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

by

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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.

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I. Introduction

When in September 2003 Hurricane Isabel rendered about three-quarters of customers in Washington D.C. area without power, a number of industry experts claimed that substantial cuts in maintenance spending over the past years, triggered by changes in regulatory system, made utilities more vulnerable to major weather events. "When the rates are frozen, the whole focus of the utility changed. The emphasis was no longer reliability. It was profit".[1]

Transition to new regulatory approach had started in the U.S. in late 1980s. Traditionally, federal and state regulatory agencies in the U.S. 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. Many states have introduced incentive regulation as an alternative to rate of return regulation. Incentive regulation is a general approach that includes a wide range of regulatory mechanisms like price caps, revenue caps, rate freezes 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, 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).

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[1] Matthew Mosk, Peter Behr and Peter Whoriskey, *"*Utilities Held Down Spending on Upkeep Regulators Didn't Order Upgrades Before Isabel', *Washington Post,* October 17, 2003.

A significant variation of regulatory policy across states represents a good opportunity for econometric analysis. Although many empirical studies to date examine the effects of incentive regulation on prices, costs, profits, and other characteristics of regulated utilities, 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 the telecommunications industry in 1990-91. They find that explicit quality standards improve performance and that 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".[2] 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. The main findings of this study are (1) incentive

[2] Ai and Sappington (1998): 2.

regulation results in quality degradation, in particular when it is not paired with explicit quality provisions, and (2) incentive regulation affects quality through its impact on operations and maintenance expenses.

The rest of this paper is organized as follows. In section II I briefly define types of incentive regulation plans and discuss the evolution of incentive regulation in the electric utility industry of the U.S. In section III I discuss the measures of quality for the distribution utilities and problems associated with data. Section IV describes empirical methodology. Section V presents estimates of the impact of incentive regulation on the duration and frequency of electric outages. Section VI analyzes the relationships among incentive regulation, operations and maintenance expenses, and quality of service. Section VII provides a brief summary of the main findings.

II. 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 is a possibility that with incentive regulation the firm might reduce quality of service in order to achieve additional cost savings. This 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.[3]

The history of incentive regulation in the electric utility industry of the U.S. is relatively short compared to the telecommunications industry. The first comprehensive

[3] 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.

incentive regulation plans in the electric utility industry 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 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 form 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.[4]

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 a quality provision as part of an incentive

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

contract from the very beginning; others have included them later on.[5] While the New York State Public Utility Commission has developed a rigorous set of quality benchmarks and 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.

III. 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,[6] presently outage-related indices are the only relatively widely accepted measures of quality across the electric utilities in the U.S. The most widely used indices are average duration and average frequency of electric outages.[7]

The System Average Interruption Duration Index (SAIDI) is computed by dividing the sum of all customer interruption durations by the number of customers served.[8] System Average Interruption Frequency Index (SAIFI) measures the average frequency of

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[5] 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 outage-related quality indexes.

[6] The list of recommended 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.

[7] Surveys conducted by the Institute of Electrical and Electronics Engineers in 1995 show that 83 and 88 percent of the utilities which responded calculate outage related indices, SAIFI and SAIDI.

[8] 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.

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 exogenous or endogenous ones. Endogenous factors, such as the equipment procurement and maintenance practices, can be controlled by the utility. Exogenous 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 endogenous 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 is worth noting, that operation and maintenance practices are essential to is reliability. When the utility experiences financial pressure or is given an explicit incentive to cut its expenditures, 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 that they define and measure interruptions.[9] 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-

[9] 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.

1999 time range for 23 states, 78 investor-owned utilities in total. The size of my sample varies from year to year, depending on the number of available observations, but on average it represents about 30 percent of total retail sales in the U.S.[10]

Figure 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 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 the 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, since there can be other external factors affecting the quality; however, the data encourage further research.

IV. 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

[10] It is worth noting that the utilities in my sample are only a fraction of all utilities in the U.S., because outage-related data is not available for all utilities. This may introduce a sample selection bias in my study. Utilities are missing from my data if the public utility commission does not require the utilities in its jurisdiction to report quality indexes. The public commission may not require a regulated utility to report outages for a number of reasons, among which are that: (1) the utility does not have reliable equipment to track these outages, or (2) there are no problems associated with quality and customer complaints in the region. These two reasons may lead the results to be biased in opposite directions: reason (1) would lead to overestimating the average number of outages and (2) would result in underestimating them.

