

# The Effects of Incentive Regulation on Quality of Service in Electricity Markets

by

Anna Ter-Martirosyan\*

Working Paper, March 2003

## Abstract

Starting from the late 80s incentive regulation has replaced rate of return regulation in many states of the U.S. By creating a profit opportunity, the shift to incentive regulation encourages the regulated utility to reduce its costs, which might result in quality cuts. This paper examines the impact of state incentive regulation on two dimensions of quality of service, the average duration and the frequency of electric outages in the electric utility industry of the U.S. between 1993 and 1999. The study is based on a panel data set for 78 major utilities from 23 states of the U.S. It finds that incentive regulation is associated with an increase in the average duration of electric outages, but the implementation of explicit quality benchmarks reduces the average duration of outages per customer. This paper also finds that incentive regulation reduces the utility's operational and maintenance expenses at the distribution level, which engenders an increase in the duration of electric outages.

\*Department of Economics, George Washington University, [atermart@gwu.edu](mailto:atermart@gwu.edu)

## 1. Introduction

Traditionally, federal and state regulatory agencies have used rate of return regulation to set prices for utilities in telecommunications and electric industries. Under rate of return regulation, prices are set to assure a specific return on investment after recouping all incurred operating costs. Therefore, the utilities may have relatively little incentive to minimize costs, since the cost reduction causes decreases in prices and, therefore, in profits. Starting from the late 1980s, incentive regulation (or performance-based regulation) has replaced rate of return regulation in many states of the U.S. Incentive regulation is a general approach that includes a wide range of mechanisms like price caps, revenue caps, rate freezes and moratoriums, and revenue sharing. All these mechanisms create a profit opportunity and encourage the utility to reduce its costs and to innovate the production technology and service.

However, there are also concerns that with the shift to incentive regulation the regulated utility may reduce its quality of service to achieve additional cost savings. For example, in 1996 the Oregon Public Utility Commission terminated its price cap regulation plan for US West due to a quality decline (Ai and Sappington 1998).

Ongoing liberalization in the electricity sector promises to revolutionize the utilities by unbundling traditionally vertically integrated generation, transmission, and distribution of electricity, and introducing competition into generation and transmission sectors. As a result, it becomes more important to examine how regulatory regimes influence the quality of service of distribution utilities.

A significant variation of regulatory policy across states represents a good opportunity for econometric analysis. Many empirical studies to date examine the effects of

incentive regulation on prices, costs, profits, and other characteristics of regulated utilities.<sup>1</sup> However, there is no study that addresses quality impacts of incentive regulation in the electric utility industry and only few studies that examine this issue for the telecommunications sector.

Tardiff and Taylor's (1993) cross-sectional study examines the impact of incentive regulation on quality for telecommunications industry in 1990-91. They find that explicit quality standards improve performance and there is no quality deterioration for states with incentive regulation compared to the states with rate of return regulation. Ai and Sappington (1998) use a panel approach to analyze the impact of incentive regulation on various quality measures in the telecommunications industry from 1990 to 1996. They find "no systematic link between incentive regulation and service quality, broadly defined".<sup>2</sup> Clements (2001) also uses a panel approach for the telecommunications industry from 1991 to 2000 and finds that price cap/rate freeze regulation is associated with lower quality of service compared to rate of return and earnings sharing regulation; he also finds that quality standards are associated with lower quality.

This paper extends the previous studies in three directions. First, it is the first study that examines quality impacts of incentive regulation in the electric utility industry. Second, it explicitly incorporates quality standards in a panel study and accounts for a possible endogeneity of both incentive regulation and quality benchmarks. Finally, it also studies the channels through which incentive regulation can affect quality, in particular, operations and maintenance expenses of electric utilities.

---

<sup>1</sup> For the electric utility industry see, for example, Berg and Jeong (1991) and St. Marie (1996); for a comprehensive survey of the empirical studies on the effects of incentive regulation in telecommunications, see Sappington and Weisman (1996).

<sup>2</sup> Ai and Sappington (1998): 2.

The rest of this paper is organized as follows. In section 2 I briefly define types of incentive regulation plans and discuss evolution of incentive regulation in the electric utility industry of the U.S. In section 3 I discuss the measures of quality for the distribution utilities and problems associated with data. Section 4 describes the related literature and empirical methodology. Section 5 presents estimates of the impact of incentive regulation on the duration and frequency of electric outages. Sections 6 analyses the relationships among incentive regulation, operations and maintenance expenses, and quality of service. Section 7 provides a brief summary of the main findings.

## 2. Incentive Regulation in Electric Utility Industry

The most commonly used regimes of incentive regulation in the electric utility industry are rate case moratoriums, rate freezes, price and revenue caps, and revenue sharing. Rate case moratorium is an agreement between the utility and the state public utility commission to discontinue rate cases for a specific period of time. Thus systematic increase or decrease of rates is not permitted, but some individual rate elements may be changed. Under a rate freeze, the company cannot change any of its rates during the commitment period. For price cap regulation the initial rates are set based on the costs and then rates are permitted to increase from year to year to allow for inflation, but they are also required to decline over time to encourage increased productivity. Revenue cap is similar to price cap but focuses on allowed revenues rather than allowed prices. The regulating commission sets an allowed level of revenues based on actual costs for a test year. Over time, the allowed level of revenues can be adjusted to account for inflation and productivity. Revenue sharing may be a part of any incentive regulation plan mentioned above. Under

revenue sharing the regulated utility is usually allowed to keep all earnings in the pre-determined return band, and share any earnings in excess of that return with its customers.

All these mechanisms, if compared to traditional rate of return regulation, weaken the link between a utility's rates and its unit cost of service. Therefore they encourage the utility to reduce its costs and innovate its production technology and service. The extent of these effects can be more pronounced under some regimes than under others. For example, depending on the width of the bands and the level of sharing, revenue sharing can provide minimal or large incentives for the firm to alter its strategic operations. Or, price cap can have more effects on costs since this regime is usually set for a longer period of time than rate freeze or rate case moratorium.

