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THE EFFECTS OF FUEL-RELATED INCENTIVES ON THE COSTS OF ELECTRIC UTILITIES

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EXECUTIVE SUMMARY

Prominent electricity analysts have raised serious reservations concerning the power of performance-based incentives when applied to a regulated electric utility.[1] They suspect that incentives such as heat rate and plant availability targets may cause a utility to increase its fuel or total costs. It is possible, for example, that a heat rate incentive may induce a utility to spend more on higher quality fuel, and a plant availability incentive may increase total costs as a utility defers scheduled maintenance.

An empirical study of the effects of a mixture of performance-based incentives was recently completed by Sanford Berg and Jinook Jeong.[2] They built a model where the firm's cost performance and the regulators' adoption of these incentives are endogenous variables. This modelling choice implies that (1) the regulators' decision to adopt such incentives is influenced by the utility's cost performance, and (2) the utility's cost performance is influenced by the regulators' decision to adopt these incentives. Berg and Jeong conclude that performance-based incentives do not have a statistically significant effect on the cost performance of an electric utility.

As one explanation of their results, there is always the possibility that performance-based incentives are redundant under a regime of rate-of-return regulation. Regulators are empowered to pass through only those prudently incurred costs of producing electricity. They also can apply used and useful standards to determine a utility's rate base. Additionally, they can order management audits to evaluate a utility's practices and procedures. Finally, they can assess the reasonableness of a utility's demand and cost forecasts. In short, regulators have access to tools that can be used to

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[1] Leland Johnson, *Incentives to Improve Electricity Performance: Opportunities and Problems* (Santa Monica, CA: Rand Corporation, 1985); Paul L. Joskow and Richard Schmalensee, "Incentive Regulation for Electric Utilities," *Yale Journal of Regulation* 4 (1986): 1-49.

[2] Sanford Berg and Jinook Jeong, "An Evaluation of Incentive Regulation for Electric Utilities," *Journal of Regulatory Economics* 3 (1991): 1-11.

pass judgement regarding the adequacy of utility behavior. In principle, they could be used to induce a utility to minimize its costs. However, our conclusions suggest that these tools have not prodded any utility to its maximum level of cost efficiency.

Our research deals with the empirical relationship between a utility's cost performance and a specific type of performance-based incentive. We only examine incentives meant to lower a utility's fuel costs, increase its economical use of purchased power, enhance its heat rate, and improve its plant availability and utilization. Additionally, we only explore the workings of incentive programs that consist of rewards and penalties. The first restriction represents our belief that targeted incentives should be examined in a targeted manner. The second restriction follows the reasoning that utility behavior will be different under reward-only, penalty-only, or reward and penalty incentive programs.

Our analytical apparatus is substantially different from that used by Berg and Jeong. Whereas Berg and Jeong posit that cost performance and the decision to adopt incentive regulation are simultaneously determined by each other, it is demonstrated in this research that the adoption of fuel-related incentives is not motivated by the regulators' observation of a utility's current cost performance. The intuition lying behind this result is that regulators are aware that a substantial information asymmetry prevents them from making accurate assessments of the adequacy of a utility's current cost performance. Consequently, they know that they must rely on a decisionmaking process that gives little or no weight to observed costs. As a result, their decisionmaking in the area of incentives adoption is guided by a growing belief that a newly proposed regulatory format is better than the current format.

Two econometric models, each consisting of two endogenous variables and two nonsimultaneous equations, are specified for the purpose of examining the effects of fuel-related incentives on a utility's costs. The endogenous variables for the first model are total fuel cost and total operating costs. Total fuel cost includes the costs of all the types of fuel that a utility might use to produce electricity. Total operating cost consists of annual expenses incurred in the production of electricity. In addition to the adoption of fuel-related incentives, the exogenous variables for the first model are the number of years a utility is subject to incentive regulation; total production of electricity by the utility; the utility's load factor, peak load, and sales; and the Producer Price Index. The endogenous variables for the second model are the fuel costs a utility incurs to generate steam, which in turn is used to produce electricity, and the total production costs that a utility incurs to generate steam. The exogenous variables for this model are the prices paid by a utility for oil, coal, and natural gas; the utility's load factor, total production of electricity by steam, peak load, sales, operation, and maintenance expenses; the adoption of fuel-related incentives by regulators; and the number of years that a utility is subject to these incentives.

Two different data sets are used in the estimation of the parameters of the two econometric models. The data set for the first model is a time series of cross-sectional data that spans a thirteen year period beginning in 1974 and ending in 1986. The information in this data set applies to the operations, activities, and regulation of thirteen utilities. The data set for the second model also is a time series of cross-sectional information. However, this data set is smaller than the other data set. It contains information on ten utilities, and it spans a nine year period beginning in 1979 and ending in 1987.

Several econometric techniques are used to estimate the regression coefficients of the four econometric equations. The ordinary least squares and error components techniques proved to be inadequate because they do not accommodate the statistical properties of the two data sets. The results of various statistical tests indicate that both data sets exhibit the statistical properties of first-order autocorrelation and cross-sectional heteroscedasticity. An acceptable way to accommodate these statistical properties is to use autoregressive estimation techniques. This approach is followed in this research.

Estimation of the four econometric equations, using procedures found in a computer program called LIMDEP, furnished the following conclusions. First, the adoption of fuel-related incentives does not cause a reduction in fuel costs. The estimation of the first model indicated that the adoption of these incentives is associated with a statistically significant increase in total fuel costs. Meanwhile, the estimation of the second model showed that the adoption of these incentives is associated with a statistically insignificant decrease in the fuel costs incurred in the generation of steam. Second, a utility's nonfuel costs can be beneficially affected by the adoption of fuel-related incentives. The estimation of the first model demonstrated that a utility's total operating costs are not materially affected by fuel-related incentives. Recalling that these incentives caused an increase in fuel costs in the first model, the implication is that the utility compensated for the increased fuel costs by reducing its nonfuel costs. Third, the estimation of the second model revealed that consumers and shareholders can benefit from the adoption of fuel-related incentives. These incentives are shown to be associated with a statistically significant decrease in the total production costs incurred by a utility to generate steam, which in turn is used to produce electricity. These cost savings can be shared by a utility's shareholders and its customers. The shareholders can receive higher profits, and the customers can be charged lower prices.

The conclusions just presented suggest that it is reasonable for regulators to consider the adoption of fuel-related incentives. Of course, this suggestion is subject to the following caveats. The adoption of a fuel-related incentive might not represent the optimal regulatory decision. Other incentives may be more powerful for the purpose of lowering a utility's costs.

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FOREWORD

Our research agenda sometimes includes quantitative analyses of a technical nature intended to break new ground in validating or invalidating an important proposition in utility regulation. This study is one of those. It deals with the empirical relationship between an electric utility's cost performance and a specific type of performance-based incentive, in this case fuel-related incentives. Its findings are an important contribution to the literature on the actual effectiveness of target incentives in regulation.

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CHAPTER 1

INTRODUCTION

The Public Utilities Regulatory Reform Act of 1978 (PURPA), among other things, encourages the more efficient operation of electric utilities. This congressional call for efficiency induced some regulators to adopt incentive programs that primarily affect the levels of fuel and other production costs. A published survey by National Economic Research Associates, Inc. (NERA) shows that thirty states have adopted some form of incentive regulation for electric utilities.[1] The vast majority of these departures from traditional regulation consist of performance-based incentives that affect only specific areas of a utility's operations. For example, a particular incentive program might target fuel and purchased power costs, or operations and maintenance costs.

Notwithstanding the areas of a utility's operations targeted for improvement, performance-based incentives are expected to lower its costs and prices. Whatever the actual structure of performance-based rewards and penalties, these incentives should be viewed as a mechanism for causing a regulated utility to do what traditional regulation cannot induce it to do. Namely, they are meant to create an environment where electricity is produced at minimum cost. Of course, the legitimacy of this view rests on the proposition that rate-of-return regulation alone is insufficient to induce minimum production costs.[2] Generally speaking then, performance-based incentives are expected

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[1] National Economic Research Associates, Inc. (NERA), *Incentive Regulation in the Electric Utility Industry* (n.p.: NERA, 1990).

[2] Harvey Averch and Leland Johnson, "Behavior of the Firm Under Regulatory Constraint," *American Economic Review* 52 (1962): 1052-69; Elizabeth Bailey and John C. Malone, "Resource Allocation and the Regulated Firm," *Bell Journal of Economics and Management Science* 1 (1970): 129-42; Alvin Klevorick, "The Behavior of a Firm Subject to Stochastic Regulatory Review," *Bell Journal of Economics and Management Science* 4 (1973): 57-88. Some quantitative efforts to confirm the existence of this deviation have met with some success. See Leon Courville, "Regulation and Efficiency in the Electric Utility Industry," *Bell Journal of Economics and Management Science* 5 (1974): 53-74; Richard Spann, "Rate of Return Regulation and Efficiency in Production: An Empirical Test of the Averch-Johnson Thesis," *Bell Journal of Economics and Management Science* 5 (1974): 38-53; Craig H. Peterson, "An Empirical Test of Regulatory Effects," *Bell Journal of Economics and Management Science* 6 (1975): 111-26.

to increase the efficiencies of the electricity industry and the utilities within it. For example, an incentive targeted at the fuel area is expected to induce a utility to expend more effort on its fuel use and fuel purchasing procedures.[3]

This research is based on a conjecture made by Leland Johnson, Paul Joskow, and Richard Schmalensee in their discussions of performance-based incentives.[4] They propose that a utility is apt to shift resources inefficiently to the areas that regulators have targeted for improvement.[5] This uneconomic behavior has the potential to increase a utility's costs and prices. A fuel use incentive, for example, might induce a utility to purchase high quality fuel, which exposes consumers to higher fuel costs that could be reflected as either higher base rates or surcharges. Meanwhile, an availability incentive may encourage a shift in resources toward plant operations in an attempt to increase the running time of a base load plant. The consequence might be deferred maintenance which could cause a utility to incur the hidden cost of a higher probability of a forced outage. These possibilities point directly to the primary objective of this research, which is to determine the effect that performance-based incentives have on a utility's fuel and production costs.

The research strategy is to develop preliminary econometric models for the purpose of inferring the statistical relationships between incentives and costs, and then to modify these models in accordance with their statistical properties. Econometric modelling is useful for identifying the quantitative aspects of these relationships. In particular, a correctly specified econometric model answers the question: Does the

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[3] An incentive targeted at power plant availability also affects fuel use and purchasing procedures. An increase in the availability of base load plants clearly shifts a utility's fuel use and fuel purchasing patterns because base load plants typically use coal and uranium as fuel, while oil and natural gas are common fuels for peaking units.

[4] Leland Johnson, *Incentives to Improve Electricity Performance: Opportunities and Problems* (Santa Monica, CA: Rand Corporation, 1985); Paul L. Joskow and Richard Schmalensee, "Incentive Regulation for Electric Utilities," *Yale Journal of Regulation* 4 (1986): 1-49.

[5] For example, see Johnson, *Incentives: Opportunities and Problems*, viii.

adoption of fuel-related incentives increase or decrease a utility's costs? The econometric models developed in this report are constructed to conform to Landon's three rules for determining the effect of incentives on costs.[6] First, there is explicit recognition of the external constraints that affect the operation of a utility. Second, the modelling effort concentrates on those portions of a utility's operations over which it has control. Third, the model contains a representation of the potential tradeoff between a utility's fuel costs and its total cost of production.

Overview of the Preliminary Econometric Models

Two preliminary econometric models are constructed to estimate the effects of fuel-related incentives on a utility's costs. The first model is a two-part system of three econometric equations. Equations (1-1) and (1-2) comprise the first part of the system. They are the structural equations for the simultaneous determination of a utility's fuel cost decisions for all modes of electricity generation and the regulators' incentive decisions.

$$c_{tf} = a_1I + a_2G + a_3L + a_4P + a_5K + e \tag{1-1}$$

$$I = b_1c_{tf} + b_2G + b_3L + b_4C + b_5K + e \tag{1-2}$$

Equation (1-1) captures the effect that the adoption of fuel-related incentives, I, has on a utility's expenditures on all types of fuels used to produce electricity. The expectation is that a utility that operates under fuel-related incentives will have lower total fuel costs when compared to a utility that is not subject to these incentives. Equation (1-2) captures the effect that the level of total fuel cost, c_{tf}, has on the regulators' decision to adopt these incentives. This equation indicates that regulators

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[6] John H. Landon, "Performance Rewards and Penalties" [Photocopied], Presented at Iowa State Regulatory Conference, Iowa State University, May 16, 1984.

observe a utility's current level of total fuel cost, and decide whether to adopt incentives. The expectation is that high fuel costs will be associated with the adoption of fuel-related incentives. Together, equations (1-1) and (1-2) suggest that regulators make decisions pertaining to incentives that are in part based on their observations of a utility's cost behavior.