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:

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

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 ε_{it}, and Y_{it} is a vector of other explanatory variables. I assume that error terms ε_{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 V I will address this issue in more detail.

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 U.S.: 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 (PRICE_CAP, FREEZE, MORATORIUM and REVENUE_CAP, SHARING)

Quality dummy Q_{it} (IR_Q) takes a value of one if the quality standards are explicitly incorporated in an incentive regulation plan for utility *i* plan in year *t* and the utility has to pay penalties for violating these standards.[11]

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 the 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 numbers of outages. If so, the coefficient for this variable is expected to have a negative sign.

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 TOTALMILE_PER is used to account for characteristics of the service territory. The coefficient of this variable is expected to be positive.

[11] 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.

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.

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.

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 on outages. Whereas theoretically having own generation facilities may mitigate the impact of major storms, at least one empirical source has expressed the opposite opinion.[12] 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.

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.

[12] 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.

V. 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 IR_Q quality dummy. The results of regressions without quality standard dummy (columns 1 for SAIDI and 2 for SAIFI) are similar to findings by Ai and Sappington (1998): there is no pronounced effect of incentive regulation on quality of service for both standards SAIDI and SAIFI. However, the results are different when a quality dummy is included (columns 3 for SAIDI and 4 for SAIFI).

For average duration of electric outages (column 3) all the important coefficients have the predicted sign. Duration of outages in general increases under incentive regulation (significant at the five percent level), while quality standards IR_Q reduce duration of outages (significant at the five percent level). The results of this regression support the hypothesis that incentive regulation has a negative impact on quality if it is not accompanied by strict quality standards. The combined effect of incentive regulation and quality standards is associated with 11 percent reduction in average duration of electric outages but it is insignificant (the F-test for no effect of incentive regulation with quality on the duration of electric outages cannot be rejected with F-statistic = 0.27 and 1,307 degrees of freedom).

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 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 is unexpectedly insignificant – indeed has the opposite sign than predicted. To some degree this can be explained by the fact tat 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) are presented in column four. 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. 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 U.S. 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 rate sharing, 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.[13]

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 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 the electric utility sector in New York State. For this case the error terms are correlated to incentive regulation and quality dummies, which will render the estimation inconsistent.[14]

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[13] 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.

[14] 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

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 Table 5.

For both, SAIDI an SAIFI, all coefficients have the same signs as in Table 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 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.

VI. Incentive Regulation and Cost Structure of Utilities

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provisions are too strict. In this case, only utilities with higher level of quality would accept quality benchmarks.

The empirical results so far suggested that incentive regulation results in a degradation of quality, in particular when it is not paired with explicit quality provisions. In some sense, the tests conducted so far were reduced form tests of a more complicated chain of causation, with utilities presumably reducing their expenditures on quality provision to increase profits under incentive regulation, and this reduction of expenditures leading to a reduction of quality. In this section I attempt to answer two questions: What is the effect of incentive regulation on operations and maintenance 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 operations and maintenance 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 then 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.

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

$$q_{it} = \psi (Y_{it,} E_{it,,} U_{i\,,} T_t) \qquad (3)$$

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 Figure 2. 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.[15] 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

[15] It should be noted that at least part of these changes must be attributed to changes in the composition of utilities with incentive regulation.

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.[16] 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 IV.

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). The combined effect of incentive regulation with quality standards are statistically significant for operations expenses (F-test that the combined effect is zero is rejected at the 10 percent significance level with F-statistic = 2.98 and degrees of freedom 1,364), but statistically insignificant for maintenance expenses (F-test that the combined effect is zero cannot be rejected, with F-statistic = 0.40 and degrees of freedom 1,364). The other statistically significant variables are income and degree of self-generation. A higher average

[16] 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 equations (2) and (3).

income per capita implies higher expenses, and a 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 the 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.[17]

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 the 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).