However, there are also concerns that with incentive regulation the firm might reduce quality of service in order to achieve additional cost savings. This possibility is widely recognized and many remedies are used to prevent quality deterioration. For example, the National Association of Regulatory Utility Commissioners (NARUC, 1997) points out that under price caps and other performance-based regulation plans, "unfettered incentives to reduce costs could result in unacceptable declines in service quality". Many states explicitly incorporate quality standards into incentive regulation plans. Often financial penalties and/or rewards are used when the regulated utility meets certain quality criteria.<sup>3</sup>

The history of incentive regulation is in the electric utility industry of the U.S. is relatively short compared to the telecommunications industry. The first comprehensive incentive regulation plans were implemented in the early 90s. In 1991 the New York Public Utility Commission approved an incentive regulation plan for Niagara Mohawk Power Company as a measure to remedy against poor performance of the company; the plan

---

<sup>3</sup> For example, New York State Regulatory Commission currently implements six performance incentive plans and each of them contains different sets of quality benchmarks and associated with them penalties.

produced considerable improvement and was terminated in 1995. In 1991 the Maine Public Utility Commission also approved revenue-per-customer cap for Central Maine Power effective over a three year period; however, the plan was not successful: the rates increased substantially over the three year period. Since then about 20 states in the U.S. have implemented some kind of incentive regulation. According to Sappington et al. (2001), of the 24 electric utilities that were under incentive regulation in 2000, 11 utilities operated under price cap and 12 operated under some forms of rate freezes or rate case moratoriums. 22 utilities also had some kind of earnings sharing provision. Unfortunately, there is no comprehensive study that evaluates how quality provisions are integrated in incentive regulation plans. The recent survey conducted by the National Regulatory Research Institute was intended to fill this gap. According to the survey, 23 states out of 40 respondents reported and monitored outage-related data in 2000, 13 had quality benchmarks and 7 had explicit rewards and/or punishment for meeting the standards. However, only 6 states account for service quality as a part of their incentive regulation mechanism.<sup>4</sup>

Table 1 presents the evolution of incentive regulation plans in the US. It shows that 66 percent of incentive regulation plans in 2000 have incorporated explicit quality benchmarks related to outages. Some states had quality provision as part of an incentive contract from the very beginning; others have included them later on.<sup>5</sup> While the New York State Public Utility Commission has developed a rigorous set of quality benchmarks and

---

<sup>4</sup> It should be noted that at least two states among non-respondents (California and Mississippi) also had incentive regulation plans.

<sup>5</sup> For example, the State Public Utility Commission of Oregon terminated performance based regulation plan for Pacific Power in 1995 because of low quality of service and renewed it in 1998 after incorporating strict quality standards for SAIDI and SAIFI.

associated with them penalties for utilities, several states do not even require reporting outages from utilities with incentive regulation plans under their jurisdiction.

In the next section I will briefly discuss the measures of quality of service that are available for a researcher.

### 3. Quality of Service for Electric Utilities: Data Issues

Lack of uniform measures of quality of service for electric utilities presents a considerable challenge for a researcher who is interested in studying the quality effects of regulation. Although there are numerous dimensions of quality of service that can be established,<sup>6</sup> presently outage-related indices are the only relatively widely accepted measures of quality across the electric utilities in the US. The most widely used indices are average duration and average frequency of electric outages.<sup>7</sup>

The System Average Interruption Duration Index (SAIDI) is computed by dividing the sum of all customer interruption durations by the number of customers served.<sup>8</sup> System Average Interruption Frequency Index (SAIFI) measures the average frequency of interruptions. It is computed by dividing the total number of customers interrupted in a year by the average number of customers served during the year.

In general, causes of electric outages can be classified as either external or internal ones. Internal factors, such as the equipment procurement and maintenance practices, can

---

<sup>6</sup> The list of recommended by National Association of Regulatory Utility Commissioners (NARUC, 1997) measures of service quality at the electric distribution level includes customer conduct indices, power quality indices and outage indices.

<sup>7</sup> Surveys conducted by the Institute of Electrical and Electronics Engineers in 1995 shows that 83 and 88 percent of the utilities which responded calculate outage related indices, SAIFI and SAIDI.

<sup>8</sup> For example, if a utility's customers were out of service for a total of 1,000,000 minutes during the year and the utility serves 20,000 customers, SAIDI would equal 50 minutes per customer.

be controlled by the utility. External factors include climate, and physical characteristics of the service territory. While external factors are usually outside of the utility control, it should be noted, that the utility could mitigate them through internal factors. For example, a utility can adopt practices to be better prepared for ice storms if they are relatively common in the region, or develop special tree-trimming programs to improve system reliability if tree-caused outages are a frequent problem.

It worth to be noted, that operation and maintenance practices are essential to controlling electric outages. When a utility experiences financial pressure, or simply has more incentives to cut its expenditures, the reliability can be affected. For example, according to APPA (1996), special tree-trimming expenditures often fall victim to cost savings and get postponed or cancelled due to lack of funding.

While outage-related indices appear to be the most standardized quality measure for electric utilities, there are still considerable differences among utilities in the ways how they define and measure interruptions.<sup>9</sup> In addition, the length of history of data collection varies considerably across states. Moreover, historic data on SAIDI and SAIFI are not published and cannot be easily accessed. Through extensive correspondence with state public utility commissions I have been able to collect the data on several years in the 1993-1999 time range for 23 states, 78 investor-owned utilities in total.

Chart 1 shows how SAIDI and SAIFI indices differ across the utilities with and without incentive regulation. If one compares utilities with incentive regulation without quality standards to all utilities, the collected data show statistically significant differences

---

<sup>9</sup> For example, some utilities define an interruption as a loss of service for a specific period of time as one minute; others use two minutes or five minutes, or even fifteen minutes. In addition, the majority of utilities report outages only after excluding major weather events caused by weather storms, while several other utilities report only total outages. Moreover, the definition of a “major weather event” varies considerably across the states and different utilities.

for both duration and frequency of electric outages. The mean outage duration for the utilities with incentive regulation without quality standards is 64 percent (13 percent for outage frequency) higher than the mean outage duration for all utilities. However, if the utility has an incentive plan with explicit quality standards then the mean outage duration is lower than mean for all utilities by 26 percent (23 percent for outage frequency). These differences are persistent across all years. Although this does not necessarily imply that these differences are caused by incentive regulation; however, the data encourages further research.

#### 4. Empirical Methodology

My empirical model is analogous to one employed by Ai and Sappington (1998) for the telecommunications industry with important modifications: I incorporate the quality standards into the vector of explanatory variables to distinguish the effects of regulatory contracts with and without quality provisions. Also, in order to isolate any effects of regulatory regime on quality of service, I include important determinants of electric outages specific to the electric utility industry. Because the length of time series for each utility is limited by available observations on quality indices SAIDI/ SAIFI, and very few changes of regulatory regimes occur during that time, I apply a random effects approach to the unbalanced panel data, 1993-1999. I estimate equations in the following form:

$$q_{it} = \alpha_0 + \sum \delta_j R_{j it} + \gamma Q_{it} + \beta Y_{it} + \mu_i U_i + \delta_t T_t + \varepsilon_{it} \quad (1)$$

Where  $q_{it}$  denotes the realization of the relevant outage index (SAIDI / SAIFI) for firm  $i$  in year  $t$ .  $R_j$  is regulatory regime dummies and  $Q$  is quality standards dummy.  $U_i$  and  $T_t$  represent the utility-specific and time-specific dummy variables, included to reduce the likelihood of omitted variables bias. The error term is  $\varepsilon_{it}$ , and  $Y_{it}$  is a vector of other explanatory variables. I assume that error terms  $\varepsilon_{it}$  are uncorrelated with  $Y_{it}$ ,  $U_i$  and  $T_t$ . However, incentive regulation dummy and quality standard dummies can be correlated with the errors term, since the choices of regulatory regime and quality benchmarks can be endogenous. In section 5 I will address this issue in more details.

Below I describe explanatory variables used in the estimation.