The other right-hand-side variables are thought to affect fuel costs and the adoption of incentives. Increases in total generation, G, peak load, K, and the Producer Price Index, P, are expected to increase fuel costs, but an increase in load factor, L, is expected to reduce fuel costs. Meanwhile, the adoption of fuel-related incentives is expected to be associated with higher values of total generation and average costs, C, and lower values of a utility's load factor and peak load. Obviously, equations (1-1) and (1-2) are comprised of extremely aggregated right-hand-side variables. Equally obvious is that no effort is expended to distinguish between prices of fuel, between steam, hydro, and nuclear generation, and the different types of costs incurred by a utility.

Equation (1-3), the second part of the system, describes the effects on total operating costs, c_{to}, induced by the regulators' decision to adopt performance-based incentives and a utility's decisions pertaining to all of its fuel purchases. This equation stands alone in the sense that the regulators' decision to adopt incentives is not affected by the utility's current level of total operating costs. According to Johnson, Joskow, and Schmalensee, the expectation is that total operating costs will be higher when regulators adopt fuel-related incentives.

$$c_{to} = c_1 I + c_2 c_{tf} + c_3 S + c_4 L + c_5 P + c_6 K + c_7 u + e \qquad (1\text{-}3)$$

Other expectations are that increases in fuel cost, peak load, the Producer Price Index, and sales, S, will yield increases in total operating costs, while increases in a utility's load factor will lower total operating costs. It also is expected that increases in the number of years incentive regulation is in effect, u, will lower total operating costs. In other words, the initial increase in total operating costs is expected to be mitigated as the utility becomes more comfortable with incentive regulation.

The second preliminary econometric model also is a two-part system of three econometric equations. Equations (1-4) and (1-5) are simultaneous equations that are used to examine the quantitative relationship between fuel-related incentives and fuel costs associated with the generation of steam, which in turn is used to produce electricity. As before, the expectation is that the adoption of these incentives is expected to lower steam-related fuel costs, c_{sf}. Finally, equation (1-6) investigates the quantitative effects of these incentives on total production costs, c_{tp}. The expectation is that the initial effect of the adoption of fuel-related incentives is to increase total production costs.

$$c_{sf} = a_1p_o + a_2p_g + a_3p_c + a_4L + a_5H + a_6I + a_7G_s + a_8K + e \tag{1-4}$$

$$I = b_1p_o + b_2p_g + b_3p_c + b_4M + b_5H + b_6c_{sf} + b_7G_s + b_8K + e \tag{1-5}$$

$$c_{tp} = c_1c_{sf} + c_2c_{o\&m} + c_3H + c_4S + c_5K + c_6L + c_7u + c_8I + e \tag{1-6}$$

The expected effects of the other right-hand-side variables in these three equations are similar to the expected effects for the right-hand-side variables in equations (1-1) through (1-3). With respect to equations (1-4) and (1-5), increases in the prices of oil, coal, and gas, p_o, p_c, and p_g, respectively, are expected to increase fuel costs and encourage the adoption of fuel-related incentives. Better heat rates, H, are expected to discourage the adoption of fuel-related incentives and to lower fuel costs. Increases in total steam generation, G_s, and peak load are expected to increase fuel costs and to encourage the adoption of incentives. An improvement in the load factor is expected to reduce fuel costs. Lastly, higher profit margins, M, are expected to be associated with the adoption of fuel-related incentives.

Equation (1-6) has expected effects that are similar to those posited for equation (1-3). Total production costs are expected to increase when there are increases in fuel costs, operating and maintenance costs, $c_{o\&m}$, sales, and peak load. Better heat rates and load factors are expected to reduce total production costs. Total production costs are expected to increase initially after the adoption of fuel-related incentives. However, the initial cost increase is expected to be mitigated over time as the utility becomes more comfortable with incentive regulation.

Two data sets consisting of a time series of cross-sectional data are used to estimate the parameters of the two preliminary econometric models. Three characteristics define a time series of cross-sectional data. The first characteristic is the cross-sectional unit. In this instance, the unit is an investor-owned electric utility. Consequently, more than one utility is contained in these data sets. The first data set, used to estimate the parameters of equations (1-1), (1-2), and (1-3), contains thirteen utilities. The second data set, used to estimate the parameter of equations (1-4) through (1-6), contains ten utilities.

The second and third characteristics are the number of years in the time series and the location of the times series on the time line. The number of years and the years covered are not the same in each data set. The first data set covers thirteen years, spanning from 1974 to 1986. The second data set spans nine years, from 1979 to 1987.

Each set of pooled data represents a set of panel data. Neither the first nor the second data set contains any missing values. Hence, the first data set contains 169 observations. The second data set contains 90 observations. An observation is defined by a utility identifier and year identifier. For example, the first observation in the first data set is information collected in 1974 for utility 1. The thirteenth observation is information collected in 1986 for utility 1. The fourteenth observation is information collected in 1974 for utility 2, and so on, until the last observation which is information collected in 1986 for utility 13. The structure of the second data set follows the same format. The first observation is comprised of information collected in 1979 for the first utility in the sample. The last observation contains information collected in 1987 for the last utility in the sample.

The pooling of a time series of cross-sectional data may create an error structure that is different from the error structure that is assumed for ordinary least squares (OLS) estimation. The OLS error structure has three characteristics. First, errors across multiple equations are independent, which means that errors, e, in equation (1-3) are not affected by errors, e, in equations (1-1) or (1-2). Second, errors within an equation are independent. Third, the variance for each of the errors within equations and across equations is the same. The third characteristic places a specific structure on the error variance. For example, it might be assumed that the error for any observation is drawn from the same normal (bell-shaped) probability distribution. Consequently, each error has the same variance even though there are different error values. Pindyck and Rubinfeld note that the OLS error structure applies when the intercepts and slopes are thought to be constant over time and over utilities. In this instance, it is appropriate to treat times series and cross-sectional data identically. They also note that the OLS error structure applies when dummy variables are added to the regression equation and the intercepts vary systematically over time and over utilities.[7]

One alternative to the OLS error structure for pooled data is an error structure with up to three error components. The "error components" technique has the advantage of treating the electric utilities contained in the pooled data set as members of a larger population.[8] The first component reflects the cross-sectional variation in the pooled data. It attempts to capture any systematic variation in the error term that is caused by the utilities contained in the sample. The second component represents the times series variation in the same data. This component attempts to measure any systematic variation in errors due to a time progression that applies to all utilities in the sample. The third component conforms to the OLS assumptions.

Under some fairly restrictive assumptions, the "error components" technique yields unbiased and consistent parameter estimates.[9] An unbiased estimate has the

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[7] Robert S. Pindyck and Daniel L. Rubinfeld, *Econometric Models and Economic Forecasts*, 2nd ed. (New York: McGraw-Hill Book Company, 1981). See in particular, pages 253, 255, and 257.

[8] W. A. Fuller and G. E. Battese, "Estimation of Linear Models with Crossed-Error Structure," *Journal of Econometrics* 2 (1974): 67-78.

[9] George G. Judge, R. Carter Hill, William E. Griffiths, Helmut Lutkepohl, and Tsoung-Chao Lee, *Introduction to the Theory and Practice of Econometrics*, 2nd ed. (New York: John Wiley & Sons, 1988): 484. See also, Pindyck and Rubinfeld, *Econometric Models*, 257.

characteristic that the expected value of the estimate is equal to the actual value of the model parameter. For example in the context of equation (1-1), this means that the expected value of a_1 is equal to the actual value of the effect of the adoption of fuel-related incentives on a utility's fuel costs. A consistent estimate has the characteristic that the variance of the estimate approaches zero as the number of utilities in the sample goes to infinity. In other words, an analyst becomes increasingly more confident that the estimate is near to the actual value of the parameter as more utilities are added to the sample.

Another alternative is an autoregressive error structure. Its distinctive characteristic is that prior values of the errors, attributable to earlier years in the sample, do affect subsequent values of the error in the later years of the sample. Estimators with this error structure can be used consistently with pooled data.[10] The error structures for the cost equations in both preliminary econometric models have been determined to be autoregressive.

A combination of probit and generalized least squares (GLS) techniques are used to estimate the parameters of the simultaneous equation portion of the two preliminary models. The same GLS technique is used to estimate the nonsimultaneous equation portion of the two systems. The probit technique is used to determine the effects that continuous right-hand-side variables have on a dichotomous left-hand-side variable. A dichotomous variable has the characteristic that its value is equal to either 0 or 1. The adoption of fuel-related incentives is a dichotomous variable in both of the data sets used in this report. This variable takes on the value of 1 when regulators have adopted these incentives. An example of a continuous right-hand-side variable is steam generation. As previously discussed, the combination of probit and GLS techniques, at the very least, produces consistent estimates of either model's parameters.

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[10] R. W. Parks, "Efficient Estimation of a System of Regression Equations When Disturbances Are Both Serially and Contemporaneously Correlated," *Journal of the American Statistical Association* 62 (1967): 500-09.

The estimation strategy used in this report is similar to the strategy used by Berg and Jeong.[11] The parameters of the reduced forms of the incentive equations are estimated by the probit estimator. The reduced form, incentive equation for each preliminary model contains all the exogenous variables of the simultaneous equation portion of the respective preliminary model on the right-hand-side of the reduced form equation. For example, the reduced form of equation (1-2) has as right-hand-side variables: total generation, G, load factor, L, peak load, K, average cost, C, and the Producer Price Index, P. The parameter estimates for these exogenous variables are used to obtain "fitted values" for incentive variable, I. A fitted value in this context is nothing more than a prediction that a particular utility in the sample would have incentive regulation in a particular sample year. Next, the "fitted values" of the incentives variable are used as data for the estimation of the fuel cost equations. A GLS estimator that allows for an autoregressive error term is used to estimate the parameters of the fuel cost equations. In addition to accommodating first-order autocorrelation, this estimator allows for heteroscedasticity and cross-sectional correlation of error terms. The parameters of the total cost equations are estimated using the same GLS estimator.

Summary of Results

The foundation of both preliminary models is the proposition that simultaneity exists in the relationships between incentives and fuel costs. Therefore, it is important to test the "truth" of this proposition. The Hausman test is used for this purpose.[12] The results of this test for the two preliminary models are that it is not appropriate to treat the regulators' adoption of fuel-related incentives as an element of a simultaneous equation system relating fuel costs to incentives.

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[11] Sanford V. Berg and Jinook Jeong, "An Evaluation of Incentive Regulation for Electric Utilities," *Journal of Regulatory Economics* 3 (1991): 1-11.

[12] Jerry A. Hausman, "Specification Tests in Econometrics," *Econometrica* 46 (1978): 1251-72.

Other statistically important results are that the error terms are first-order autocorrelated and also exhibit the property of heteroscedasticity. As a result, it is not proper to use OLS techniques to estimate the parameters of the fuel and total cost equations. However, the test for cross-sectional correlation is negative. Consequently, cross-sectional correlation should not be considered as a restriction on either econometric model. These three results indicate that it is proper to use an autoregressive estimation technique that corrects for first-order autocorrelation and heteroscedasticity.

Another important result is that the two modified models yield different conclusions about the effectiveness of fuel-related incentives. The first model shows fuel-related incentives as increasing total fuel costs and not having any effect on total operating costs under the model restriction of group specific, first-order autocorrelation. This combination of results has an intuitive explanation. The utilities in the first data set may be purchasing higher quality fuel in an effort to achieve improvements in capacity factors, system availability, and heat rates. Furthermore, any incentive to substitute economy purchases for utility generation may make higher fuel cost look more attractive to the utility. Meanwhile, the utilities in this sample did make efficiency improvement outside of the fuel area to compensate for the increase in fuel costs. This secondary outcome is implied by the statistically insignificant, negative effect of fuel-related incentives on the utility's total operating cost. Therefore, the effects of fuel-related incentives did spill over into other aspects of the utility's operations. Under the same restriction of group specific, first-order autocorrelation, the second modified model paints a different picture with the same implications. Fuel costs are not influenced by these incentives, but the adoption of fuel-related incentives does lower production costs. Therefore, these incentives did induce the utilities in the second sample to become more efficient even though they do not seem to materially affect the utilities' management of their fuel resources. Once again, the effects of fuel-related incentives spill over into other aspects of the utilities' operations.

Still, the marked differences in the estimates of the effects of fuel-related incentives on a utility's costs indicate that model specification and data availability are two important empirical issues. The first model, built around readily available data, suggests that consumers do not benefit much from the adoption of fuel-related incentives. Fuel costs rise, and these increased costs are offset by cost reductions elsewhere in the utility's operations. However, the second model, built around less accessible information, suggests that consumers do benefit from the adoption of fuel-related incentives. Notwithstanding the incentives poor performance in the area of fuel costs, consumers do seem to be enjoying the benefits of lower production costs.

