce electricity delivered. The model (Table 10) can be expressed as:

$$\ln Edel = \beta_0 + \beta_1 \ln OPEX + \beta_2 \ln NetLength + \beta_3 \ln Einput + \gamma_1 density + \gamma_2 mix + \alpha t + v_i - u_i \quad (13)$$

Table 10: Stochastic Frontier Model with Environmental Variables						
Stoc.Frontier half normal model					Number of obs=115 Wald chis(4)=17603.1	
Log Likelihood=134.272					Prob>chi2=0.000	
logEdeliver	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
LogEpurchased	1.064	0.017	61.790	0.000	1.030	1.097
LogNetlength	-0.032	0.053	-0.610	0.545	-0.135	0.071
LogOPEX	0.060	0.035	1.720	0.085	-0.008	0.128
logCdensity	-0.243	0.046	-5.270	0.000	-0.334	-0.153
logresident	0.064	0.326	0.200	0.845	-0.576	0.704
t	-0.010	0.007	-1.470	0.142	-0.023	0.003
_cons	-0.335	0.344	-0.970	0.330	-1.009	0.339
/lnsig2v	-6.662	0.541	-12.310	0.000	-7.723	-5.602
/lnsig2u	-4.303	0.254	-16.960	0.000	-4.800	-3.806
sigma_v	0.036	0.010	0.021	0.061		
sigma_u	0.116	0.015	0.091	0.149		
sigma2	0.015	0.003	0.009	0.021		
lambda	3.254	0.023	3.210	3.298		
Likelihood-ratio test of sigma_u=0:			chibar2(01)=6.40 Prob>=chibar(2)=0.006			

The relative importance of inefficiency is measured by $\lambda = \sigma_u / \sigma_v$. The SFA model with environmental variables yields $\lambda = 3.25$, which means that the inefficiency is the main source of the deviations from expected output. We also see that the null hypothesis σ_U=0 is rejected at the level p=0.01. The sign on density is negative, not positive. Similarly, the sign of the customer mix is not consistent with our expectation, nor is it significant. The reason might be the relative small variance of this variable. All the other signs of the coefficients are consistent with expectations.

Rossi and Ruzzier (2000) argued that a dummy variable indicating ownership should not be included in a model intended for yardstick comparisons, since the ownership effect would be netted out from the efficiency measures, thus punishing the firms belonging to the relatively efficient ownership type. However, the inclusion of an ownership variable provides information on the impact of ownership type on performance. We add the ownership as a dummy input (privatised=1, state-owned=0) in equation 12 to check the impact of privatisation on REC efficiency. The results of SFA with three environmental variables are presented in Table 11.

Table 11: Stochastic Frontier Model with 3 Environmental Variables						
Stoc.Frontier half normal model					Number of obs=115	
					Wald chis(4)=24434.73	
Log Likelihood=146.382					Prob>chi2=0.000	
logEdeliver	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
LogEpurchased	1.108	0.017	63.980	0.000	1.074	1.142
LogNetlength	-0.028	0.044	-0.620	0.532	-0.115	0.059
LogOPEX	0.000	0.030	0.010	0.994	-0.059	0.060
logCdensity	-0.217	0.042	-5.120	0.000	-0.299	-0.134
logresident	-0.089	0.298	-0.300	0.766	-0.673	0.496
t	-0.008	0.006	-1.510	0.132	-0.019	0.002
ownership	0.082	0.016	5.130	0.000	0.051	0.114
_cons	-0.205	0.298	-0.690	0.492	-0.788	0.379
/lnsig2v	-6.927	0.549	-12.620	0.000	-8.003	-5.851
/lnsig2u	-4.495	0.246	-18.260	0.000	-4.977	-4.012
sigma_v	0.031	0.009	0.018	0.054		
sigma_u	0.106	0.013	0.083	0.135		
sigma2	0.012	0.002	0.007	0.017		
lambda	3.374	0.020	3.335	3.413		
Likelihood-ratio test of sigma_u=0:			chibar2(01)=6.05 Prob>=chibar(2)=0.007			

With the inclusion of the ownership variable, the estimated coefficients of the control variables have signs consistent with our predictions. The sign of the coefficient of customer mix variable is now negative (though it is still insignificant). The coefficient for density remains negative, suggesting that economies of density outweigh the factors that would contribute to a positive sign. Privatization is shown to exert a positive and significant impact on reducing the network losses. This result confirms the chain of reasoning presented in Section 4.