Incentive regulation dummy  $R_j$  is equal to one when the utility has an incentive regulation plan in the given year and takes a value of zero otherwise. There are four regulatory schemes currently used in the electric utility industry of the US: rate case moratoriums, rate freezes, price caps and revenue caps. Because of the limited number of utilities with each regulatory regime, I use one dummy variable incentive regulation IR, for all types of incentive regulation plans. This pooling can be justified by the fact that theoretically all these mechanisms have a similar impact on the quality of service: by weakening the link between a utility's rates and its unit cost of service, they create an incentive for quality cuts. However, in addition to the main model, I will also estimate a separate model including separate regulatory regime dummies for each regulatory regime. Also, I estimate a model that employs a dummy for revenue sharing, SHARING (takes a value of one if incentive regulation has sharing provision and zero otherwise), since the majority of incentive regulation plans implement earnings sharing with customers, and theoretically revenue sharing may decrease the incentives for cost cutting.

Quality dummy  $Q$  takes a value of one if the quality standards are explicitly incorporated in incentive regulation plan for utility  $i$  plan in year  $t$  and the utility pays penalties for violating these standards.<sup>10</sup>

There are several additional variables included in the vector  $Y$ , that account for specific characteristics of electric utilities, and economic characteristics of service territories:  $INCOMER\_PER$ ,  $POLEMILES\_PER$ ,  $UNDERGROUND\_SHARE$ ,  $SELF\_GENERATION$  and  $WEATHER$ .

$INCOME\_PER$  denotes an average income per capita on the territory served by utility, expressed in thousands of dollars per person. Income variable is used as a measure of economic environment. I assume that in the more prosperous regions the customers of the utility show less tolerance to high number of outages.

Characteristics of service territory also have an influence on power outages. In rural areas, for example, less people are impacted by power outages but outages are longer due, to the time that is required to find and correct the problem. The average length of line per customer  $POLEMILE\_PER$  is used to account for characteristics of service territory

As a measure of composition of the utility's distribution lines, I use a variable  $UNDERGROUND\_SHARE$ . This variable shows what is the share of underground lines in the total distribution lines. I include this variable because the composition of distribution lines is mostly outside of the utility's control in the short-run and underground lines are less influenced by weather storms.

The variable  $SELF-GENERATION$  denotes the share of electricity that is self-generated by the utility. There are contrasting opinions about the effects of own generation

---

<sup>10</sup> 23 utilities in my sample have had incentive regulation plans during the period from 1993 to 1999, and 16 utilities have included quality standards, at least for some period, in their incentive regulation plans. Also, 18 utilities have sharing provisions.

on outages. Whereas theoretically having own generation facilities may mitigate the impact of major storms, at least one empirical source has expresses the opposite opinion.<sup>11</sup> Since no reliability statistics exist to compare distribution utilities with generation facilities versus those without their own generation, the inclusion of this variable can shed some light on this question.

Since climate is a major factor impacting reliability, the weather variable is also included in the estimation. WEATHER is calculated as the total damage due to weather storms on the territory served by the utility, measured in thousands of U.S. dollars. It should be noted, that the outage indices used in the estimation are calculated by excluding major storm events, and, therefore, the impact of weather is reduced.

Table 2 provides some statistics for the dependent and explanatory variables in equation (1). In the next section I analyze the effects of incentive regulation on outage related quality indices.

## 5. Results

Table 3 presents the coefficients for explanatory variables for the estimation of average duration of electric outages and average frequency of electric outages, without and with SHARING dummy (columns 1 and 2 for SAIDI, and columns 3 and 4 for SAIFI).

Overall, both regressions, in column one and column two, support the hypothesis that incentive regulation has a negative impact on quality (in particular, the duration of the electric outages) if it is not accompanied by strict quality standards. Duration of outages in

---

<sup>11</sup> An article by a local newspaper stated that “ PF&E says it’s unfair to compare it with these tiny systems (Santa Clara, Palo alto and Alameda)... because they are more flexible and able to quickly switch supplies”. *Cities Explore Do-it-Yourself Utilities*, Mercury Center San Jose Mercury News, May 21, 1996.

general increases under incentive regulation, while quality standards IR\_Q reduce duration of outages. The combined effect of incentive regulation and quality standards is associated with 11 percent reduction in average duration of electric outages (21 percent in case if SHARING is included).

The coefficient for income per capita has a negative sign, which means that states with higher personal income on average have lower duration of outages per customer. As expected, the total length of pole miles per customer adds to outage duration, while the share of underground miles in the total miles makes duration shorter. The degree of self-generation does not have a significant impact on the duration of outages.

It should be noted, that the coefficient of weather has a “wrong” sign and is insignificant. To some degree this can be explained because the dependent variable is the duration of outages excluding major weather events; therefore, there can be some “over-exclusion”, which will result in lower reported duration in the year when major storms occur.

Regression results for frequency of electric outages (SAIFI) without and with sharing dummy are presented in columns three and four respectively. Almost all coefficients have the same sign as the coefficients in the regressions for outages durations. The coefficient of weather variable becomes positive but it is still not significant. In addition, the coefficient of self-generation becomes positive which implies that the high degree of self-generation increases probability of electric outages. The coefficient of the share of underground miles is also positive but insignificant. It appears that there is no significant impact of composition of electric lines on the frequency of electric outages.

When examining the variables that are the main interest of this study - incentive regulation and quality dummies - there is no significant impact of incentive regulation on frequency of outages according to the results for both columns. There are several explanations of the differences in the results between duration and frequency of outages.

First, there can be other factors contributing to frequency of outages that are not included in the model. Second, there are different causes that contribute to frequency of outages and outage duration. A recent survey conducted by the Oregon Public Utility Commission shows that the main cause of outage occurrence, associated with SAIFI index, is equipment failure, whereas outage duration is mostly affected by storms and the time it takes to repair the damage. If incentive regulation affects the cost structure of the regulated utility, the impact on equipment is a long-run effect. Therefore, an appropriate model to use for SAIFI is a model with lagged values of regulatory regimes. However, the short history of incentive regulation in the electric utility industry of the US and lack of available historical data on SAIFI do not allow testing this model yet.

Table 4 presents coefficients for estimation SAIDI/SAIFI quality indices with separate regime dummies for price caps, rate case moratorium, rate freeze and revenue caps. The coefficients in all columns have the same sign and magnitude as the coefficients in corresponding columns of Table 3. As it was assumed, all incentive regimes have a similar impact on quality. All types of incentive regulation cause a significant increase in the duration of electric outages if they are not accompanied by strict quality standards. It appears that price cap regulation has the strongest impact on the duration of outages. Other regulatory regimes (except rate freeze in column 1) are not significant, which may be due to the fact that the number of observations is not sufficient to establish statistical significance.<sup>12</sup>

The general conclusion from the results presented in Tables 3 and 4 is that incentive regulation has a statistically significant impact on the duration of electric outages, but there is no evidence that it affects the outage frequency. However, there is an additional

---

<sup>12</sup> 11 utilities have had price cap regulation, 8 utilities have had rate freeze regulation, and 4 and 3 utilities have had rate case moratorium and revenue sharing, respectively.

issue to consider. The incentive regulation and quality standards may be endogenous, because they are more likely to be imposed when the utility has a poor performance. For example, the weak performance of the Niagara Mohawk Power Company led in 1991 to the design of the first incentive regulation program for electric utility sector in New York State. For this case the error terms are correlated to incentive regulation and quality dummies and the negative impact of incentive regulation may be overstated.<sup>13</sup>

To correct potential problems of endogeneity, I construct instruments for regime and quality dummies and re-estimate equation (1). The methodology of constructing these instruments is described in the Appendix, and the results of the estimation including instruments are presented in the Table 5.