The empirical results just summarized are generally in opposition to results presented by Berg and Jeong. They conclude that the adoption of performance-based incentives did not materially affect management slack, a measure of a utility's cost efficiency.[13] Therefore, it is important to note at this time the differences between Berg and Jeong's research and the research in this report.

Berg and Jeong use the constructed variable, management slack, as the cost element that is influenced by the adoption of performance-based incentives. This choice is appropriate because Berg and Jeong are considering several different types of performance-based incentives. Because some of their utilities are facing incentive programs that target something other than fuel-related activities, Berg and Jeong need a broad measure of utility costs. Management slack is such a measure because it emphasizes the percentage deviation of a utility's actual operating costs relative to its predicted operating costs.

Our research focuses on a specific type of performance-based incentive. The only incentive programs included in our data sets are those targeted to the direct or indirect reduction of fuel and purchased power costs through the use of an incentive mechanism that consists of a system of rewards and penalties. Consequently, we are able to use more narrow measures of the utility's costs. In particular, we concentrate on the analysis of fuel and total production costs.

Another possible reason for the incompatibility of our findings with those of Berg and Jeong is perhaps their decision to examine a set of performance-based incentives

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[13] Berg and Jeong, "Incentive Regulation for Electric Utilities," 9.

that contain penalty-only mechanisms as well as reward and penalty mechanisms. The inclusion of penalty-only mechanisms in their data set has the potential to create two problems that could serve to complicate the estimation of their simultaneous system of costs and incentives. The first problem is that penalty-only programs may be adopted only after a utility has made a grievous error in the eyes of regulators. In this instance, the adoption of a penalties-only mechanism would be correlated with the utility's past cost performance, and the econometric equation regressing incentives on management slack would have to contain lagged values of the management slack variable.[14] This problem is less likely to arise in data consisting only of incentive programs with rewards and penalties. The second potential problem is that penalty-only programs do not encourage a utility to lower costs below predicted levels. Consequently, the minimum measure of the management slack variable for these mechanisms would tend to a floor of zero. Meanwhile, the management slack variable for mechanisms comprised of rewards and penalties would have no such floor. The combination of a limited-dependent and an unlimited-dependent variable may bias the regression of management slack on the incentives variable.

Outline of Report

The second chapter presents a principal-agent framework for analyzing the effects of fuel-related incentives on a utility's costs. The third chapter presents some hypotheses concerning how the regulators' adoption of fuel-related incentives might alter the profit-maximizing behavior of a utility that is otherwise subject to the practices and procedures of rate-of-return regulation. The fourth chapter presents the theory lying behind our econometric models of fuel-related incentives. The summary of this theory is that a utility is perceived as a profit maximizer with private information who is willing to lower

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[14] A corollary complication is that case studies of the utilities would be needed for the purpose of selecting the proper lengths of the periods between poor cost performance and the adoption of incentive regulation.

its costs if the rate-of-return constraint is relaxed. The fifth chapter describes the two modified econometric models in more detail, and it more fully develops the econometric approach for estimating the parameters of these models. The sixth chapter contains the results of this analysis. The seventh chapter contains conclusions and a policy observation.

CHAPTER 2

A FRAMEWORK FOR FUEL-RELATED INCENTIVES

As of 1990, New Jersey and North Carolina have incentives that target capacity factor as the means to lower fuel costs.[1] Wisconsin has used incentives meant to achieve reductions in fuel costs per kilowatthour (kWh), and Virginia has incentives meant to lower fuel expenses and to improve generating unit performance.[2] Ohio has incentives that underscore the importance of lowering fuel costs and improving operating efficiency.[3] Florida has incentives that stress the reduction of heat rates and the improvement of the equivalent availability factor.[4] Finally, California and New York have incentives that target reductions in fuel and purchased power costs.[5]

The purpose of this chapter is to provide a principal-agent framework that can be used to analyze these fuel-related incentives. The incentives have two common characteristics. First , utilities are granted a reward for good performance and assessed a penalty for bad performance. Incentive mechanisms that assess only penalties or grant only rewards are not considered at this time. Second, these incentives are incomplete in the sense that the systems of rewards and penalties are not based on lowering the utility's total costs or improving the utility's level of management efficiency. Instead, these incentives are based on meeting or failing to meet preset goals for a limited set of performance measures.

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[1] National Economic Research Associates, Inc. (NERA), *Incentive Regulation in the Electric Utility Industry* (n.p.: NERA, 1990): 23, 27.

[2] Ibid., 31.

[3] Ibid., 29.

[4] Ibid., 9.

[5] Ibid., 3, 25.

The principal-agent framework proposed in this chapter is built on the expectation that fuel-related incentives will lower a utility's fuel costs. The next section examines the necessary conditions for a quantitative analysis of fuel-related incentives.[6] The section after this explains the role of private information as regulators attempt to construct fuel-related incentive mechanisms. The next-to-last section describes the principal-agent framework used to analyze fuel-related incentives. Some concluding remarks are presented in the final section.

Necessary Conditions for a Quantitative Analysis of Fuel-Related Incentives

At a minimum, there are three necessary conditions that must be met before it is possible to do a quantitative analysis of fuel-related incentives. The first and most important is that fuel-related incentives emerge onto the regulatory landscape because regulators have decided that inducing a change in utility behavior is a relatively more fruitful activity than other regulatory initiatives. In the course of making this decision, regulators may have determined those aspects of a utility's operations where changes are most likely to improve the welfare of a utility's customers. The second condition is that the effects of these changes must in some sense be measurable. Suppose, for the sake of argument, that a fuel use target has been set and achieved. If regulators cannot determine how the target was hit, then they cannot determine whether the utility is being rewarded because of its own efforts or simply because of change in the economic environment over which the utility has no control. Consequently, utility performance, as it applies to progress toward a quantified target, must be measurable. The third condition, pertaining to the manner in which a utility attempts to hit a fuel use target, depends on the system of rewards and penalties approved by regulators. For example, a

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[6] Of course, a quantitative analysis of fuel-related incentives is not the only possibility. Regulators could decide not to quantify these incentives. For example, the optimal response to a fuel-related incentive might be expending the best effort to achieve a nonquantified performance objective.

utility might be less cautious about actions meant to achieve a fuel use target when the potential rewards are large and the potential penalties are small.

These three necessary conditions for quantitative analysis show that a quantified fuel-related incentive is a mechanism that sets the levels of rewards and penalties on the basis of a preset performance measure.[7] However, a slightly different interpretation, more useful for policymaking purposes, is that fuel-related incentives create a regulatory format where a utility expends sufficient effort to fulfill the socially desirable objective of reduced fuel costs.[8] The policy aspect of the alternate view is the definition of what it takes to fulfill a quantified objective. To what degree should a performance target be quantified? Should fulfilling an objective mean that a performance target is exceeded or is simply met? Should performance criteria be inclusive or narrowly focused? The regulators' answers to the second and third questions settle the issue of the type of effort that will be expended by a utility. A more quantified fuel reduction target is apt to cause a utility to favor changes to fuel use activities whose outcomes are easily measured.[9] Narrowly focused performance criteria for fuel procurement are apt to bring forth utility personnel with expertise in contract negotiations. The regulators' answer to the first question determines how much effort a utility will expend to reduce fuel costs. A utility is apt to expend a greater amount of effort on fuel reduction when regulators decide that quantified performance targets should be exceeded as compared to when these targets simply have to be met.

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[7] Paul L. Joskow and Richard Schmalensee, "Incentive Regulation for Electric Utilities," *Yale Journal of Regulation* 4 (1986): 1.

[8] Kenneth W. Costello and Sung-Bong Cho, *A Review of FERC's Technical Reports on Incentive Regulation* (Columbus, OH: The National Regulatory Research Institute, 1991).

[9] These types of incentives are more frequently used at the present time because of the ready availability of certain types of accounting data. See, Joskow and Schmalensee, "Incentive Regulation," 44.

Whatever the actual answers to these questions, it would seem that mutually acceptable objectives would be immensely important to a utility and its regulators. It seems indisputable that the interests of regulators and utilities are better served when both parties are committed to the criteria underlying the standards that determine the receipt of a reward or the assessment of a penalty.[10] What makes it so difficult to accomplish this task is that the interests of regulators and utilities are different. Regulators do not want to inappropriately reward the utility, and the utility does not want to be penalized inappropriately. A typical regulatory fear is that a utility has been unjustly rewarded because a low performance standard has been adopted. Meanwhile, the usual utility fear is that it has been penalized unjustly because regulators selected a performance standard that did not reflect the utility's gains in productivity before the incentives were implemented. Either fear can be dismissed after utilities and regulators understand the role that private information plays in establishing the linkage between performance, rewards, and penalties.

The Role of Private Information

The possession of private information by utilities and the resulting information asymmetry are common regulatory occurrences. Utilities always have private information about their costs and management practices, and the general availability of this information, among other things, is a prerequisite for the selection of reasonable performance standards. Without it, regulators cannot make assessments of the utilities' capabilities and intentions.

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[10] Criteria that imply unreachable objectives are inappropriate for the following two reasons. First, such criteria can deter a utility from expending effort to improve its productive efficiency when regulators do not assess a penalty for failing to reach these objectives. A utility may reason that it is wasteful to expend the effort to gain a reward that can never be received because the prerequisite objectives cannot be achieved. Second, criteria implying unreachable goals coupled with penalties for failing to reach these goals are equivalent to the confiscation of the utility's property.

Unfortunately, it is likely that regulators will decide on performance standards without the benefit of the utilities' private information on their cost-reducing potential. Because regulators often lack access to essential information, they often imperfectly assess utility behavior with the result that they are ill-positioned to rule on the efficiency or inefficiency of this behavior.[11] There is an obvious reason why this happens. The utilities do not want to provide the regulators with additional ammunition when the regulators dominate the selection of performance standards. Consequently, the basic issue confronting regulators is how to overcome the utilities' reluctance to freely share their information with their regulators.

Description of the Principal-Agent Framework

A useful perspective to adopt when describing regulation is to treat regulators as principals and utilities as agents.[12] This point-of-view allows regulators to decide on the appropriate levels of rewards and penalties. However, its adoption often carries with it some hidden assumptions. For example, it often is assumed that regulator and consumer interests are perfectly matched. Consequently, regulators may be viewed as conduits for the transmission of the customers' wants and needs. Additionally, it often is assumed

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[11] Joskow and Schmalensee, "Incentive Regulation," 43.

[12] Some analyses of regulation using the principal-agent approach are: David P. Baron and David Besanko, "Regulation, Asymmetric Information, and Auditing," *Rand Journal of Economics* 15 (1984): 447-70; Lorenzo Brown, Michael Einhorn, and Ingo Vogelsang, *Incentive Regulation: A Research Report* (Washington, D.C.: Federal Energy Regulatory Commission, Office of Economic Policy Technical Report, November 1989); Sanford V. Berg, W. Erwin Diewert, Edward P. Kahn, Tracy R. Lewis, and David E. M. Sappington, *The Potential for Using Performance Indices to Provide Regulatory Incentives: Final Report to the New York Public Service Commission* (n.p.: Performance Incentives Consultants, December, 1992); Tracy R. Lewis and David E. M. Sappington, "Regulatory Options and Price-Cap Regulation," *Rand Journal of Economics* 20 (1989): 405-16; David Sibley, "Asymmetric Information, Incentives and Price-Cap Regulation," *Rand Journal of Economics* 20 (1989): 392-404.

that the interests of a utility's managers and shareholders are matched perfectly. Therefore, shareholders do not find it necessary to devise incentive mechanisms for the managers. This is obviously a simplifying assumption as is proven by the existence of incentive compensation plans in many utilities.

Whatever the actual assumptions underlying the principal-agent behavior between regulators and utilities, an appropriately designed incentive induces the utilities to increase their productivity when regulators are open to increasing the utilities' profits.[13] Additional profits are justified on the grounds that it is in the best interest of the utilities' customers to induce the utilities to reveal their private information truthfully to regulators.[14] In effect, additional profits cause these utilities to expend more effort to achieve better performance. Essentially then, regulators need to design incentives that raise both profit and consumer surplus.[15]

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[13] David Baron and Roger Myerson, "Regulating a Monopolist with Unknown Cost," *Econometrica* 50 (1982): 911-30; David E. M. Sappington, "Optimal Regulation of a Multiproduct Monopoly with Unknown Technological Capabilities," *Bell Journal of Economics* 14 (1983): 453-63; Jean-Jacques Laffont and Jean Tirole, "Using Cost Observations to Regulate Firms," *Journal of Political Economy* 94 (1986): 614-41; Michael Riordan and David E. M. Sappington, "Information, Incentives, and Organizational Mode," *Quarterly Journal of Economics* 52 (1987): 243-63; Tracy Lewis and David E. M. Sappington, "Regulating a Monopolist with Unknown Demand," *American Economic Review* 78 (1988): 986-98; Tracy Lewis and David E. M. Sappington, "Regulating a Monopolist with Unknown Demand and Cost Functions," *Rand Journal of Economics* 18 (1988): 438-57.