5.3 Accounting for the Operating Environment in DEA

DEA can also accommodate environmental or non-discretionary variables. This measure-specific DEA models was first proposed by Banker and Morey (1986). Let $I \subseteq \{1,2,\cdots,m\}$ and $O \subseteq \{1,2,\cdots,s\}$ represent the sets of controllable inputs and outputs, respectively. Based upon DEA, we can obtain a set of measure-specific models where only the inputs associated with I or the outputs associated with O are optimized. The models determine the maximum potential decrease/increase of the controllable (preferable) inputs/output while keeping other inputs and outputs at current levels. It can be expressed as:

$$
\begin{aligned}
&\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
&s.t. \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{io} \, (i \in I) \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \, (i \notin I) \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \, (r = 1,2,\cdots,s) \\
&\lambda_j \geq 0; \, j = 1,2,\cdots,n \\
&s_i^-, s_r^+ \geq 0
\end{aligned} \tag{14}
$$

The correlation matrix of different methods is showed in Table 12, where DEA2 refers to the 3 input and 2 output DEA model (model 2), DEAen is model 2 plus 2 environmental variables, SFA is the SFA model without environmental variables and SFAen is the SFA model with environmental variables.

Table 12:Correlations of Efficiency Scores

		DEA2	DEA en	SFA	SFAen
DEA	Pearson Correlation	1	0.719**	0.767**	0.830**
	Sig. (2-tailed)	.	.000	.000	.000
	N	115	115	115	115
DEA en	Pearson Correlation	0.719**	1	0.380**	0.661**
	Sig. (2-tailed)	.000	.	.000	.000
	N	115	115	115	115
SFA	Pearson Correlation	0.767**	0.380**	1	0.901**
	Sig. (2-tailed)	.000	.000	.	.000
	N	115	115	115	115
SFA en	Pearson Correlation	0.830**	0.661**	0.901**	1
	Sig. (2-tailed)	.000	.000	.000	.
	N	115	115	115	115

** Correlation is significant at the 0.01 level (2-tailed).

From the table, we see that the efficiency score of DEA model 2 is highly correlated with those of all the three other models. Thus, our analysis is robust to the model choice (non-parametric DEA vs. parametric SFA) and the inclusion/exclusion of environmental variables. The correlation between SFA and SFAen is also very high and significant at the 0.01 level. In addition, the scores for DEAen are highly correlated with SFAen. More importantly, all these models show that the efficiency scores of privatized firms are significantly higher than those of state-owned companies, once line losses are incorporated into the models.

6. CONCLUDING OBSERVATIONS

The cost-based DEA model (DEA1) shows significant cost inefficiency of privatized companies, especially for companies privatized in 1998 by Investment Pool. However, the inclusion of network losses in the DEA model (DEA2) leads to comparable efficiency scores for state-owned and privatized companies. It appears that in response to the regulatory environment, private RECs are more motivated than state-owned companies to optimize their financial position, and are more interested in deferring maintenance and reducing network losses to improve cash flows (primarily by reducing nonpayment by residential and some large customers and reducing electricity theft). However, private RECs are more willing to inflate their operating costs—in response to the cost-plus nature of incentives.

Both state-owned and privatized companies have incentives to reduce electricity losses to target levels; otherwise, a private company's profit (shareholders' value) falls and a state-owned company can face financial distress. However, we have some evidence that state-owned companies do not address electricity distribution network losses as effectively as privatized companies, perhaps due to low managerial motivation (weak governance systems). The results also suggest that, in contrast to state-owned firms, privatized companies responded aggressively to the regulatory incentives associated with the cost-plus price formula. One explanation of the differential behavior is that managers and employees of state-owned RECs have weak internal incentives for loss reduction. Low salaries in state-owned companies provide weak incentives for high performance. Also, local political pressure can reduce managerial interest in addressing the severe problem of network losses.[23]

The current Ukraine regulatory framework that uses mark-up regulation provides weak incentives for cost containment by RECs, allowing managers to inflate costs. According to model 1, managers of privatized firms appear to be increasing shareholder value through cost inflation that can be passed through to customers via tariff increases. The short time lag between rate reviews means that cost-containment is not rewarded and cost-inflation is not punished.[24] In addition, the results from models 1 and 2 underscore the sensitivity of performance rankings to alternative specifications of DEA models. The results from the stochastic frontier analysis (reported in Section 5) are comparable to those from DEA, even with the inclusion of customer density and customer mix variables, indicating the consistency of performance rankings across methodologies. Privately owned firms do respond to incentives that add to net cash flows (associated with reducing commercial and non-commercial network losses). However, they also respond more aggressively than do state-owned distribution utilities to mark-up (cost-plus) regulatory incentives that increase profits but decrease efficiency. Thus, comparisons of public and private utility performance need to be explicit about the incentive regimes facing both ownership types.

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[23] We must be somewhat cautious in interpreting the results of Models 1 and 2 because there is a potential endogeneity problem. Perhaps the privatized firms were selected because of the better potential for reducing such losses. In fact, on average, they had slightly lower losses in 1998, the year of the first privatization. However, preliminary analysis using an event study (Tsaplin 2001) indicates that privatization led to decreases in network losses.

[24] Our results are consistent with findings by Arocena and Price (2002), who conclude that publicly owned companies in Spain are more efficient under cost-of-service regulation and private firms are more efficient under price cap regulation. Efficiency studies of privatized firms under incentive regulation could be used to establish benchmarks in setting prices for state-owned companies.

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