VII. 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 quality benchmarks. However, if quality benchmarks are present, the quality of service is

[17] 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 the majority of utilities or change very insignificantly.

the same or even higher than the 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 is associated with some reduction of operations and maintenance expenses. Also, the levels of both operations and maintenance expenses affect the average duration of electric outages per customer.

There are several observations related to these findings that are worth discussing. First, while effects of incentive regulation on the duration of outages are significant, the outage frequency appears to be unaffected by either incentive regulation or O&M expenses. The differences in results for outage duration and outage frequency may be explained by the differences in the causes contributing to duration and frequency of electric outages. Frequency of electric outages is mostly affected by equipment failures and, therefore, by the maintenance expenses of electric utilities. When we study effects of incentive regulation on operations and maintenance expenses presented in Table 7, we can see that effects are much stronger for operations expenses. But operations expenses contribute relatively less than maintenance expenses to frequency of electric outages. It appears that effects of incentive regulation on frequency of electric outages are more long-run effects, and they can be estimated when more data will become available.

Second, it is important to compare the results of this study with the ones obtained for the telecommunications industry. While there are considerable differences in the quality measures and determinants due to the industry specifics, my findings can shed some light on results obtained by Ai and Sappington (1998). 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, the omission of a quality dummy also undermines the significance of the coefficients for incentive regulation, because the effects of incentive contracts with and without quality provision are mixed.

Finally, it is interesting to see how the theoretical and empirical conclusions of this study relate to the practical situation in the electric utility industry. This study shows that incentive regulation does not cause quality deterioration, if it is paired with explicit quality benchmarks. In practice, it appears that the regulators learn this through experience. There have been several cases when the incentive regulation regime without quality provision has been terminated, and later on was replaced with another one with quality benchmarks. This paper also shows how incentive regulation affects quality through its impact on the composition of operations and maintenance expenses. Indeed, many states have moved from monitoring only the outcome (the particular reliability index) to requiring regulated utilities to implement special programs aimed to reduce the probability of electric outages. For example, presently many states require regulated utilities to provide special reports related to tree trimming programs.

In summary, this study finds a strong negative impact of incentive regulation without quality provisions on quality of service. However, it should be noted that I have not studied the socially optimal quality level. The quality decline associated with incentive regulation could be justified, if the level of quality under rate of return regulation was too high for the social optimum. More generally, the results point to the importance of more detailed analyses of the effects of incentive regulation on quality.

There are four main directions in which my findings can be extended. First, finer classifications of incentive regulation contracts could 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 an additional impact on quality. In addition, in this study I use a quality standards dummy only for utilities with incentive regulation, while in practice some utilities with a rate of return regulation also have quality benchmarks and penalties. Therefore, in the future, it will be important to take into account also the differences among utilities with non-incentive regulation.

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. Since quality of service in the electric utilities market is a complex issue, effects of regulation on various dimensions of quality should be also considered, perhaps using a simultaneous equations approach.

Third, the sample should be enlarged, since more and more utilities started reporting reliability indexes in the beginning of the 2000s. The larger sample with longer history would allow reaching more decisive conclusions about the effects of incentive regulation on quality of service. However, if the latest period data is considered (after 1999), one should also include in the estimation some measures of on-going deregulation in the electric utility industry, since the level of competition both in the generation stage and the distribution stage may also have an impact on quality.[18]

Finally, it would be of great interest to expand the geographic scope of this study and see whether the results would be similar for U.S. and other developed countries that have a considerable history of incentive regulation.

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[18] Ai and Sappington (2002) find that competition and incentive regulation may play complementary roles in motivating cost reduction.