For both, SAIDI and SAIFI, all coefficients have the same signs as in Tables 3. The magnitude of the coefficients for incentive regulation and quality dummies is much lower, but the impact of incentive regulation remains statistically significant. A fall in the magnitude of coefficients for incentive regulation and quality dummies occurs because instrumental estimation eliminates two extreme cases (1) when the poor quality performance of the utility results in incentive regulation and (2) when the superior quality causes the utility to accept strict quality standards.

In general, the three distinct approaches applied in this section have produced similar results: incentive regulation or probability of adopting incentive regulation is associated with higher duration of power outages, while the quality standards imply lower

---

<sup>13</sup> In general, it is more difficult to predict the sign of correlation between incentive regulation and quality dummies and the error terms. On the one hand, quality standards are more likely to be imposed when a utility has poor performance. On the other hand, a utility may reject the incentive regulation contract, if the quality provisions are too strict. In this case, only utilities with higher level of quality would accept quality benchmarks.

duration of outages. On the other hand, it appears that frequency of power outages is not affected by incentive regulation.

In the next section I will address the chain through which the incentive regulation affects quality of service.

## 6. Incentive Regulation and Cost Structure of Utilities

The impact on the design of regulatory policy instruments would be greater if one is able to determine not only whether the quality effects of incentive regulation exist, but also through what channels incentive regulation affects the service reliability. In this section I attempt to answer two questions: What is the effect of incentive regulation on O&M expenses of the utility? How operations and maintenance expenses affect quality of service, in particular, electric outages?

Since one of the important goals of incentive regulation is to reduce the operating costs of the regulated utility, several empirical studies have addressed the cost structure of the regulated firm. Shin and Ying (1993) find that incentive regulation is associated with a one percent increase in operating costs. Magura (1998) finds that fixed costs are 17 percent lower for production under incentive regulation. Ai and Sappington (2002) find that operating expenses are 4.5 percent lower under the rate case moratorium than under rate of return regulation. However, they do not find any evidence that other regimes of incentive regulation affect costs.

The focus of this paper is different from the above mentioned studies since I am interested only in changes in O&M expenses that may weaken the quality of service rather than general effects of incentive regulation on costs. For example, if under incentive

regulation the utility has more incentives to cut its expenditures than it may postpone or cancel a tree-trimming program, which would result in both, a reduction of operations expenses, and a possible increase in number and duration of electric outages.

To see whether incentive regulation actually affects the distribution-related expenses and whether decrease of these expenses results in a decline of quality, I propose the two-stage extension of the basic model, presented in section 4.

$$e_{it} = \zeta(R_{it}, Q_{it}, P_{it}, U_i, T_t) \quad (2)$$

$$q_{it} = \psi(Y_{it}, E_{it}, U_i, T_t) \quad (3)$$

At the first stage, O&M expenses per customer  $e$  are estimated as a function of the regulatory regime  $R$ , quality standards  $Q$ , vector of external factors that influence expenses  $P$ , and time and utility dummies  $T$  and  $U$ . At the second stage, outage duration and frequency are estimated as a function of O&M expenses per customer  $e$ , time and utility dummies  $T$  and  $U$ , and vector of other explanatory variables  $Y$ , used in equation (1).

Evolution of O&M expenses per customer for the utilities in my sample is presented in Chart 1. If one compares between utilities with incentive regulation plans, the utilities with quality standards have on average higher expenses per customer than the utilities without quality standards for all years. In addition, for the utilities with quality standards their total distribution-related expenses go up through time, while for utilities without quality standards total expenses go down. This is especially transparent for operations expenses. Since 1993 they have increased by more than 17 percent for the utilities with quality standards

and have fallen by about 37 percent for the utilities without quality standards.<sup>14</sup> If comparing between utilities with and without incentive regulation one can observe that both operations and maintenance expenses per customer are higher for utilities without incentive regulation. One can offer two explanations: (1) utilities with rate of return regulation have an incentive to overinvest since their profit depends on incurred costs; (2) the utilities with incentive regulation plans have an incentive to cut their costs to increase their profits even if it affects the quality of service. The last reason is supported by the fact that all expenses are higher for utilities with quality standards than without them.

Tables 6 and 7 present the results of estimation for equations 2 and 3 respectively.<sup>15</sup> SALES\_PER\_CUSTOMER are defined as average megawatt sales per customer, O\_EXP and M\_EXP are operations and maintenance expenses per customer at the distribution level. All other variables are defined as in section 4.

As is illustrated in Table 6, incentive regulation is associated with lower expenses per customer for both, operations and maintenance expenses. For the utilities with incentive regulation the operations expenses are on average 18 percent lower and maintenance expenses are 8 percent lower. Quality standards are associated with higher level of expenses (16 percent for operations expenses and 5 percent for maintenance expenses).

---

<sup>14</sup> It should be noted that at least part of these changes must be attributed to changes in the composition of utilities with incentive regulation.

<sup>15</sup> It should be noted, that Equations 2 and 3 are estimated using a fixed-effects approach, rather than random effects applied to Equation 1. I am able to apply fixed-effects because I don't have limitations imposed by availability of data on SAIDI and SAIFI indices for equation (2), and unlike the regime dummies that are constant through the period of estimation for most of the utilities in the sample, expenses do change through time in equation (3).

The other statistically significant variables are income and degree of self-generation. A higher average income per capita implies higher expenses, and high degree of self-generation is associated with lower expenses.

Table 7 shows that both types of expenses have statistically significant impact on the average duration of electric outage (SAIDI): they reduce duration of outages. The magnitudes of these effects are also rather substantial. According to Table 7, incentive regulation is associated with 18 percent decline in operations and 8 percent decline in maintenance expenses. If these variables in the equation change by the same amounts, it would bring 30 percent increase in duration of electric outages. For average frequency of outages (SAIFI) the coefficients for both types of expenses are insignificant.<sup>16</sup>

Summarizing my findings, it appears that presence of incentive regulation is associated with decrease in the overall level of expenses. This may be due to two causes: (1) overspending in case of rate of return regulation and (2) underspending in case of price caps and other forms of incentive regulation. Estimation of the impact of operations expenses and maintenance expenses on quality of service reveals that there is a strong impact of operations and maintenance spending per customer on the duration of electric outages, which supports explanation (2).