[14] Principal-agent theories are designed to deal with the nonavailability of relevant information to the regulators. By keeping this information private, a utility is able to expend less effort improving productivity without any appreciable negative effect on its profits.

[15] Consumer surplus is a conceptual measure of the sum of the value in excess of price that each consumer realizes from the use of the product. Consumer surplus increases when the market clearing price falls and the market clearing output increases. This occurs because every consumer does not value a product or service equally, and hence, some consumers are willing to pay more for a product or service than others. As a result, each consumer's contribution to consumer surplus can be different.

Regulatory incentives can be linked to other principal-agent relationships. For example, there is the long-standing relationship between regulators and legislatures. Here the legislature is the principal and regulators are the agents. This relationship captures the overlapping responsibilities of legislative committees and regulators in the area of economic regulation. It is a principal-agent relationship that is difficult to ignore because legislative committees control the funds for the continuing work of regulation. Another important principal-agent relationship is the one between utilities and legislatures. In this instance, the utilities are the principals and the legislatures are the agents. This relationship captures the peculiar circularity of regulatory policy. It is simply a matter-of-fact that utilities are not restricted to merely responding to the inducements of regulators. Utilities have the wherewithal to act proactively through the legislature in favor of their own interests.

Effective regulation is dependent on the ability of regulators to find a way to incorporate these two additional principal-agent relationships into the day-to-day business of regulation. An approach suggested here is that regulators treat the principal-agent relationship between themselves and utilities and both of the additional principal-agent relationships as if each relationship is equally powerful with respect to the formation of regulatory policy.[16] This perspective suggests a system of countervailing power among regulators and utilities. Although utilities are in the position to induce a legislating body to use its private information to act in their best interests, they are not in the position to induce regulators to act in this manner. Meanwhile, regulators are not in

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[16] Two other descriptions of the three principal-agent relationships suggest themselves. First, regulators can treat each of the three principal-agent relationships as independent of the other, and then attempt to deal individually with the political fallout of each relationship. Second, regulators can define a hierarchy of the three principal-agent relationships in an effort to capture the formal and informal institutional relationships among them. A possible hierarchy is the utility (principal) and the legislature (agent) superior to the legislature (principal) and regulators (agent) superior to regulators (principal) and the utility (agent). No doubt, other hierarchies are immediately apparent.

the position to induce the legislature to use its private information to promote the regulators' best interests.[17]

When distinct principal-agent relationships compete with each other, a reasonable course of action for all parties concerned might be to expend effort to gain broad-based support for their objectives. Regulators, in particular, might gain this support by proposing performance criteria that result in lower utility costs, lower electricity prices, more utility profits, and more electricity for consumers. Not surprisingly, such performance criteria would be ideal from the perspective of most participants in the regulatory process. However, a problem lurks in the background. Cost reduction efforts spent outside the targeted performance areas may not earn a return for the utilities. The lowered costs may be flowed through to customers with no long-term improvement in the utilities' bottom lines.

Concluding Remarks

It has been argued that regulators have to complete several tasks before fuel-related incentives can be offered to utilities. First, regulators have to ascertain standards for utility performance in the fuel-related areas. Second, the linkages between performance standards, rewards, and penalties have to be understood. Third, the markets affected by fuel-related incentives have to be identified. Fourth, expected reductions in the cost of producing electricity have to be estimated. Fifth, rewards and penalties have to be arranged in a manner consistent with the expected cost reductions.

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[17] It is not difficult to explain how this specification of the interaction between the three principal-agent relationships generates regulatory incentives in a natural fashion. Begin by supposing that utilities move first, and the legislature passes a law that enhances the utilities' ability to earn profits. Let the law contain statutory language that causes regulators to promulgate a system of incentive regulation. The regulatory incentives are rewards when the utility meets productivity objectives and penalties when it does not.

The discussion in this chapter also suggests that no participant in the regulatory process is completely subservient to any other participant in the process. Therefore, regulators act at their own risk when they treat their relationship with utilities as independent of the other relationships that characterize the regulatory process. Moreover, its seems that regulators are ill-advised to establish standards criteria without input from the utilities.

CHAPTER 3

EXPECTED EFFECTS OF FUEL-RELATED INCENTIVES ON ELECTRICITY COSTS

None of the current specifications of the principal-agent model of regulation is suitable for the analysis of fuel-related incentives. Existing specifications are tied to the incentive compatibility and individual rationality constraints.[1] When neither constraint is violated, a utility can be induced to truthfully reveal its private information to its regulators. This information is reflected in the utility's selection of its best strategy for meeting regulatory objectives. Unfortunately, fuel-related incentives do not induce a utility to truthfully reveal its costs or productivity to its regulators. As discussed in Chapter 2, they merely induce a utility to take actions that earn rewards without too much regard for how these rewards are earned. A utility may purchase higher quality fuel in an effort to improve the heat rates of its plants, or it may defer scheduled maintenance in an effort to increase its capacity factors.

The principal-agent model developed for this report is based on the transmittal to a utility of the regulators' preferences for lower utility costs and electricity prices. These preferences are reflected in the regulators' desire to use incentives to improve economic dispatch and system availability, and to lower purchased power, operation and maintenance, and fuel costs. Consequently, the relevant principal-agent model lies outside of the procedure of inducing truth telling by the utilities. Instead, the regulators' problem, in the context of fuel-related incentives, is the design of incentive mechanisms that act directly on the utilities' costs and prices.

It is generally not possible to affect a utility's costs and prices without also affecting its profits. The next section describes the profit-maximizing behavior of a utility under fuel-related incentives. The following section more fully discusses the constraints

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[1] The incentive compatibility constraint ensures that the utility is at least as profitable when it tells the truth to regulators, as compared to when it does not truthfully reveal its private information to regulators. The individual rationality constraint means that a utility is profitable under the incentive scheme that is developed by its regulators.

on profit-maximizing behavior that are caused by the adoption of fuel-related incentives. The next section presents some expected effects associated with the adoption of fuel-related incentives. The next-to-last section discusses the substitution opportunities between capital and noncapital resources caused by fuel-related incentives. This chapter concludes with some summary remarks regarding the expected changes in utility behavior that have been induced by these incentives.

Utility Profit-Maximizing Behavior Under Fuel-Related Incentives

The purpose of this section is to explain the behavior of a profit-maximizing utility subject to a flexible rate-of-return constraint and fuel-related incentives.[2] Flexibility in rate-of-return is needed because the utility has the opportunity to earn a reward for good performance in fuel-related areas, or to be assessed a penalty for poor performance in these areas. Profit maximization has been selected as the modelling tool on the basis of the assumption that the utility's management has the fiduciary responsibility to attempt to maximize the returns to the owners.[3] When management acts consistently with these responsibilities, production levels, prices, management perks, employment levels, and investment decisions are optimal in the sense of profit maximization.

However, the profit-maximizing behavior of a utility is different from the profit-maximizing behavior of an unregulated firm. Whereas an unregulated firm can concentrate on increasing the return on its investment, a utility can pursue this strategy

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[2] An outline of the static equilibrium results for our theoretical model is available upon request from the authors.

[3] Perhaps unfortunately, Averch-Johnson type behavior provides a utility with an alternative to higher rates of return. Averch and Johnson developed a profit maximization model where a utility maximizes its profits by inflating its capital-labor ratio in relation to its cost-minimizing, capital-labor ratio. As a result, utility profit-maximizing behavior cannot be construed as cost-minimizing behavior.

only in the interval between rate cases. But even this strategy is not clear cut, as a utility has to worry about the political effects of high rates of return.[4]

Because the adoption of fuel-related incentives does not ensure that a utility will minimize its costs, some additional structure on the utility's behavior has to be imposed to ensure that the utility will indeed minimize its costs. Diewert has completed this task for a profit-maximizing utility that is not subject to any type of incentive regulation.[5] Diewert proved that a utility minimizes its variable (operating) costs in the course of earning the maximum-allowed profits when it purchases its factors of production in perfectly competitive markets, sells its services in imperfectly competitive markets, and meets all of the demand that is generated at the posted prices.

Diewert describes a two-stage procedure that a utility can follow to achieve profit maximization through the minimization of variable costs. The first stage has the utility minimizing its variable costs. This behavior ensures that the utility's input choices are feasible in relation to the need to generate the forecasted amount of electricity. The second stage has the utility maximizing its profits subject to the rate-of-return constraint and the supply-must-meet-demand constraint. This behavior provides a basis for the assertion that a utility subject to fuel-related incentives may work very hard to minimize its variable costs because it may earn profits that exceed its preauthorized rate of return. In addition, this second stage behavior suggests that an Averch-Johnson approach is suitable for modelling fuel-related incentives, as long as any premium over the preauthorized rate of return is capped, and the utility cannot influence the prices of the capital, labor, intermediate goods, and raw materials that it uses to produce its services.

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[4] B. Carsberg, "Review of British Telecom's Tariff Changes, November, 1986," *Report of the Director General of Telecommunications* (n.p.: Office of Telecommunications, 1986); Raymond W. Lawton, "Factors Affecting the Continuation of Pricing Indexing Systems for Regulated Utilities: An Examination of Four Historical Instances of Indexing," *NRRI Quarterly Bulletin* 12 (1991): 5-31.

[5] W. Erwin Diewert, "The Theory of Total Factor Productivity Measurement in Regulated Industries," in *Productivity Measurement in Regulated Industries*, eds. Thomas G. Cowing and Rodney E. Stevenson (New York: Academic Press, 1981), 17-44.

The effect of a capped premium is to somewhat cautiously raise the level of the rate-of-return constraint. Meanwhile the utility's lack of influence in the resource markets ensures that it buys its inputs at competitive prices.

The assumption that an electric utility faces a competitive capital market seems reasonable. An electric utility competes with many other types of firms who are attempting to raise money in the capital markets. As a result, an individual utility will find it difficult to materially influence the industry's average cost of capital, or the economy's competitive rate of return on investment.

An electric utility is in the same position in the labor market. This firm competes for the services of engineers, accountants, managers, statisticians, economists, administrative personnel, and clerical personnel along with other large and technically oriented firms. Moreover, an electric utility usually is located in the same geographic areas as these other large firms. Consequently, an electric utility appears to face a competitive labor market. Similar arguments can be made for the intermediate goods markets, which provide an electric utility with things such as computers and pencils.

The procurement of raw material is the one instance where an electric utility may not face a competitive market. Some utilities own coal mines and this vertical integration presents the possibility of noncompetitive prices. It arises because a vertically integrated utility has control over its fuel prices and it can use this control to manipulate the cost of this factor of production in an effort to maximize its profits. Although it is assumed, for the remainder of this report, that a vertically integrated utility cannot affect the price of the fuel that it uses to produce electricity, this assumption is not particularly appealing. However, in a forced choice, it is believed that regulators have the power to prevent the overpricing or underpricing of fuel bought by an electric utility from a vertically integrated subsidiary.

The decision to rule out any distorting influence from vertical integration is not the only addition to Diewert's assumption set that is required to model the profit-maximizing behavior of a utility subject to fuel-related incentives. Other assumptions are necessary in the areas of the reward and penalty structure, performance monitoring costs, and the costs of auditing performance. In the area of incentives structure, it is assumed that the rewards and penalties are not onerous. An incentive mechanism without this characteristic would not be individually rational from the utility's perspective because its absence suggests an opportunity for regulators to confiscate the utility's property.[6] In the area of performance monitoring, it is assumed that regulators can monitor performance measures at low costs within acceptable limits of accuracy. As a result, audits represent an acceptable course of action for regulators. Finally in the area of the costs of performing an audit, it is assumed that a utility is not able to influence these costs.

To summarize, the extensions to Diewert's assumption set are as follows:

(1) A utility can earn profits above the preauthorized level.

(2) A vertically integrated utility cannot affect the prices of fuel used to produce electricity.

(3) An audit of a performance measure is within acceptable levels of accuracy.

(4) An audit of a performance measure is low cost, and this cost cannot be influenced by a utility.