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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	SAIDI	SAIFI	SAIDI	SAIFI
	Dependent Variable			
	Without Quality Standard		With Quality Standard	
	(1)	(2)	(3)	(4)
C	220.82**	1.88*	208.81**	1.85*
	(100.65)	-0.86	(97.83)	(0.87)
IR	10.31	0.05	114.75**	0.18
	(24.86)	-0.2	(51.41)	(0.50)
IR_Q			-128.64**	-0.15
			(55.71)	(0.53)
INCOME_PER	-4.48	-0.03	-4.07	-0.04
	(3.55)	-0.03	(3.44)	(0.03)
SELF_GEN	8.98	0.16	-1.25	0.16
	(28.09)	-0.63	(27.68)	(0.23)
UNDERGROUND_SHARE	-53.80	0.11	-47.01	0.12
	(85.28)	-0.8	(83.31)	(0.81)
TOTALMILES_PER	0.10	0	0.42	0.00
	(1.08)	-0.01	(1.06)	(0.01)
WEATHER	-30.61	0.16	-24.68	0.17
	(82.07)	-0.63	(81.59)	(0.64)
Y_94	41.87	0.21	42.25	0.21
	(27.92)	-0.22	(27.88)	(0.22)
Y_95	45.55*	0.62***	45.78*	0.62***
	(27.92)	-0.21	(27.86)	(0.22)
Y_96	13.54	0.25	11.48	0.25
	(23.34)	-0.22	(28.22)	(0.22)
Y_97	7.13	0.08	3.71	0.07
	(29.68)	-0.23	(29.45)	(0.24)
Y_98	54.07	0.25	50.67	0.25
	(32.86)	-0.26	(32.46)	(0.27)
Y_99	19.14	0.15	15.02	0.14
	(35.06)	-0.28	(34.56)	(0.29)
Observations	321	300	321	300
Adjusted R-squared	0.49	0.62	0.49	0.62

Notes: Random-effects applied to unbalanced panel, 1993-1999
*= 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 (Outage Duration) (1)	Dependent Variable: SAIFI (Outage Frequency) (2)
C	194.21**	1.78**
	(100.66)	(0.91)
PRICE_CAP	102.42*	0.17
	(58.79)	(0.59)
FREEZE	96.04	0.19
	(66.20)	(0.60)
MORATORIUM	94.77	0.41
	(76.81)	(0.73)
REVENUE_CAP	69.86	0.03
	(74.48)	(0.68)
IR_Q	-126.01**	-0.16
	(60.91)	(0.56)
SHARING	28.75	0.03
	(47.94)	(0.45)
INCOME_PER	-3.58	-0.03
	(3.55)	(0.03)
SELF_GEN	-2.63	0.15
	(27.97)	(0.24)
UNDERGROUND_SHARE	-42.43	0.22
	(84.40)	(0.83)
TOTALMILES_PER	0.58	0.00
	(1.08)	(0.01)
WEATHER	-24.53	0.18
	(82.01)	(0.64)
Y_94	41.95	0.22
	(28.09)	(0.22)
Y_95	44.46*	0.62**
	(28.13)	(0.22)
Y_96	7.82	0.23
	(28.78)	(0.23)
Y_97	-0.64	0.05
	30.12	0.25
Y_98	46.02	0.21
	(33.27)	(0.27)
Y_99	9.14	0.10
	(35.46)	(0.30)
Adjusted R-squared	0.48	0.62
Observations	321	300

Notes: Random-effects applied to unbalanced panel; 1993-1999
*= 10 %, ** = 5 %, *** = 1 % significance level, standard errors are in parentheses

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

	Dependent Variable	
	SAIDI	SAIFI
Explanatory Variable	(Outage Duration)	(Outage Frequency)
C	217.12**	1.85*
	(99.14)	(0.87)
IR_INSTRUMENT	43.94*	0.12
	(27.87)	(0.22)
IR_Q_INSTRUMENT	-32.78	0.00
	(27.95)	(0.22)
INCOME_PER	-4.45	-0.03
	(3.49)	(0.03)
SELF_GEN	5.36	0.17
	(27.98)	(0.22)
UNDERGROUND_SHARE	-36.31	0.13
	(84.53)	(0.80)
TOTALMILES_PER	0.16	0.00
	(1.06)	(0.01)
WEATHER	-33.21	0.15
	(81.98)	(0.63)
Y_94	43.32	0.21
	(27.93)	(0.22)
Y_95	45.57*	0.62***
	(27.92)	(0.22)
Y_96	13.23	0.25
	(28.29)	(0.22)
Y_97	8.09	0.07
	(29.52)	(0.24)
Y_98	52.11	0.23
	(32.82)*	(0.27)
Y_99	16.10	0.13
	(34.98)	(0.29)
Adjusted R-squared	0.49	0.62
Observations	321	300