## 7. Conclusions

I have found that incentive regulation is associated with deterioration of some dimensions of quality of service for distribution utilities if it is not accompanied with strict

---

<sup>16</sup> It should be noted that coefficients for POLEMILES\_PER and UNDERGROUND\_SHARE change their sign and become less significant under fixed effects approach, due to the fact that these variables either do not change through time for majority of utilities or change very insignificantly.

quality benchmarks. However, if quality benchmarks are present, the quality of service is the same or even higher than quality without incentive regulation. This finding is supported by a separate study of the channels through which incentive regulation may influence quality. It appears that incentive regulation affects the quality through its impact on composition and size of operations and maintenance expenses.

These findings can shed some light on results obtained by Ai and Sappington (1998) for the telecommunications industry. Ai and Sappington did not distinguish between incentive regulation plans with and without quality standards, and found no pronounced effects of incentive regulation on quality. In my study omission of quality dummy would also undermine significance of incentive regulation, because the effects of incentive contracts with and without quality provision would be mixed.

There are two main directions in which my findings can be extended. First, finer classifications of incentive regulation contracts shall be considered. For example, not all revenue sharing contracts are the same, and the degree of sharing may affect quality of service; also, the duration of incentive contract may have the additional impact on quality. Second, although setting explicit quality standards appears to be a remedy against quality cuts, one should consider the possibility that strict benchmarks for some dimensions of quality may negatively affect other dimensions.<sup>17</sup> Since quality of service in the electric utilities market is a complex issue, effects of regulation on various dimensions of quality should be considered.

---

<sup>17</sup> See Holmstrom and Milgrom (1991)

## References

- Ai, Chunrong, and David Sappington, "The Impact of State Incentive Regulation on the US Telecommunications Industry." Working Paper. Draft: 1998.
- Ai, Chunrong, and David Sappington, "The Impact of State Incentive Regulation on the US Telecommunications Industry." *Journal of Regulatory Economics*; 22:2, 2002, pp. 133-160.
- Amemiya, Takeshi, "The Estimation of a Simultaneous Equation Generalized Probit Model", *Econometrica*, 1978, 46:5, pp. 1193-1205.
- American Public Power Association, "The Relative System Reliability of Publicly Owned and Privately Owned Electric Utilities", 1996.
- Berg, Sanford V., and Jinook Jeong, "An Evaluation of Incentive Regulation for Electric Utilities", *Journal of Regulatory Economics*, 3, 1991, pp. 45-55.
- Braeutigam, Ronald R., Mathew Magura and John C. Palzar, "The Effects of Incentive Regulation on U.S. Local Telephone Rates." Northwestern University mimeo. 1997.
- Clements, Michael, "Local Telephone Quality-of-Service: The Impact of Regulation and Competition", Ph.D. Dissertation, The Ohio State University, 2001.
- Donald, Stephen, and David Sappington, "Choosing Among Regulatory Options in the United States Telecommunications Industry", *Journal of Regulatory Economics*, 12, 1997, pp. 227-243.
- Edison Electric Institute, *Performance Based Regulation EEI Member Survey*, conducted September 1998; updated March 2000.
- Heckman, James J., "Dummy Endogenous Variables in a Simultaneous Equation System", *Econometrica*, 1978, 46:6, pp. 931-959.
- Holmstrom, Bengt., and Paul Milgrom, "Multitask Principal Agent Analysis: Incentive Contracts, Asset Ownership and Job Design", *Journal of Law, Economics and Organization*, 7, 1991, pp. 26-52.
- Joskow, Paul L, "Regulatory Failure, Regulatory Reform and Structural Change in the Electric Power Industry", *Brookings Papers on Economic Activity*, pp. 125-99.
- Judge, George G., W.E. Griffiths, R. Carter Hull, Helmut Lutkepohl, and Tsoung-Chao Lee. *The Theory and Practice of Econometrics*. New York, NY: John Wiley and Sons, 1985.
- Kaestner, Robert, and Brenda Kahn, "The Effects of Regulation and Competition on the Price of AT&T Intrastate Telephone Service," *Journal of Regulatory Economics*

363, 1990.

Kwoka, John, Jr., "Productivity and Price Caps in Telecommunications" in Einhorn (ed.), "Price Caps and Incentive Regulation in Telecommunications", Boston: Kluwer Academic Publishers, 1991, pp. 77-93.

Kwoka, John, Jr., "Implementing Price Caps in Telecommunications", *Journal of Policy Analysis and Management*, 12(4), 1993, pp. 726-752.

Lowry, Mark Newton, and Lawrence Kaufmann, "Performance-Based Regulation of Energy Utilities", Working Paper, 2002.

Magura, Mathew, "Incentive Regulation and Local Exchange Carrier Pricing Policies." Northwestern University mimeo. 1998.

National Association of Regulatory Utility Commissioners, "Performance Based Regulation in a Restructured Electric Industry", 1997.

National Regulatory Research Institute, "NARUC / NRRI Electric Reliability Survey Results", presented at the 79th National Conference of Regulatory Utility Commission Engineers, 2001.

Nwaeze, Emeka T., and Janice R. Mereba, "Market Implications of Regulatory Form in the Electric Utility Industry: An Assessment of Incentive Regulation", *Journal of Accounting, Auditing and Finance*, 12(3) 1997, pp. 285-307.

Roycroft, Trevor R., and Martha Garsia-Murrilo, "Trouble Reports as an Indicator of Service Quality: The Influence of Competition, Technology, and Regulation", *Telecommunications Policy*, 24 (10-11), 2000, pp. 947-967.

Sappington, David, and Dennis Weisman, "Designing Incentive Regulation for the Telecommunication Industry", Cambridge, MA, 1996: MIT Press.

Sappington, David, "Price Regulation and Incentives", University of Florida Discussion Paper, 1999.

Sappington, David, Johannes P. Pfeifenberger, Philip Hanser and Gregory N. Basheda, "The State of Performance-Based Regulation in the U.S. Electric Utility Industry", *The Electricity Journal*, 2001, pp. 71-79.

Sheshinski, Eytan, "Price, Quality and Quantity Regulation in Monopoly Situations", *Economica*, New Series, 43(170), 1976, pp.127-137.

Shin, Richard, and John Ying, "Efficiency in Regulatory Regimes: Evidence from Price Caps". Presented at Twenty First Annual Telecommunication Policy Research conference: Solomons, Maryland, 1993.

Schmalensee, Richard, and Jeffrey Rohlfs, "Productivity Gains Resulting from Interstate

- Price Caps for AT&T," National Economic Research Associate, Research Paper, 1992.
- Spence, Michael, "Monopoly, Quality and Regulation", *The Bell Journal of Economics*, 6(2), 1975, pp.417-429.
- State Public Utility Commissions.
- St. Marie, Stephen Michael, "Effectiveness of Incentive Regulation: Nuclear Power Plant Performance and Operating and Maintenance Costs", Ph.D. Dissertation, 1996.
- Tardiff, Timothy, and William Taylor, "Telephone Company Performance Under Alternative Forms of Regulation in the US", National Economic Research Associates Mimeo, 1993.
- Taylor, William E., "Small Sample Considerations in Estimation from Panel Data", *Journal of Econometrics*, 1980:13, pp. 203-223.
- United State Department of Commerce. 200. Bureau of Labor Statistics web site ([www.bls.gov](http://www.bls.gov)).
- United State Department of Commerce. 200. Bureau of Census web site ([www.census.gov](http://www.census.gov))
- Vickers, J., and George Yarrow 1988. *Privatization: An Economic Analysis*. Cambridge, MA: MIT Press, 1988.
- Welfens, Pail J.J., and George Yarrow, *Telecommunication and Energy in Systematic Transformation*, Springer, 1999.