Constraints on Profit-Maximization Under Fuel-Related Incentives

Under rate-of-return regulation with fuel-related incentives, a utility is allowed to exceed its approved rate of return indefinitely. A straightforward way to discuss the

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[6] There are many possible confiscation scenarios. Some of them involve the taking of property when the utility is earning positive economic profit. Others involve regulatory decisions that cause a utility to earn negative accounting profits. Negative accounting profit is defined as the situation where the utility's out-of-pocket expenses plus depreciation exceed its revenues. As a result, the utility does not earn any rate-of-return on existing investment and does not completely recover its existing investment in the time period under analysis. Negative profit can differ from subnormal economic profit in the following manner. Subnormal profit occurs when a utility earns accounting profit that is below the positive level of accounting profit that could be earned in a perfectly competitive market. Therefore, a utility that earns subnormal economic profit also can earn positive accounting profit. An example is a huge penalty for the failure to reach a particularly stringent performance objective, which in turn causes the utility to earn a subnormal profit.

behavioral constraints associated with fuel-related incentives is to extend an existing model of utility behavior. Fuss and Waverman's multiproduct model has been selected for this purpose.[7]

Fuss and Waverman's model has four important characteristics. First, a utility is able to sell more services only after it lowers its prices. Second, a utility purchases capital, labor, and raw materials in perfectly competitive markets. Third, a utility is always able to produce the amounts of services that are required to meet the quantities demanded of these services. Fourth, a utility can earn no more than the approved rate of return. These four characteristics imply that a utility is a pricetaker on the production side, and a pricemaker on the consumption side. Consequently, the utility's accounting profits are influenced by competitively set prices for capital, labor, and raw materials. However, the profits actually earned by the utility are determined by its selection of its capital/labor ratio and its selection of the prices for its services. In other words, the Fuss-Waverman model is a variant of the Averch-Johnson model of profit-maximizing behavior by a utility.

Three modifications to the Fuss-Waverman model are made to deal with the existence of fuel-related incentives. The first modification alters the utility's profit function. A utility is modelled as taking action to lower its costs after the adoption of fuel-related incentives. Because this utility is a pricetaker when purchasing productive inputs, the only way for the utility to lower its costs is to change the amounts of capital, labor, fuel, and other raw materials that it uses to produce a given amount of electricity.

The second modification alters the structure of the rate-of-return constraint. In the original Fuss-Waverman model, a utility earns an approved rate of return that does not include a reward for meeting performance objectives. The modified Fuss-Waverman model allows a utility to earn such a reward. Consequently, a decision has been made to model a utility's rate-of-return constraint in terms of two components. The first

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[7] Melvyn Fuss and Leonard Waverman, "Regulation and the Multiproduct Firm: The Case of Telecommunications in Canada," in *Studies in Public Regulation*, ed. Gary Fromm (Cambridge: The MIT Press, 1981), 275-313.

component is a fixed rate of return that is approved by regulators in a formal regulatory proceeding. The second component represents changes to the approved fixed rate of return that are due to the adoption of fuel-related incentives.[8] These changes may be an addition to, or a subtraction from, the approved rate of return.

The third modification adjusts a utility's electricity prices. There are two ways to accomplish this adjustment. The first approach is to allow the second component of the rate-of-return constraint to be thought of as capturing the effects of the lower prices that a utility is expected to charge after the adoption of fuel-related incentives. The alternative approach is to create a new decision variable that directly affects the profit-maximizing prices for electricity services. The alternate is taken for two reasons. It is easier to adjust prices directly rather than to rethink the interpretation of the second component of the rate-of-return constraint, and regulators expect that the adoption of fuel-related incentives will lower a utility's profit-maximizing prices.

In summary, the original Fuss-Waverman model has been modified in three directions. First, a utility's profit rate may exceed the approved rate of return indefinitely. Second, a variable component has been introduced into the rate-of-return constraint. Third, a new dimension has been added to a utility's pricing decisions.

Expected Effects of Fuel-Related Incentives

The expected effects attributable to the adoption of fuel-related incentives can be separated into two categories. The first contains expectations regarding how fuel-related

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[8] The second component of the earned rate of return is the transformation of the additional profits earned by meeting performance objectives into a rate of return on rate base. To simplify the discussion of the second component of the earned rate of return, it is convenient to assume that the rate of return approved by the regulators does not include a band around it; then the additional profits to the utility due to incentive regulation are immediately transformable into a higher earned rate of return. However, it is assumed that the second component of the utility's rate of return has a predetermined upper bound.

incentives might affect a utility's fuel and total production costs.[9] The second contains expectations regarding how these incentives might affect substitution opportunities between labor and raw materials, and the substitution opportunities between capital and noncapital resources. It is noted at this time that these expectations are extracted from the formal solution of the theoretical model.

The first expected effect is:

> *A utility will lower its total production costs (which do not include a return on investment) when the approved rate of return does not change as a result of the adoption of fuel-related incentives and the incentive structure indicates increasing rewards for increasing efforts at cost reduction.*

In support of this expectation, recall that a utility's actual rate of return is the summation of the first and second rate-of-return components. The second (variable) component is positive when a reward is granted for meeting performance objectives, or it is negative when a penalty is assessed for not meeting the objectives. Because the first component of a utility's actual rate of return is assumed to be fixed despite the adoption of fuel-related incentives, its actual rate of return will increase when the second or variable component is positive, and it will decrease when the variable component is negative. Consequently, a utility has a reason to lower its total production costs because such behavior increases the profits that a utility is allowed to keep indefinitely.

How much a utility is expected to reduce its production costs depends on the maximum-allowed incentive premium (the variable component of the rate-of-return constraint) and the size of a utility's rate base. The interaction between the premium and the rate base places a ceiling on the amount of cost savings that can be retained in

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[9] Total production cost is defined as the sum of the costs of all noncapital factors of production.

the form of increased profits. To show this, assume that the rate base is fixed and that a utility cannot earn more than five percentage points over the approved and fixed rate of return. Under these conditions, the additional profits can be no more than ".05 times the rate base." If it is assumed that electricity prices remain unchanged after the adoption of fuel-related incentives, and hence the utility's production of electricity remains unchanged, then the utility can keep all of its cost savings up to ".05 times the rate base." However, any cost savings in excess of ".05 times the rate base" must be rebated fully to its customers.

The preceding example should not be taken to suggest that the adoption of fuel-related incentives has no effect on the size of the rate base. It is indeed possible that a utility might substitute capital for noncapital resources after the adoption of fuel-related incentives. The reason why this might be done is easily understood. A utility will be able to retain more of its reduction in production costs because more profits can be earned on a larger rate base. In fact, Fuss and Waverman in their 1981 article on the productivity of Canadian telecommunications firms suggest that substitutions of this type are expected to occur even without the added thrust of performance-based incentives.[10]

The second expected effect is:

> *Any tendency on the part of a utility to substitute capital for labor after the adoption of fuel-related incentives will weaken as the utility is allowed to earn an actual rate of return that represents a larger positive deviation from its cost of capital.*

A utility, after all, can achieve the same dollar volume of profits from less investment as the maximum-allowed incentive premium increases. This result may be desirable from a utility's perspective because the adoption of fuel-related incentives presents the utility

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[10] Fuss and Waverman, "Regulation and the Multiproduct Firm," 306.

with an opportunity to simultaneously increase its profits and reduce its investment budget. These two outcomes would benefit stockholders. Stockholders would enjoy an increased rate of return on existing investment, and they would have far less to fear with respect to the dilution of their investments because the utility's management would have less reason to invest in physical facilities as a means to increase profits.

Substitution of Capital and Noncapital Resources

In our model, the substitution of capital for noncapital resources and vice versa is caused by changes in the shadow prices of capital and noncapital resources. Shadow prices are unobservable prices that are known only to the utility. They play an important role in determining the optimal amount of capital and noncapital resources that are required to produce the utility's profit-maximizing level of electricity; namely, they provide information to the utility on the true cost of using different combinations of capital and noncapital resources. In the context of our model, the utility creates shadow prices by multiplying the market prices for capital and noncapital resources by internally generated adjustment factors. These particular adjustment factors capture the effects of fuel-related incentives on the utility's operations. These adjustment factors can lead to either increases in the shadow prices of capital and noncapital resources relative to their market prices, or decreases in the shadow prices of these resources relative to their market prices. Clearly, the shadow price of a capital or noncapital resource used to produce electricity is not always the market price that a utility actually pays to the supplier of the resource.

Unfortunately, it is not possible to unambiguously predict how the adoption of fuel-related incentives will affect the shadow price of capital relative to its market price, and the shadow prices of noncapital resources relative to their market prices. Three out of many possible shadow price movements are considered in the following paragraphs to make this point.

The first movement begins with the assertion that the adoption of fuel-related incentives affects only the shadow prices of noncapital resources and causes a utility to increase its use of all noncapital resources. A potential explanation for the latter part of the assertion is that the adoption of incentives has altered the relationship between the shadow prices of noncapital resources and the shadow price of capital. In particular, the increased use of noncapital resources to produce electricity suggests that the shadow prices for noncapital resources are now relatively lower when compared to the shadow price of capital.

The second movement begins with the assertion that the adoption of fuel-related incentives affects only the shadow price of capital and causes a utility to use more capital to produce electricity. Once again, the adoption of incentives may have caused a relative decrease in a shadow price. However, in this instance, it is the shadow price of capital that may be declining relative to the shadow prices of noncapital resources. In response to this particular price movement, capital would be substituted for noncapital resources.

The third price movement is a mixture of the first two price movements. It begins with the assertion that the adoption of fuel-related incentives causes an increase in the use of capital and noncapital resources because the utility has increased its production of electricity. Capital may be substituted for noncapital resources under these conditions whenever the shadow price of capital is decreasing more rapidly than the shadow prices of noncapital resources. However, noncapital resources are substituted for capital when the shadow price of capital is declining less rapidly than the shadow prices of noncapital resources.

Other price movements can be constructed that describe different relationships between the shadow prices of capital and noncapital resources. For example, a fourth price movement can be constructed where the shadow prices of noncapital resources rise relative to the shadow price of capital. But these additional price movements are extraneous in the sense that the three price movements considered above are sufficient to demonstrate why it is not possible to predict how the adoption of fuel-related incentives will affect the substitution of capital for noncapital resources or vice versa.

Using the Averch-Johnson context, it is not too difficult to explain why this ambiguity arises. All that needs to be recognized is that the adoption of fuel-related incentives has unique effects on the use of specific types of noncapital resources. It is indeed possible that these incentives will not affect a utility's use of noncapital resources that are deployed outside of the areas targeted for improvement. Assuming this possibility actually arises, a utility would substitute capital for these noncapital resources whenever it is profitable to do so. Perhaps, cost-saving capital, deployed in areas targeted for improvement, would be substituted for noncapital resources deployed outside of the targeted areas. This behavior is rational for two reasons. First, a utility increases its rate base by substituting capital for noncapital resources. Consequently, the utility has placed itself in the position of earning more profits. Second, the utility has reduced its production costs. This outcome increases the probability that the utility will actually earn more profits.

However, it also is possible, and indeed is expected, that the adoption of fuel-related incentives will affect the use of noncapital resources that are deployed in the areas targeted for improvement. Two additional substitution possibilities arise as a result of this context. The first substitution possibility deals with the case where the affected noncapital resources are not used extensively prior to the adoption of fuel-related incentives. It is likely that any moderate increase in the utility's use of these resources will not have much of an effect on the regulators' desire to alter the use of these resources in the future. But suppose for the sake of illustration that an increase in the use of these particular resources causes the utility to earn a reward because performance has improved in the targeted areas. In this context, the affected noncapital resources will be substituted for capital deployed outside of the targeted areas.[11]

It is these two opposing forces associated with the adoption of fuel-related incentives that create any ambiguity surrounding the prediction of the expected substitution opportunities between capital and noncapital resources after the adoption of

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[11] Perhaps, some readers are surprised by the possibility of the substitution of noncapital resources for a capital resource. Averch-Johnson-type models usually predict that utilities can earn more profits by deploying additional capital. Therefore, the possibility of the substitution of noncapital resources for capital under fuel-related incentives points to the need to compare the rates of change of shadow prices for noncapital resources to the rate of change of the shadow price of capital.

fuel-related incentives. If the increase in the use of noncapital resources deployed within the targeted areas exceeds the increase in the use of cost-saving capital deployed in the targeted areas, then the adoption of fuel-related incentives results in the overall substitution of noncapital resources for capital. The overall substitution is in favor of capital for noncapital resources when the deployment of cost-saving capital within the targeted areas exceeds the increase in the use of noncapital resources in these same areas.

Concluding Remarks

Two expected changes in utility behavior have been suggested in this chapter. A utility is expected to lower its total production costs after the adoption of fuel-related incentives. It also is expected that any tendencies on the part of a utility to substitute capital for labor after the adoption of fuel-related incentives will weaken as the utility is allowed to earn an actual rate of return that represents a larger positive deviation from its cost of capital. In support of the second expectation, it has been suggested that the adoption of fuel-related incentives might not appreciably change the capital bias of the Averch-Johnson model of regulation. Capital resources can become relatively less expensive than noncapital resources after the adoption of these incentives with the result that fuel-related incentives intensify the capital bias of the Averch-Johnson model. However, this undesirable outcome appears to be dependent on the opportunities for a utility to profitably substitute cost-saving capital in the areas targeted for improvement for noncapital resources that do not affect performance in the targeted areas.