Notes: Random-effects two-stage estimation is applied to an unbalanced panel, 1993-1999.
The probabilities of adopting incentive regulation and quality standards are used as instruments
at the first stage; *= 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	Dependent Variable: Total Maintenance Expenses
IR	-7.14*	-3.63
	(4.51)	(2.58)
IR_Q	6.29	2.19
	(4.90)	(3.60)
SHARING	-0.97	1.03
	(3.02)	(4.38)
INCOME_PER	1.09**	1.95**
	(0.57)	(0.81)
SELF_GEN	-5.71***	-7.44***
	(2.13)	(3.07)
SALES_PER_CUSTOMER	0.30	0.56
	(0.29)	(0.41)
UNDERGROUND_SHARE	-6.66	4.41
	(6.56)	(9.56)
TOTALMILES_PER	0.07	0.09
	(0.11)	(0.16)
WEATHER	3.00	9.99
	(4.6)	(6.66)
Y_94	-1.95	-1.45
	(1.39)	(1.99)
Y_95	-3.38	-3.28
	(1.65)**	(2.36)
Y_96	-2.63	-5.50*
	(2.11)	(2.98)
Y_97	-2.69	-8.89**
	(2.72)	(3.87)
Y_98	-3.73	-10.23**
	(3.51)	(5.00)
Y_99	-3.08	-7.77
	(4.07)	(5.74)
Adjusted R-squared	0.82	0.73
Observations	387	387

Notes: Fixed-effects approach is applied to unbalanced panel data 1993-1999,
*= 10 %, ** = 5 %, *** = 1 % significance level, standard errors in parentheses.
The alternative specification of the model with SHARING excluded yields very similar results.

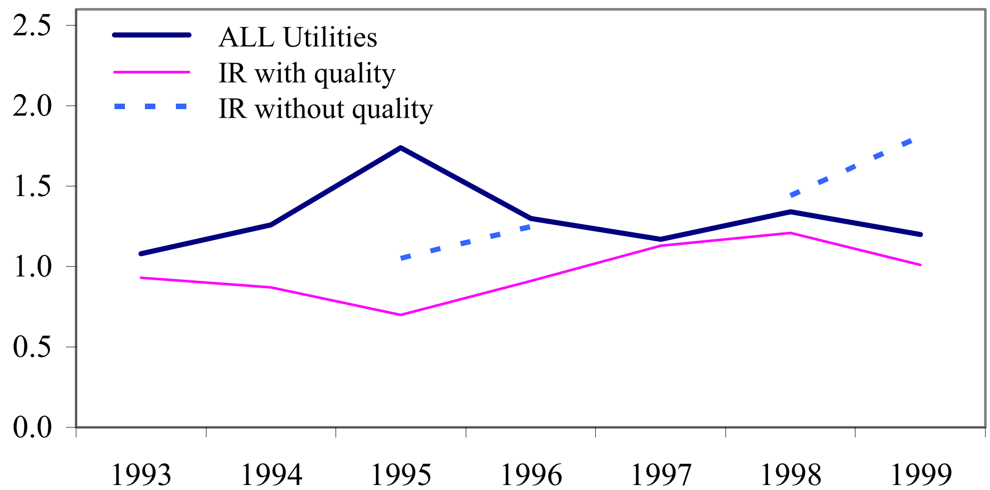
Table 7. Outage Duration and Frequency as Function of O&M Expenses: Fixed Effects

Explanatory Variable	Dependent Variable SAIDI	SAIFI
O_EXP	-2.26**	0.01
	(1.14)	(0.00)
M_EXP (LAG1)	-2.89***	-0.01
	(0.95)	(0.00)
INCOME_PER	5.28	0.04
	(10.55)	(0.09)
SELF_GEN	16.43	0.34
	(41.53)	(0.34)
UNDERGROUND_SHARE	36.05	0.17
	(126.47)	(0.48)
TOTALMILES_PER	-0.73	-0.04
	(2.11)	(0.02)
WEATHER	-0.01	0.19
	(0.08)	(0.71)
Y_94	38.47	0.15
	(27.54)	(0.25)
Y_95	29.28	0.50***
	(31.44)	(0.28)
Y_96	-8.24	0.08
	(38.88)	(0.34)
Y_97	-22.62	-0.21
	(50.42)	(0.43)
Y_98	-5.99	-0.21
	(66.06)	(0.56)
Y_99	-22.32	-0.36
	(76.32)	(0.64)
Adjusted R-squared	0.39	0.53
Observations	319	298