Table 1. Number of Utilities and States with IR and Quality Standards

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
States with IR	2	2	2	3	6	5	7	10	11	11
Utilities with IR	2	2	4	5	10	9	12	23	24	23
Utilities with IR and Quality Standards	1	1	3	4	8	8	10	16	16	16

Sources: Sappington et al.(2001), NRRI survey (2000), and state public utility commissions.

Note: The data in this table do not contain information on several states that did not respond to NRRI survey and my inquiries. Only 11 out of the 18 states that have had incentive regulation record are included, since other states either do not have a history of collecting reliability data or do not make it public. "Quality standards" definition implies that outage related indices are explicitly incorporated in the regulatory contract and a utility receives punishment if it does not meet the quality benchmarks.

Table 2. Description of Variables

	Mean	Maximum	Minimum	Std. Dev.
SAIDI_EX	124.65	1550.0	7.0	134.2
SAIFI_EX	1.29	15.3	0.10	1.1
O_EXP	38.4	822.3	10.8	59.1
M_EXP	46.0	660.8	8.4	55.3
SALES_PER_CUSTOMER	24.99	107.6	5.9	9.7
FREEZE	0.04	1	0	0.19
INCOME_PER	24.49	43.81	15.29	5.0
IR	0.16	1	0	0.4
IR_Q	0.12	1	0	0.3
MORATORIUM	0.03	1	0	0.18
POLEMILES_PER	26.40	402.0	0.02	25.9
PRICE_CAP	0.07	1	0	0.25
REVENUE_CAP	0.02	1	0	0.15
SELF_GEN	0.81	1.9	0.00	0.4
SHARING	0.12	1	0	0.3
UNDERGROUND_SHARE	0.26	1.00	0.00	0.2
WEATHER	0.03	0.80	0.00	0.1

Data Sources:

Data on reliability indices (SAIDI, SAIFI) with major storm events included and excluded were acquired by direct contacting states public utility commissions and utilities in the U.S.

Information on service territory, in particular, on counties served by each utility was obtained from the state regulatory commissions and Platt's 2002 Directory of Electric Power Producers and Distributors.

Data on length of pole and underground lines were taken from Electric World industry publication (issues: 1992-2002).

Data on number of employees, customers, sales, revenues and self-generation and various categories of operations and maintenance expenses were obtained from FERC Form-1.

Data on population and income by counties were obtained from Bureau of Economic Analysis' Annual State Personal Income web site: <http://www.bea.doc.gov/bea/regional/spi/>

Weather related data was obtained from the National Climatic Data Center web page: <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms>

Table 3. Effects of Incentive Regulation:  
Random Effects with Common Incentive Regulation Dummy

Explanatory Variable	Dependent Variable			
	SAIDI		SAIFI	
	(Outage Duration)		(Outage Frequency)	
C	208.81** (97.83)	194.54** (100.09)	1.85* (0.87)	1.82** (0.89)
IR	114.75** (51.41)	98.35* (56.57)	0.18 (0.50)	0.15 (0.56)
IR_Q	-128.64** (55.71)	-133.05** (56.17)	-0.15 (0.53)	-0.15 (0.54)
SHARING		31.25 (44.92)		0.06 (0.40)
INCOME_PER	-4.07 (3.44)	-3.54 (3.53)	-0.04 (0.03)	-0.03 (0.03)
SELF_GEN	-1.25 (27.68)	-2.48 (27.77)	0.16 (0.23)	0.16 (0.23)
UNDERGROUND_SHARE	-47.01 (83.31)	-47.67 (83.42)	0.12 (0.81)	0.12 (0.81)
POLEMILES_PER	0.42 (1.06)	0.53 (1.07)	0.00 (0.01)	0.00 (0.01)
WEATHER	-24.68 (81.59)	-24.92 (81.66)	0.17 (0.64)	0.17 (0.64)
Y_94	42.25 (27.88)	41.34 (27.94)	0.21 (0.22)	0.21 (0.22)
Y_95	45.78* (27.86)	44.22* (27.97)	0.62*** (0.22)	0.62*** (0.22)
Y_96	11.48 (28.22)	8.78 (28.51)	0.25 (0.22)	0.25 (0.23)
Y_97	3.71 (29.45)	0.73 (29.79)	0.07 (0.24)	0.07 (0.24)
Y_98	50.67 (32.46)	47.44 (32.82)	0.25 (0.27)	0.24 (0.27)
Y_99	15.02 (34.56)	11.24 (35.02)	0.14 (0.29)	0.13 (0.29)
Adjusted R-squared	0.49	0.49	0.62	0.62

\*= 10 %, \*\* = 5 %, \*\*\* = 1 % significance level, standard errors are in parentheses

Table 4. Effects of Incentive Regulation:

Random Effects with Separate Regime Dummies

Explanatory Variable	Dependent Variable			
	SAIDI		SAIFI	
	(Outage Duration)		(Outage Frequency)	
C	206.00** (98.27)	194.21** (100.66)	1.79** (0.89)	1.78** (0.91)
PRICE_CAP	119.54** (51.79)	102.42* (58.79)	0.19 (0.51)	0.17 (0.59)
FREEZE	102.87* (65.04)	96.04 (66.20)	0.20 (0.59)	0.19 (0.60)
MORATORIUM	109.20 (72.88)	94.77 (76.81)	0.43 (0.67)	0.41 (0.73)
REVENUE_CAP	81.80 (71.77)	69.86 (74.48)	0.05 (0.63)	0.03 (0.68)
IR_Q	-119.01** (59.28)	-126.01** (60.91)	-0.16 (0.56)	-0.16 (0.56)
SHARING		28.75 (47.94)		0.03 (0.45)
INCOME_PER	-3.98 (3.46)	-3.58 (3.55)	-0.03 (0.03)	-0.03 (0.03)
SELF_GEN	-2.40 (27.82)	-2.63 (27.97)	0.15 (0.24)	0.15 (0.24)
UNDERGROUND_SHARE	-42.89 (84.01)	-42.43 (84.40)	0.22 (0.82)	0.22 (0.83)
POLEMILES_PER	0.48 (1.06)	0.58 (1.08)	0.00 (0.01)	0.00 (0.01)
WEATHER	-24.69 (81.91)	-24.53 (82.01)	0.18 (0.64)	0.18 (0.64)
Y_94	42.66 (28.06)	41.95 (28.09)	0.22 (0.22)	0.22 (0.22)
Y_95	45.53* (28.06)	44.46* (28.13)	0.62** (0.22)	0.62** (0.22)
Y_96	9.67 (28.58)	7.82 (28.78)	0.23 (0.22)	0.23 (0.23)
Y_97	1.42 (29.87)	-0.64 30.12	0.05 0.24	0.05 0.25
Y_98	48.91 (32.85)	46.02 (33.27)	0.22 (0.27)	0.21 (0.27)
Y_99	12.32 (34.97)	9.14 (35.46)	0.11 (0.29)	0.10 (0.30)
Adjusted R-squared	0.49	0.48	0.62	0.62