CHAPTER 4

A BASE MODEL OF FUEL-RELATED INCENTIVES

The purpose of this chapter is to develop a base model suitable for testing hypotheses regarding the adoption of fuel-related incentives. The next section presents the model. The section after that describes several econometric specifications of the base model. Concluding remarks are presented in the final section.

The Base Model

The foundation of the base model is that the adoption of fuel-related incentives will have cost-reducing effects on an electric utility. Therefore, an appropriate starting point *a la* Fuss and Waverman is a cost function of the form shown in equation (4-1).[1]

$$C^* = f(\mathbf{P}^*, \mathbf{Y}) \tag{4-1}$$

C^* is the utility's constrained costs; $\mathbf{P}^*$ is a vector of shadow prices for capital and noncapital resources; $\mathbf{Y}$ is a vector of the utility's outputs. Constrained costs are the largely unobservable costs that the utility incurs during the process of constrained profit maximization. The shadow price vector is determined by the utility's profit-maximizing behavior subject to the constraints imposed by fuel-related incentives, rate-of-return regulation, and the utility's obligation to meet all quantities of electricity demanded at posted prices.

For any output level, the utility's constrained cost function is described by equation (4-2).

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[1] Melvyn Fuss and Leonard Waverman, "Regulation and the Multiproduct Firm: The Case of Telecommunications in Canada," in *Studies in Public Regulation*, ed. Gary Fromm (Cambridge: The MIT Press, 1981), 303.

$$C^* = g(P^*, K, X; Y) \tag{4-2}$$

K represents capital; and X is a vector of noncapital resources. Clearly, equation (4-2) characterizes a utility's constrained costs in terms of the resources that are required to produce a predetermined amount of electricity services, Y.

However, a constrained cost function based on shadow prices is not particularly useful for estimation purposes. Fortunately, the constrained cost function can be restated in terms of market prices. The trick is to substitute market prices and other relevant variables for the shadow prices of capital and noncapital resources. These substitutions generate the constrained cost function described by equation (4-3).

$$C^* = h(P_X, X, P_K, K, sr, \lambda_1, e, e') \tag{4-3}$$

P_X is a vector of the market prices for noncapital resources; P_K is the market price for capital; *sr* is the product of the approved rate of return, *s*, and the incentive premium, *r*; *r* is the utility's reward for meeting performance objectives set by regulators; λ_1 is a technical parameter of the profit maximization problem; specifically, it is the Lagrangian multiplier associated with the utility's profit-maximizing behavior after the adoption of fuel-related incentives; *e* is the cost-reducing effect associated with these incentives; and *e'* is the change in this effect with respect to a change in the mixture of capital and noncapital resources. The inclusion of *e* and *e'* in the constrained cost function amounts to an explicit recognition of the possibility that the adoption of fuel-related incentives can affect the shadow prices for capital and noncapital resources.

In contrast to the unobservable costs denoted by equation 4-3, the utility's observable costs are described by equation (4-4).

$$C = k(P_X, X, P_K, K) \tag{4-4}$$

Comparison of equations (4-3) and (4-4) indicates that constrained costs are obtained by adjusting observed costs for the effects of fuel-related incentives and changes in the effectiveness of these incentives due to changes in the utility's mix of its factors of production. Therefore, under an assumption of linearity, equation (4-3) can be rewritten as equation (4-5).

$$C^{*} = C + h(sr, \lambda_1, e, e') \tag{4-5}$$

$h(sr, \lambda_1, e, e')$ is a function that determines the difference between the utility's constrained costs and its observed costs, $C^{*} - C$.

Standard algebraic manipulation yields equation (4-6) as the expression of the utility's observed costs in terms of its constrained costs and adjustments to these constrained costs.

$$C = C^{*} - i(sr, \lambda_1, e, e') \tag{4-6}$$

Obviously, $i(sr, \lambda_1, e, e')$ is a function with the same absolute value as the function $h(sr, \lambda_1, e, e')$.

To derive an estimable model of observed costs from equation (4-6), it is necessary to describe the regulatory relationship underlying *sr*. Recall *sr* is the product of the approved rate of return and the incentive premium. The regulatory relationship underlying this variable is that the difference between the utility's revenues, $P_Y Y$, and its costs, $P_X X e + P_K K$, cannot exceed the product of "*sr* times K." Therefore, *sr* can be described by the function shown as equation (4-7).

$$sr = m(P_Y, Y, P_X, X, e, P_K, K) \tag{4-7}$$

P_Y is the vector of the profit-maximizing prices under fuel-related incentives.[2]

All that is required to fully describe the utility's observed cost function is to meld equation (4-7) with the second term on the right-hand-side of equation (4-6). The result of this effort is equation (4-8).

$$C = C^* - i(P_Y, Y, P_X, X, P_K, K, \lambda_1, e, e') \tag{4-8}$$

The arguments of the second term on the right-hand-side of equation (4-8) may be surprising to some readers because they contain P_Y. Typically, the prices of the utility's outputs are not included in the observed cost function. However, it is necessary to include these prices in this cost function because they cannot be ignored by the utility during its efforts to stay within the boundaries of its rate-of-return constraint.

Comparison of equation (4-3), which describes constrained costs, to equation (4-6), which describes the actual rate of return, indicates that the second term of the right-hand-side of equation (4-8) contains all the information that is necessary to estimate the observed cost function of a utility subject to fuel-related incentives. Therefore, a base model of fuel-related incentives would have the form shown in equation (4-9).

$$C = n(P_Y, Y, P_X, X, P_K, K, \lambda_1, e, e') \tag{4-9}$$

If the utility's observed costs is a separable mixture of capital and noncapital costs, then equation (4-9) can be rewritten as equation (4-10).

$$\begin{aligned} C = {} & p(P_K, K, P_Y, Y, \lambda_1, e, e') + \\ & q(P_Y, Y, P_X, X, \lambda_1, e, e') \end{aligned} \tag{4-10}$$

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[2] In the Fuss and Waverman approach, a utility chooses its own prices and its own mix of the factors of production. The utility also purchases all of its factors of production in perfectly competitive markets, and sells its services in imperfectly competitive markets.

p(.) and q(.) represent capital and noncapital costs, respectively. Equation (4-10) is written in a manner that indicates that fuel-related incentives affect capital costs as well as noncapital costs.

If noncapital costs also are assumed to be separable, then noncapital costs can be represented as the sum of fuel and nonfuel costs as shown in equation (4-11).

$$\begin{aligned} C_{NC} &= v(P_Y, Y, P_{Xf}, X_f, \lambda_1, e, e') + \\ &\quad w(P_Y, Y, P_{Xnf}, X_{nf}, \lambda_1, e, e') \end{aligned} \qquad (4\text{-}11)$$

C_{NC} denotes the utility's noncapital costs; and v(.) and w(.) represent fuel and nonfuel costs, respectively. Equation (4-11) implies that the level of fuel costs does not influence the level of nonfuel costs. This characteristic of the base model is used to develop econometric models that test the cost-reducing capability of fuel-related incentives.

Equation (4-11), like many other equations used in the derivation of this base model, contains variables that are related to the adoption of fuel-related incentives. There is λ_1, which is a technical parameter of the utility's profit maximization process; λ_1 measures the effect on profits caused by relaxing the modified rate-of-return constraint. There is e, which represents the utility's cost efficiency. Lastly, there is e', which represents the change in this cost efficiency. Because each of these variables is unobservable, and because each of them is related to the adoption of incentives, we have decided to represent their influence by constructing the dichotomous variable, I, which has a value of 1 when the regulators have adopted fuel-related incentives and a value of 0 otherwise. Then equation (4-11) may be rewritten as equation (4-12).

$$C_{NC} = v(P_Y, Y, P_{Xf}, X_f, I) + w(P_Y, Y, P_{Xnf}, X_{nf}, I) \qquad (4\text{-}12)$$

I represents the effects of fuel-related incentives on noncapital costs.

Testable Models of Fuel-Related Incentives

Testable models of the effects of fuel-related incentives are comprised of functional relationships between endogenous and exogenous variables. Endogenous variables are also known as dependent variables, and they are typically found on the left-hand-side of the equation. Meanwhile, exogenous variables are also known as independent variables, and they are always found on the right-hand-side of the equation. For example, noncapital costs, C_{NC}, is the endogenous variable with respect to equation (4-12). The exogenous variables are easily found by inspection of this equation. A testable model, based on equation (4-12), would examine the effects of the exogenous variables on the endogenous variable, C_{NC}.

Testable models need to be specified. The specification of a model explicitly reveals the relationship between endogenous and exogenous variables and any additional interactions between these variables. We may find it necessary to specify more than one model as we investigate the effects of incentives on a utility's costs. Perhaps, the proper statistical relationship between fuel-related incentives and costs is a recursive model. A possible specification of a recursive model relating incentives to fuel and production costs might be that incentives affect both fuel and productions costs, and the level of fuel costs influences the level of production costs. Additionally, the recursive specification would require that fuel costs and production costs are influenced by the same set of other exogenous variables. Taken together, equations (4-13) and (4-14) are an example of a recursive specification of the effects of fuel-related incentives on a utility's costs.

$$C_f = v(P_Y, Y, P_{Xf}, X_f, I, Z) + e_f \qquad (4\text{-}13)$$

$$C_p = u(P_Y, Y, P_{Xf}, X_f, I, Z, C_f) + e_p \qquad (4\text{-}14)$$

C_f represents fuel costs; C_p represents production costs; Z represents other exogenous influences on fuel and noncapital costs; e_f is the random error term for equation (4-13);

and e_p is the random error term for equation (4-14). These random error terms are assumed to be unrelated to each other.

The requirement that the same set of exogenous variables affects all endogenous variables is rather restrictive. When this requirement is relaxed, it is possible that different sets of exogenous variables influence the endogenous variables. Under this condition, a possible specification is a nonrecursive model. Equations (4-15) and (4-16) are an example of a nonrecursive model.

$$C_f = v(P_Y, Y, P_{Xf}, X_f, I, Z_1) + e_f \tag{4-15}$$

$$C_p = u(P_Y, Y, P_{Xf}, X_f, I, Z_2, C_f) + e_p \tag{4-16}$$

Z_1 represents a set of exogenous variables influencing fuel costs that is different from Z. Z_2 represents a set of exogenous variables influencing production costs that is different from Z and Z_1; once again, e_p and e_f are random error terms that are not related to each other.

Recursive and nonrecursive models are not the only possibilities. Another specification is a simultaneous equation model. Equations (4-17) and (4-18) represent an example of a simultaneous equation model.

$$C_f = v(P_Y, Y, P_{Xf}, X_f, I, Z_3) + e_f \tag{4-17}$$

$$I = z(P_Y, Y, P_{Xf}, X_f, I, Z_4) + e_I \tag{4-18}$$

Z_3 and Z_4 represent different sets of exogenous variables that are different from Z, Z_1, and Z_2; the variables contained in Z_3 are thought to influence fuel costs; the adoption of fuel-related incentives is influenced by the variables contained in Z_4; e_I is the random error term for the incentive equation; and e_f is the random error term of the fuel cost equation. However, in this instance, these two error terms are related to each other in the sense that the adoption of fuel-related incentives and the level of the utility's fuel costs are influenced by e_I and e_f.

Equations (4-17) and (4-18) describe a situation where the adoption of fuel-related incentives and the level of the utility's costs are jointly determined. A model of this type is used by Berg and Jeong in their analysis of the effects of performance-based incentives on the utility's level of management slack.[3] More will be said about this study in subsequent chapters of this report.

The possibility that equations (4-17) and (4-18) may be the appropriate model for testing the effects of fuel-related incentives on a utility's costs implies that the endogenity of incentives has to be tested. The Hausman test is used for this purpose.[4] It examines whether predetermined endogenous variables are correlated with random error terms.[5] Perhaps, a detailed explanation of the procedure would be helpful to some readers.

The Hausman test rests on a specific characteristic of a simultaneous system of equations. Recall that each endogenous variable is affected by every error term of the simultaneous system. In our case, fuel costs, C_f, is correlated with e_I as well as e_f. Meanwhile, the adoption of fuel-related incentives is correlated with e_f and e_I. Conversely, C_f would not be correlated with e_I when equation (4-17) is not part of a simultaneous system of equations, and I would not be correlated with e_f when equation (4-18) is not part of the same simultaneous system of equations. These statistical relationships imply that the endogenity of I can be tested by regressing I on C_f, and determining whether C_f is correlated with the error term, e_{If}, associated with this regression. If C_f and e_{If} are correlated, then I is endogenous. Recall that C_f is always correlated with e_I when a simultaneous equation system describes the structural relationship between C_f and I.

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[3] Sanford V. Berg and Jinook Jeong, "An Evaluation of Incentive Regulation for Electric Utilities," *Journal of Regulatory Economics* 3 (1991): 7.