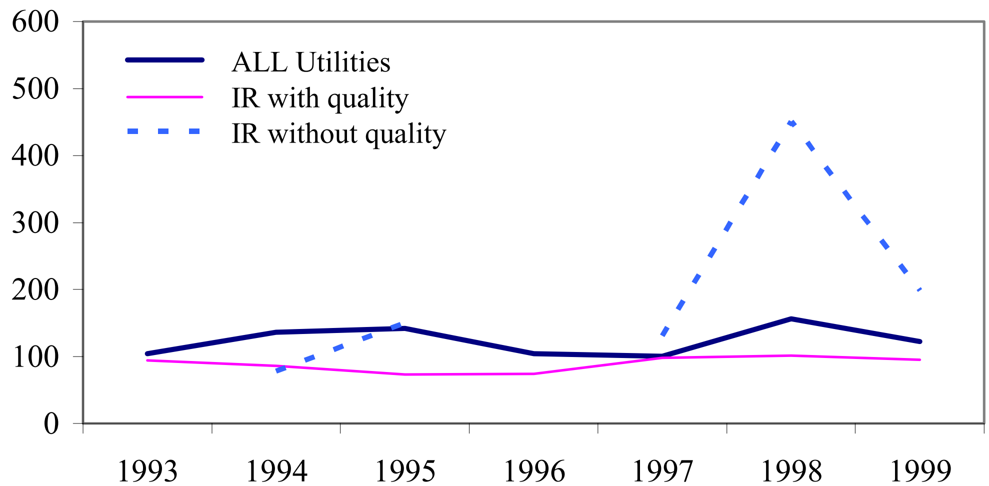
Notes: Fixed-effects approach is applied to unbalanced panel data 1993-1999,
*= 10 %, ** = 5 %, *** = 1 % significance level, standard errors in parentheses.

Figure 1. SAIFI and SAIDI Indices, 1993-1999

Average Frequency of Electric Outages: SAIFI



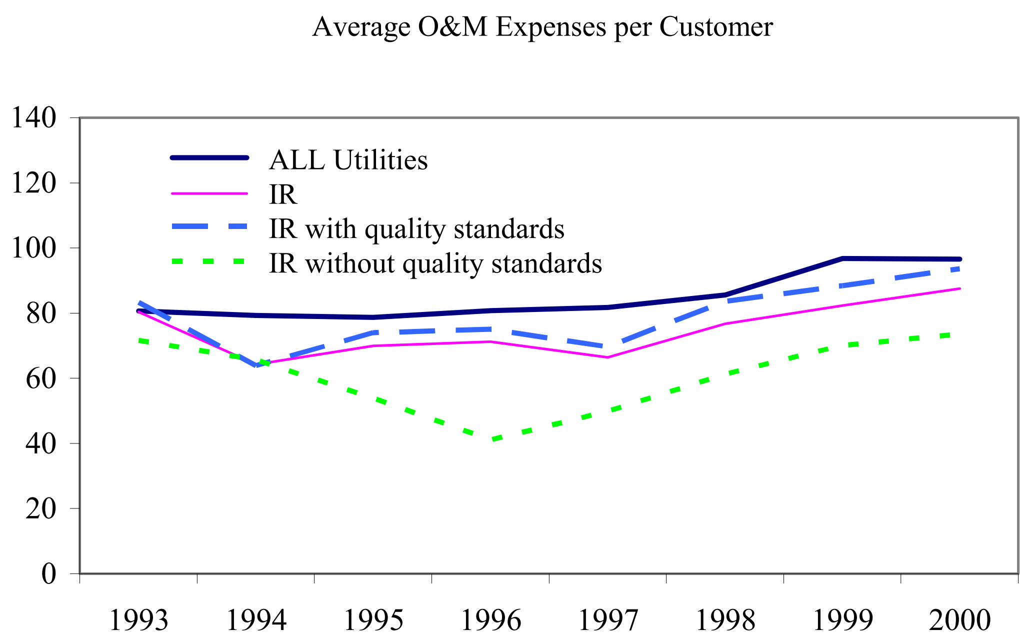
Average Duration of Electric Outages: SAIDI