\*= 10 %, \*\* = 5 %, \*\*\* = 1 % significance level, standard errors are in parentheses

Table 5. Effects of Incentive Regulation:  
Results with Instruments for Regime and Quality Dummies

Explanatory Variable	Dependent Variable	
	SAIDI (Outage Duration)	SAIFI (Outage Frequency)
C	217.12** (99.14)	1.85* (0.87)
IR_INSTRUMENT	43.94* (27.87)	0.12 (0.22)
IR_Q_INSTRUMENT	-32.78 (27.95)	0.00 (0.22)
INCOME_PER	-4.45 (3.49)	-0.03 (0.03)
SELF_GEN	5.36 (27.98)	0.17 (0.22)
UNDERGROUND_SHARE	-36.31 (84.53)	0.13 (0.80)
POLEMILES_PER	0.16 (1.06)	0.00 (0.01)
WEATHER	-33.21 (81.98)	0.15 (0.63)
Y_94	43.32 (27.93)	0.21 (0.22)
Y_95	45.57* (27.92)	0.62*** (0.22)
Y_96	13.23 (28.29)	0.25 (0.22)
Y_97	8.09 (29.52)	0.07 (0.24)
Y_98	52.11 (32.82)*	0.23 (0.27)
Y_99	16.10 (34.98)	0.13 (0.29)
Adjusted R-squared	0.49	0.62
*= 10 %, ** = 5 %, *** = 1 % significance level, standard errors are in parentheses		

Table 6. O&M Expenses as Function of Regulatory Regimes:

Fixed Effects

Explanatory Variable	Dependent Variable	
	Total Operations Expenses	Total Maintenance Expenses
IR	-7.14* (4.51)	-3.63 (2.58)
IR_Q	6.29 (4.90)	2.19 (3.60)
SHARING	-0.97 (3.02)	1.03 (4.38)
INCOME_PER	1.09** (0.57)	1.95** (0.81)
SALES_PER_CUSTOMER	0.30 (0.29)	0.56 (0.41)
SELF_GEN	-5.71*** (2.13)	-7.44*** (3.07)
SALES_PER_CUSTOMER	0.30 (0.29)	0.56 (0.41)
UNDERGROUND_SHARE	-6.66 (6.56)	4.41 (9.56)
POLEMILES_PER	0.07 (0.11)	0.09 (0.16)
WEATHER	3.00 (4.6)	9.99 (6.66)
Y_94	-1.95 (1.39)	-1.45 (1.99)
Y_95	-3.38 (1.65)**	-3.28 (2.36)
Y_96	-2.63 (2.11)	-5.50* (2.98)
Y_97	-2.69 (2.72)	-8.89** (3.87)
Y_98	-3.73 (3.51)	-10.23** (5.00)
Y_99	-3.08 (4.07)	-7.77 (5.74)
Adjusted R-squared	0.82	0.73
* = 10 %, ** = 5 %, *** = 1 % significance level, standard errors in parentheses		

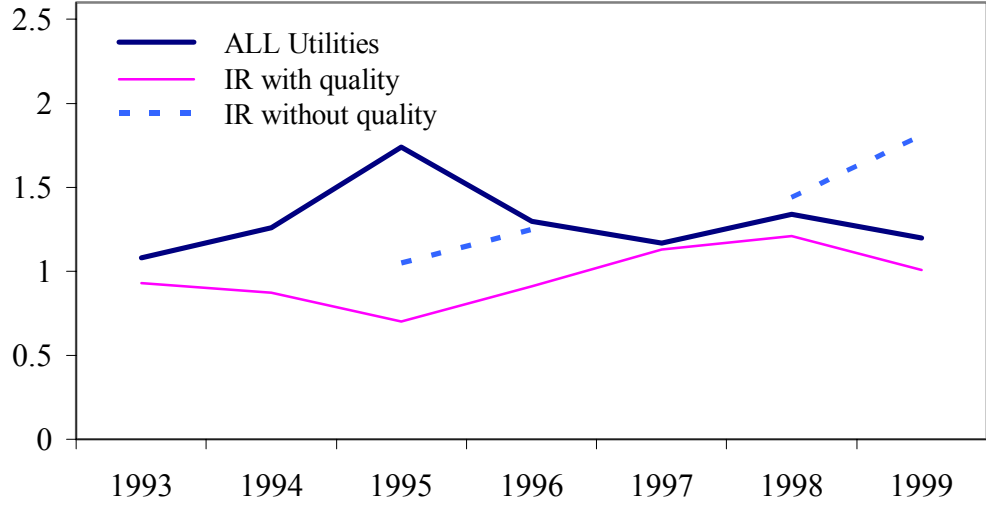
Table 7. Outage Duration and Frequency as Function of O&M Expenses:

Fixed Effects

Explanatory Variable	Dependent Variable	
	SAIDI	SAIFI
O_EXP	-2.26** (1.14)	0.01 (0.00)
M_EXP (LAG1)	-2.89*** (0.95)	-0.01 (0.00)
INCOME_PER	5.28 (10.55)	0.04 (0.09)
SELF_GEN	16.43 (41.53)	0.34 (0.34)
UNDERGROUND_SHARE	36.05 (126.47)	0.17 (0.48)
POLEMILES_PER	-0.73 (2.11)	-0.04 (0.02)
WEATHER	-0.01 (0.08)	0.19 (0.71)
Y_94	38.47 (27.54)	0.15 (0.25)
Y_95	29.28 (31.44)	0.50*** (0.28)
Y_96	-8.24 (38.88)	0.08 (0.34)
Y_97	-22.62 (50.42)	-0.21 (0.43)
Y_98	-5.99 (66.06)	-0.21 (0.56)
Y_99	-22.32 (76.32)	-0.36 (0.64)
Adjusted R-squared	0.39	0.53
* = 10 %, ** = 5 %, *** = 1 % significance level, standard errors in parentheses		