[4] Jerry A. Hausman, "Specification Tests in Econometrics," *Econometrica* 46 (1978): 1251-72.

[5] Gregory C. Chow, *Econometrics* (New York: McGraw-Hill Book Company, 1983).

The most simple Hausman test requires only one endogenous variable and one potentially endogenous variable. In our case, the endogenous variable is C_f. The potentially endogenous variable is I. The objective is to establish the endogenity or exogenity of I. The procedure is to assume I to be the endogenous variable, and then let C_f be the exogenous variable. Therefore, equation (4-19) is the starting point for the Hausman test.

$$I = \gamma C_f + e_{If} \tag{4-19}$$

The null hypothesis for equation (4-19) is that C_f is not correlated with e_{If}.[6] The Hausman test is applied by finding an estimator other than γ, which is a consistent estimator of the effect of fuel costs, C_f, on the adoption of fuel-related incentives, I, even if the new estimator is derived from an incorrectly specified model. With respect to equation (4-19), the existence of this alternate estimator rests on the existence of a suitable instrumental variable, W, for the endogenous variable, C_f.[7] When this instrumental variables exists, the Hausman test is performed by estimating equation (4-20), and testing whether the null hypothesis, $\alpha = 0$, can be rejected.[8]

$$I = \gamma C_f + \alpha V + e \tag{4-20}$$

$$V = [I - W(W'W)_{-1}W']C_f \tag{4-21}$$

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[6] Chow, *Econometrics*, 314.

[7] There are four statistical properties that characterize an instrumental variable. First, the instrumental variable, W, and the error term of the regression, e, are uncorrelated. Second, the instrumental variable, W, and the original variables, X, are correlated. Third, linear independence characterizes multiple instrumental variables. Fourth, the original variables, X, are linearly independent. See Ronald J. Wonnacott and Thomas H. Wonnacott, *Econometrics* (New York: John Wiley & Sons, Inc., 1970): 153, 341.

[8] Hausman, "Specification Tests," 1259.

V is a Hausman variable; $\mathbf{I}$ is the identity matrix; W is the instrumental variable for C_f. Typically, the instrumental variable for C_f is selected from the exogenous variables identified in equations (4-17) and (4-18). Consequently, the instrumental variable may be drawn from $\mathbf{P_Y}$, $\mathbf{Y}$, $\mathbf{P_{Xf}}$, $\mathbf{X_f}$, $\mathbf{Z_3}$, and $\mathbf{Z_4}$.

Concluding Remarks

It is demonstrated in the next chapter that a simultaneous equation model is not appropriate for a system of equations relating fuel costs of all types to the adoption of fuel-related incentives. It also is shown in that chapter that a simultaneous equation model is not appropriate for a system of equations relating the adoption of fuel-related incentives to fuel costs incurred to generate steam.

CHAPTER 5

SELECTION OF ECONOMETRIC MODELS FOR TESTING THE EFFECTS OF FUEL-RELATED INCENTIVES ON A UTILITY'S COSTS

The purpose of this chapter is to select econometric models for testing the effects of fuel-related incentives on a utility's costs. Some preliminary work has to be completed before this task can be begun. The two systems of simultaneous equations, noted near the end of Chapter 4, have to be specified using available data. The results of this effort are described in the next two sections. The third section discusses the results of the tests of the endogenity of the adoption of fuel-related incentives. The fourth section discusses the selection of the econometric models that are estimated in the next chapter. The fifth section contains concluding remarks.

Systems of Simultaneous Equations

The distinguishing feature of a system of simultaneous equations is that two or more variables are functions of each other. The most simple system is described by equations (5-1) and (5-2).

$$C_f = a + bI \tag{5-1}$$

$$I = c + dC_f \tag{5-2}$$

C_f is a linear function of I; I is a linear function of C_f; and a, b, c, d are known constants.

The two systems of simultaneous equations developed for this research are only slightly more complicated than the system described by equations (5-1) and (5-2). The first system has the total cost of all types of fuel, c_{tf}, influencing the adoption of fuel-related incentives, I. This system is denoted by equations (5-3) and (5-4).

$$c_{tf} = a_1I + a_2G + a_3L + a_4P + a_5K + e \tag{5-3}$$

$$I = b_1c_{tf} + b_2G + b_3L + b_4C + b_5K + e \tag{5-4}$$

On the one hand, the total cost of all types of fuel, c_{tf}, is specified as a function of the regulators' decision to adopt fuel-related incentives, I, the Producer Price Index, P, the utility's total generation, G, total in-house generation as a percent of potential in-house generation, L, and peak load, K. On the other hand, the regulators' decision to adopt fuel-related incentives, I, is specified as a function of the utility's total cost of fuel, c_{tf}, total generation, G, total in-house generation as a percent of potential in-house generation, L, average cost, C, and peak load, K.

The second system considers the possibility that the cost of all types of fuel used to generate steam has affected the regulators' decision to adopt fuel-related incentives. Equations (5-5) and (5-6) describe this possibility.

$$c_{sf} = a_1p_o + a_2p_g + a_3p_c + a_4L + a_5H + a_6I + a_7G_s + a_8K + e \tag{5-5}$$

$$I = b_1p_o + b_2p_g + b_3p_c + b_4M + b_5H + b_6c_{sf} + b_7G_s + b_8K + e \tag{5-6}$$

The nine exogenous variables for this simultaneous system are: the price of oil, p_o, the price of coal, p_c, the price of gas, p_g, electricity generated in-house by steam, G_s, an efficiency measure for fuel used to generate steam, H, a profit measure, M, total in-house generation as a percent of potential in-house generation, L, and the peak load, K.

Equations (5-3) and (5-4), as well as equations (5-5) and (5-6) are estimable econometrically because data are available. Actual data exist for the fuel prices, peak load, the amount of electricity produced from steam, total in-house generation, system capacity, the Producer Price Index, the adoption of fuel-related incentives, the cost of fuel used to generate steam, and the cost of all types of fuel used to produce electricity. Proxy data are available for the efficiency measure and the profit measure.

The discussion of the expected signs for each of the right-hand-side variables specified in the two sets of simultaneous equations is deferred to the next chapter. At present, the issue is the endogenity of the incentive variable, I. This issue is resolved in the next section of this chapter.

Test of the Endogenity of Fuel-Related Incentives

There are several ways to perform a Hausman test. One way is to use an econometric program that calculates the Hausman statistic as a matter of course. Another way is to specify an econometric model that is equivalent to testing if fuel costs are correlated with the error term of the incentive equation. Both methods are used in this research. Our econometric program is LIMDEP.[1] It contains a routine for calculating the Hausman statistic. The alternative approach is to include the fitted value for the adoption of fuel-related incentives in the structural econometric equation used to regress fuel costs on fuel-related incentives and the exogenous variables. Berndt notes that testing the statistical significance of the coefficient on the fitted incentives variable is equivalent to performing the standard Hausman test.[2]

The Hausman statistics are not reported here. Instead, the more intuitive concept of statistical significance is used to test the endogenity of fuel-related incentives. Following Greene's suggestion, the fitted values of the incentives variable are added to equations (5-3) and (5-5). These additions create new structural equations for fuel costs. They are denoted as equations (5-7) and (5-8).

$$c_{tf} = a_1 I + a_2 G + a_3 L + a_4 P + a_5 K + a_6 I^F + e \qquad (5\text{-}7)$$

$$c_{sf} = a_1 p_o + a_2 p_g + a_3 p_c + a_4 L + a_5 H + a_6 I + a_7 G_s + a_8 K + a_9 I^F + e \qquad (5\text{-}8)$$

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[1] William H. Greene, *LIMDEP: User's Manual and Reference Guide - Version 6.0* (Bellport, NY: Econometric Software, Inc., 1991).

[2] Ernst R. Berndt, *The Practice of Econometrics: Classic and Contemporary* (Reading, MA: Addison-Wesley Publishing Company, Inc., 1991): 379-80.

I^F is the fitted value of the incentives variable.[3]

With respect to equation (5-7), the null hypothesis is that the regression coefficient, a_6, is not statistically different from zero. The null hypothesis for equation (5-8) is that the regression coefficient, a_9, is not statistically different from zero. If we fail to reject both null hypotheses, then the regression coefficient, $a_{1,}$ in equation (5-7) and the regression coefficient, a_6, in equation (5-8) are the asymptotically efficient estimates of the effect of the adoption of incentive regulation on fuel costs without the restriction that the adoption of incentive regulation is correlated with the error term.[4] In effect, any failure to reject either null hypothesis indicates that the incentives variable is exogenous. In our case, we fail to reject both null hypotheses.

Equations (5-9) and (5-10) present the results of using panel data to estimate equations (5-7) and (5-8), respectively. The t-statistics are in parentheses.

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[3] The actual fitted values used to estimate equations (5-7) and (5-8) are derived from probit models. These models have a dichotomous variable as their dependent variable. In our probit models, the adoption of fuel-related incentives is the dichotomous variable. It takes on a value of 1 when regulators have adopted incentives, and it takes on a value of 0 when they have not done so. The fitted values for equation (5-7), which also are elements of a dichotomous variable, are obtained by regressing the adoption of fuel-related incentives on the reduced form incentive equation that is derived from equations (5-3) and (5-4). The reduced form incentive equation derived from equations (5-5) and (5-6) is used to obtain the fitted values for equation (5-8). The first equation below is the reduced form equation used in the estimation of equation (5-7). The second equation below is the reduced form equation used to help estimate equation (5-8).

$$I = b_1P + b_2G + b_3L + b_4C + b_5K + e$$

$$I = b_1p_o + b_2p_g + b_3p_c + b_4M + b_5H + b_6L + b_7G_s + b_8K + e$$

These equations differ from equations (5-4) and (5-6) in the following respects. The second equation above is constructed by substituting the Producer Price Index, P, for total fuel costs, c_{tf}. The first equation above is constructed by substituting in-house generation as a percent of potential in-house generation, L, for the fuel costs incurred to generate steam, c_{sf}.

[4] Gregory C. Chow, *Econometrics* (New York: McGraw-Hill Book Company, 1983): 314.

$$c_{tf} = \underset{(4.07)^{*}}{34.994\ I} + \underset{(5.21)^{*}}{.00416\ G} - \underset{(-7.27)^{*}}{82.422\ L} + \underset{(5.18)^{*}}{.40475\ P} + \underset{(10.54)^{*}}{.04164\ K} + \underset{(.147)}{.39515 I^{F}} \qquad (5\text{-}9)$$

$$c_{sf} = \underset{(-.270)}{-1.9282\ p_o} + \underset{(1.293)}{58.615\ p_g} + \underset{(.246)}{2.1462\ p_c} - \underset{(-.527)}{528.42\ L} - \underset{(-.345)}{12.073\ H} - \underset{(-1.596)}{412.91\ I}$$

$$+ \underset{(5.066)^{*}}{14.542\ G_s} + \underset{(4.415)^{*}}{.31679\ K} + \underset{(.000)}{.03426\ I^{F}} \qquad (5\text{-}10)$$

The t-statistics for the estimated effects of I^F on fuel costs show that both regression coefficient are statistically significant. Therefore, it is concluded that the incentives variable in either econometric model is not endogenous.

Description of Data Used to Test the Endogenity of Incentive Regulation

Two different data sets are used to estimate the parameters of equations (5-3) and (5-5). Information pertaining to thirteen utilities is used to generate the first data set. The utilities are Arkansas Power and Light, Carolina Power and Light, Commonwealth Edison of Illinois, Consumers Power Company, Duke Power Company, Iowa Electric Light and Power, Iowa-Illinois Gas and Electric, Niagara Mohawk Power, Northern States Power of Minnesota, Philadelphia Electric Company, Rochester Gas and Electric, Virginia Electric and Power Company, and Wisconsin Electric Power Company. Information relating to the operations of ten utilities is used to develop the second data set used in this research. The utilities selected for this data set are Southern California Edison Company, Commonwealth Edison of Illinois, Consumers Power Company, Northern States Power of Minnesota, Niagara Mohawk Power, Rochester Gas and Electric, Carolina Power and Light, Duke Power Company, Philadelphia Electric Company, and Wisconsin Electric Power Company.