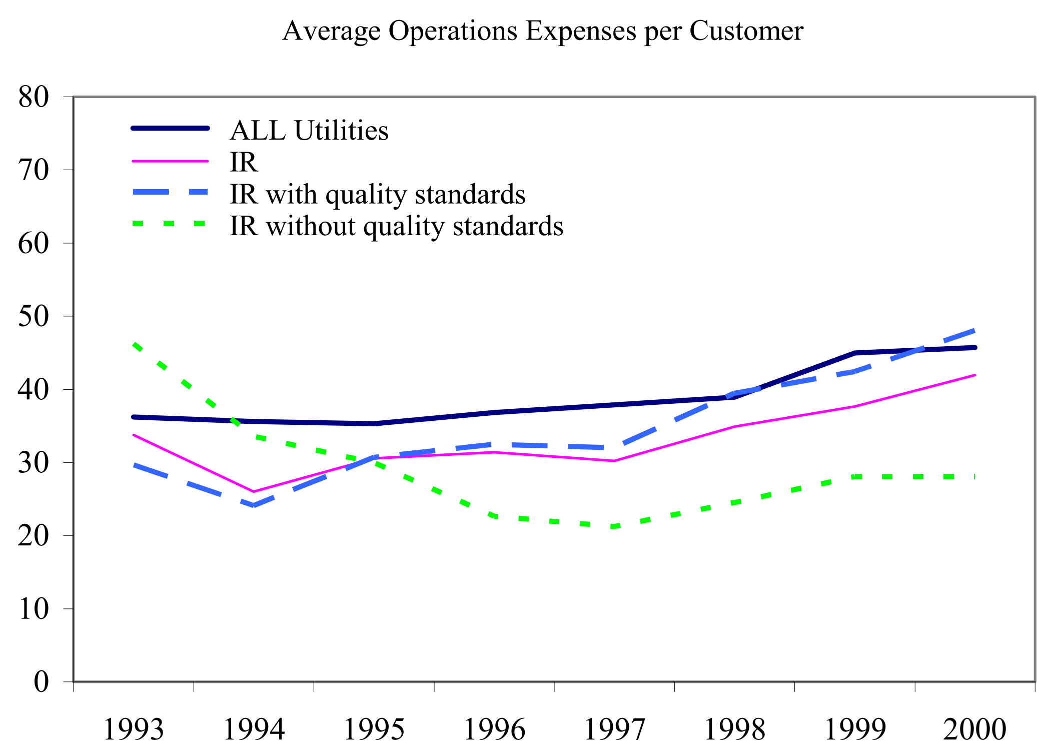


System Average Interruption Frequency Index (SAIFI) measures the average frequency of interruptions. It is computed by dividing the total number of customers interruptions in a year by the average number of customers served during the year.

System Average Interruption Duration Index (SAIDI) is computed by dividing the sum of all customer interruption durations by the number of customers served. It is measured in minutes per customer. 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.

Figure 2. Operations and Maintenance Expenses Per Customer





Expenses are measured in dollar per customer.

Appendix

To construct instruments for the regulatory regime and quality variables, I follow the methodology applied by Berg and Jeong (1991) and Ai and Sappington (2002). This approach was originally proposed by Amemiya (1978), Heckman (1978), and Lee (1979). First I separately estimate the probabilities of adopting incentive regulation and quality standards using the probit estimations. After that I re-estimate Equation (1) using a two-stage least square estimation where the fitted probabilities obtained from probit serve as instruments for endogenous incentive regulation and quality standards variables.

For probit regressions I employ explanatory variables similar to the ones used by Donald and Sappington (1997) for the telecommunications industry in the U.S. The explanatory variables exclude demographic, economic and political characteristics for 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, and 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, and previous experience in incentive regulation.[19] The correct predictions for incentive regulation and quality dummies are 62 and 95, respectively.

[19] Data sources and estimation results can be obtained from the author upon request.