Chart 1. SAIFI and SAIDI Indices, 1993-1999

Average Frequency of Electric Outages: SAIFI



Average Duration of Electric Outages: SAIDI

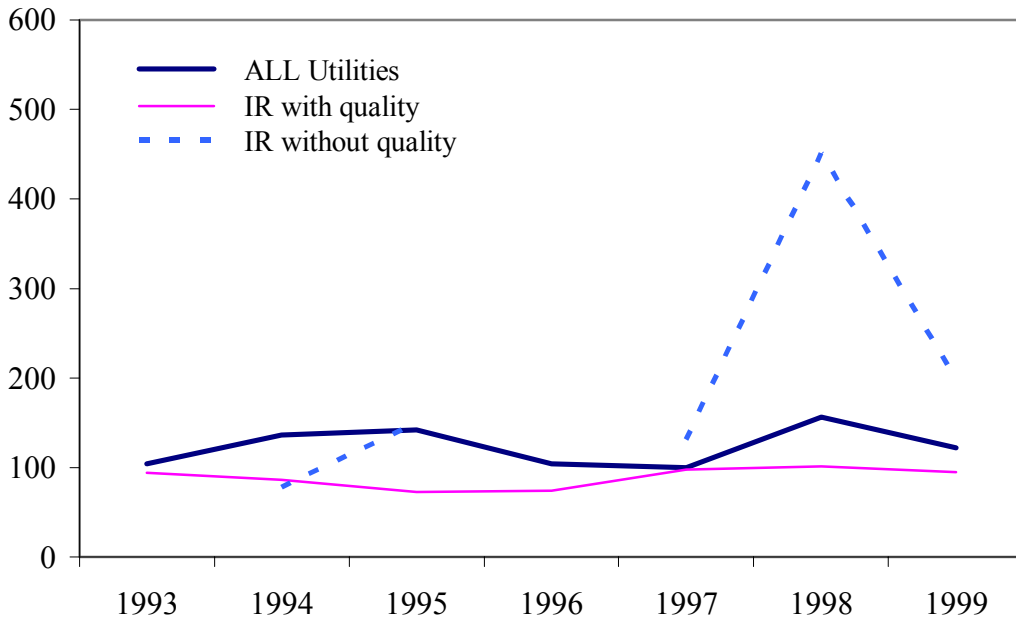
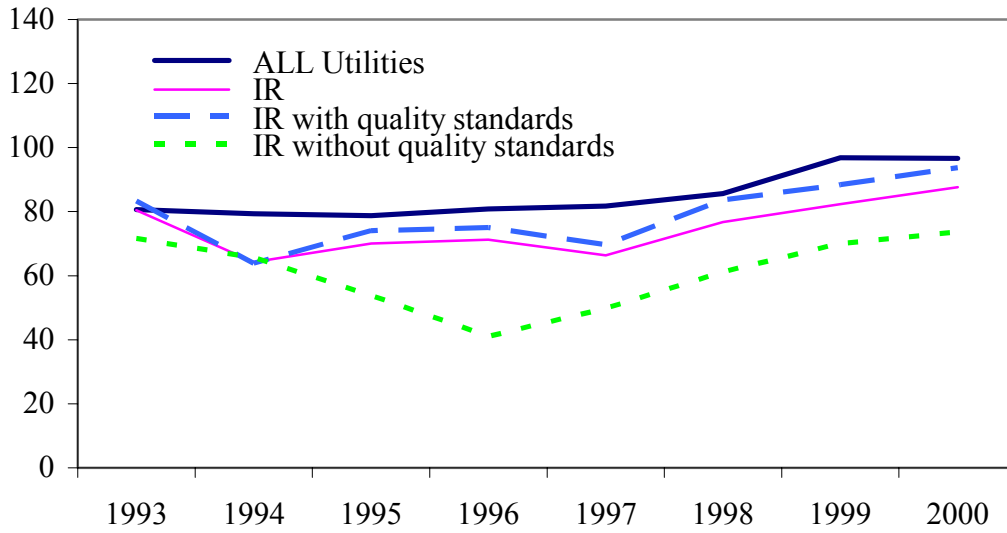
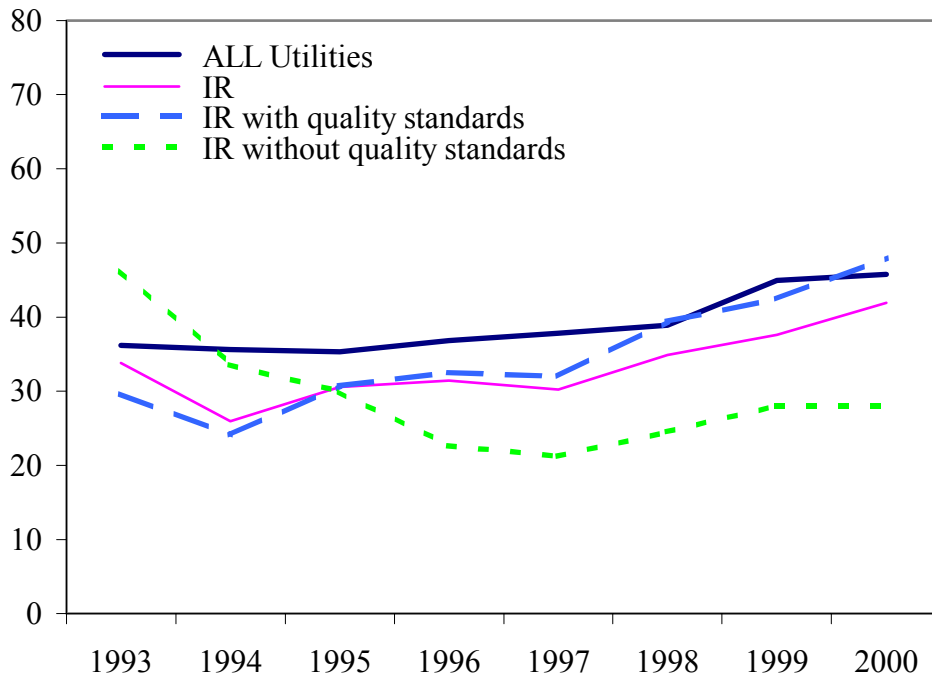


Chart 2. Operations and Maintenance Expenses Per Customer

Average O&M Expenses per Customer



Average Operations Expenses per Customer



## Appendix

To construct instruments for the regulatory regime and quality variables, I follow the methodology applied by Ai and Sappington (1998). This methodology is based on the “limited dependent simultaneous equation system” approach proposed by Amemiya (1978), Heckman (1978), and Lee (1979).

I employ explanatory variables similar to the ones used by Donald and Sappington (1997) for the telecommunications industry in the US and estimate probit regressions in which the probabilities of accepting incentive regulation and quality standards serve as dependent variables. The explanatory variables exclude demographic, economic and political characteristics on the territories served by the utility, and characteristics of public utility commissions. The additional variables at the utility level used in the estimation include the number of customers of the utility, price level, sales, share of the territory served by the utility in the total state area. At the state level the variables are the political affiliation of the state governor, the size of the staff of the state regulatory commission, previous experience in incentive regulation.<sup>18</sup> The correct predictions for incentive regulation and quality dummies are 90 and 95 percent correspondingly for all observations, and 62 and 97 percent, respectively, for cases when the dependent values are equal to one.

The estimated probabilities serve as instruments for incentive regulation and quality dummies in equation (1).

---

<sup>18</sup> Data sources and estimation results can be obtained from the author upon request.