The first data set spans a period of thirteen years, which begins in 1974 and ends in 1986. Table 5-1 shows that utilities in this data set were subjected to incentive

TABLE 5-1

ELECTRIC UTILITIES IN FIRST DATA SET

Company Name	Length of Time Incentives in Effect
Arkansas Power and Light	1981 - 1987
Carolina Power and Light	1978 - 1987
Commonwealth Edison of Illinois	No incentive regulation
Consumers Power Company	1983-1987
Duke Power Company	1978-1987
Iowa Electric Light and Power	No incentive regulation
Iowa-Illinois Gas and Electric	No incentive regulation
Niagara Mohawk Power	1982-1987
Northern States Power of Minnesota	No incentive regulation
Philadelphia Electric Company	1985-1987
Rochester Gas and Electric	1983-1987
Virginia Electric and Power Company	No incentive regulation
Wisconsin Electric Power Company	No incentive regulation

regulation for different lengths of time during the study period. Philadelphia Electric Power characterizes a utility subject to fuel-related incentives for a short period of time. Its regulators adopted these incentives in 1985. Meanwhile, Rochester Gas and Electric was under incentive regulation for four of the years during the study time period. Niagara Mohawk faced incentive regulation for five years, and Arkansas Power and Light dealt with incentive regulation for six years during the sample period. Finally, Consumer Power Company and Duke Power Company labored under incentive programs for nine years from 1978 to 1986.

These fuel-related incentive programs are comprised of a system of rewards and penalties. In some instances, the same incentive program is applied to all utilities in the state. In other instances, the incentive program is applied only to the major investor-owned utilities operating within the state.

During the study period, Arkansas Power and Light faced a performance incentive based on capacity factors. Regulators set a capacity factor target for the utility's nuclear power plants. The target contained a deadband of "plus or minus" 2.5 percentage points. Arkansas Power and Light was allowed to recover all of its fuel and purchased power costs when the actual capacity factor for each of the targeted power plants fell within the deadband. It was penalized when the actual capacity factors fell below the targets, and it was rewarded when the actual capacity factors exceeded the targets. Rewards and penalties were reflected in the monthly fuel adjustment factor.

The fuel-related incentives for Niagara Mohawk, and Rochester Gas and Electric affect their purchases of fuel and economy power.[5] Both utilities forecast their expected fuel and purchased power costs for the upcoming year, and rewards and penalties are determined on the basis of differences from their forecasts. Niagara Mohawk is allowed to keep 80 percent of the difference between actual fuel and purchased power costs and forecasts of these costs when forecasted costs exceed actual costs by $50 million or less. Rochester Gas and Electric is allowed to keep 80 percent of the difference when forecasted costs exceed actual costs by $30.5 million or less. Niagara Mohawk's reward increases to 90 percent of the savings when actual fuel and purchased power costs fall short of forecasted costs by more than $50 million and less than or equal to $100 million. This utility is allowed to keep all of the difference when savings exceed $100 million. The 100 percent threshold for Rochester Gas and Electric is $30.5 million. Symmetrical penalties are assessed when actual fuel and purchased power costs exceed forecasted

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[5] Starting in 1983, Niagara Mohawk Power also is subject to an incentives program based on construction costs. This program applies to the utility's Nine Mile Point Unit No. 2. The utility is rewarded for reducing construction costs below $4.6 billion, and is penalized if construction costs exceed $4.6 billion. The reward or penalty is set equal to 20 percent of the cost underrun or overrun, respectively.

costs. This penalty structure limits Niagara Mohawk's maximum annual exposure to losses of $15 million, and Rochester Gas and Electric's maximum annual exposure to losses of $6.1 million.

Carolina Power and Light and Duke Power Company also face incentives that affect their purchases of fuel and power. However, the system for following through rewards and penalties is different from that which applies to Niagara Mohawk and Rochester Gas and Electric. Uncapped annual increments or decrements to these utilities' revenue requirements are made through a fuel-charge-adjustment rider. These adjustments are based on full evidentiary hearings. This incentive program was in effect for all North Carolina utilities for the years 1982 through 1987.[6]

Prior to 1982, Carolina Power and Light and Duke Power were subject to a penalty-only program based on capacity factors. This program links fuel adjustments to the performance of nuclear and fossil fuel generating units. The capacity factor for nuclear units is fixed at 60 percent, while the capacity factors for fossil fuel units are based on their histories. Deviations from these standards have to be justified in a follow-up proceeding. Penalties are imposed when the utilities' explanations are found to be nonpersuasive by the North Carolina Utilities Commission.

Consumers Power Company was subject to three types of incentives during the study period. The first monitors its operations and level of administrative costs. The regulatory objective is to reduce expenses. Consumers Power keeps the entire difference when actual expenses fall short of projected expenses.[7] It absorbs the difference when actual exceeds projected expenses. The second type links this utility's rewards and penalties to a measure of availability. Specifically, regulators set a performance target for system availability. The utility is rewarded by an increment to its rate of return when the target is hit. A penalty amounting to a decrement to the rate of return is assessed

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[6] Since 1987, fuel cost recovery has been tied to a nuclear unit performance standard. This program also applies to all utilities in North Carolina.

[7] It is worthwhile to note for completeness sake that the projected growth in administrative expenses is tied to the Consumer Price Index (CPI).

when actual performance misses the target. The third type of incentive was based on fuel and purchased power costs. Regulators asked Consumers Power to forecast its fuel and purchased power costs. Actual costs are compared to forecasted costs. This utility is permitted to collect 90 percent of the excess of actual over forecasted costs. It retains 10 percent of the savings when actual costs are less than forecasted costs. All Michigan utilities faced the third incentive. Detroit Edison in addition to Consumers Power had to deal with the first and second incentives.

The reward and penalty structure confronting Philadelphia Electric Company during this study period is a function of its fuel costs, heat rates, capacity factors, and system availability. This incentive program is similar to the programs ordered for Arkansas Power and Light, Carolina Power and Light, and Duke Power Company.

Each incentive program for the five states contained in the first data set has one characteristic in common. The utilities are rewarded or penalized through the fuel adjustment clause. In some instances, they are rewarded for keeping fuel costs below forecasted levels. In other instances, they are rewarded for achieving or exceeding a predetermined capacity factor, which also tends to keep fuel costs low. Therefore, it is safe to say that the primary function of each incentive is to reduce the utilities' fuel costs.

Annual data on eight variables were collected for each utility.[8] Data on the adoption of incentives and the number of years they were in effect during the study period were found in two reports published by National Economic Research Associates, Inc.[9] The data pertaining to fuel costs, total operating costs, load factors, peak loads, total electricity generation, and average costs were provided graciously by Sanford Berg and Jinook Jeong. The Producer Price Index data were obtained directly from the

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[8] The selected utilities are either independent investor-owned utilities or subsidiaries of investor-owned public utility holding companies.

[9] John H. Landon and David A. Huettner, *Utility Performance Evaluation: A Report to the Rate Research Committee of the Edison Electric Institute* (n.p.: National Economic Research Associates, Inc., September 18, 1984). National Economic Research Associates, Inc. (NERA), *Incentive Regulation in the Electric Utility Industry* (n.p.: NERA, 1990).

information service of Bureau of Labor Statistics, Department of Commerce. The sales data were extracted from documents published by the Energy Information Administration of the U.S. Department of Energy.[10] Table 5-2 contains descriptive statistics for the nondichotomous variables.

TABLE 5-2

DESCRIPTIVE STATISTICS FOR FIRST DATA SET

Variable	N	Minimum	Maximum	Mean	Standard Deviation
c_{tf}	230	1.2800	2016.73	346.700	363.530
c_{to}	230	68.200	3092.75	790.380	657.920
u	169	0.0000	9.00000	4.50000	1.76000
SC	230	773.13	20724.0	6875.49	5065.99
S	230	3033.7	67489.6	26647.6	18506.9
C	230	0.0001	5.69100	1.27055	0.75187
K	230	723.13	15683.0	5469.03	4079.04
G	230	170.06	69306.0	23071.7	18232.2

c_{tf}:	Fuel cost in millions of dollars
c_{to}:	Total operating cost in millions of dollars
u:	Duration of incentive regulation in years
SC:	System capacity (MW)
S:	Sales in megawatthours (MWh)
C:	Average cost per million Btu
K:	Peak load in thousands of kilowatts (kW)
G:	Total electricity generation in millions of kilowatthours (kWh)

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[10] U.S. Department of Energy, *Financial Statistics of Selected Investor-owned Electric Utilities: 1989* (Washington, D.C.: Energy Information Administration, January, 1991); U.S. Department of Energy, *Financial Statistics of Selected Investor-owned Electric Utilities: 1990* (Washington, D.C.: Energy Information Administration, January, 1992).

The data comprising the first data set do not contain any missing values. Additionally, these data are balanced in the sense that the number of utilities with fuel-related incentives are approximately equal to the number of utilities without them. For the most part, these data are associated with utilities facing incentive programs consisting of rewards and penalties.[11]

The second data set spans a period of nine years, which begins in 1979 and ends in 1987. The second data set is created by adding and deleting utilities from the first data set. Southern California Edison has been added to the first data set.[12] This utility has been simultaneously subject to various forms of incentive regulation since 1981. Most of these incentives are meant to improve plant operations and fuel-related practices, and hence, they contribute toward lower fuel costs. Additionally, California's removal of the conservation disincentive, via the Electricity Rate Adjustment Mechanism (ERAM), can be thought of as contributing to lower fuel costs because it enables the utility to react more favorably to conservation opportunities. Table 5-3 list the utilities in the second data set.

Annual data on eleven variables were collected for these utilities. Data on incentives, profit margins, peak loads, and in-house generation as a percent of potential in-house generation were obtained from the computer tape provided by Berg and Jeong. Data on sales and steam generation were obtained from the Energy Information Administration's publications. Data on fuel prices, utility costs, and heat rates were obtained from National Technical Information Service computer tapes. These tapes contain FERC Form 1 data. Table 5-4 contains some descriptive statistics for these variables.

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[11] These data do contain one penalty-only incentive program that was in effect for Carolina Power and Duke Power from 1974 to 1981.

[12] The deleted utilities are Arkansas Power and Light, Iowa Electric Light and Power, Iowa-Illinois Gas and Electric, and Virginia Electric and Power Company.

TABLE 5-3

ELECTRIC UTILITIES IN SECOND DATA SET

Company Name	Length of Time Incentives in Effect
Carolina Power and Light	1978 - 1987
Commonwealth Edison of Illinois	No incentive regulation
Consumers Power Company	1983-1987
Duke Power Company	1978-1987
Niagara Mohawk Power	1982-1987
Northern States Power of Minnesota	No incentive regulation
Philadelphia Electric Company	1985-1987
Rochester Gas and Electric	1983-1987
Southern California Edison Company	1981-1987
Wisconsin Electric Power Company	No incentive regulation

TABLE 5-4

DESCRIPTIVE STATISTICS FOR SECOND DATA SET

Variable	N	Minimum	Maximum	Mean	Standard Deviation
p_o	90	0.00000	73.8130	27.1033	11.75060
p_c	90	0.00000	57.9560	35.5630	16.06440
p_g	90	-0.8300	9.24670	3.18451	1.936950
c_{sf}	90	36.9730	1928.52	481.669	399.7190
c_{stp}	90	36.2085	1971.72	509.699	414.2079
$c_{o\&m}$	90	15.8870	330.234	123.788	81.75451
u	90	0.00000	10.0000	2.57777	3.097580
H	90	7071.33	18777.0	12449.3	2235.570
S	90	6369.13	67489.6	35009.8	18251.62
K	90	950.000	15683.0	7233.77	4254.570
G_s	90	1491.16	51624.3	18907.0	11514.96
L	90	0.52700	0.71090	0.60460	0.045767

p_o: Delivered price of oil purchased in \$/barrel
p_c: Delivered price of coal purchased in \$/ton
p_g: Delivered price of gas purchased in \$/1000 cubic feet
c_{sf}: Steam fuel cost in millions of dollars
c_{stp}: Steam total production costs in millions of dollars
$c_{o\&m}$: Steam operating and maintenance costs without fuel in millions of dollars
u: Duration of incentive regulation in years
H: Average Btu/kilowatthour (kWh)
S: Sales in thousands of megawatthours (MWh)
K: Peak load in thousands of kilowatts (kW)
G_s: Steam generation in thousands of megawatthours (MWh)
L: Total generation/(System capacity * 8760)

Description of the Econometric Models

Equations (5-11) and (5-12) describe the first econometric model used in this research.

$$c_{tf} = a_1 I + a_2 G + a_3 L + a_4 P + a_5 K + e \tag{5-11}$$

$$c_{to} = b_1 I + b_2 c_{tf} + b_3 S + b_4 L + b_5 K + b_6 P + b_7 u + e \tag{5-12}$$

The first equation contains nominal fuel costs as the endogenous variable. The exogenous variables are total electricity generation, load factor, the Producer Price Index, peak demand, and an indicator variable for fuel-related incentives. The endogenous variable in the second equation is total operating costs. Total fuel costs, total sales, load factor, peak load, the Producer Price Index, an indicator variable for fuel-related incentives, and the duration of these incentives are exogenous variables in the second equation.

A critical feature of this model is that changes in total operating costs, c_{to}, do not induce changes in total fuel costs, c_{tf}. This modelling choice is made for the following reasons. First, it is always true that total operating costs increase when fuel costs rise and nonfuel costs are held constant. Therefore, it is tautological to treat a change in total operating costs as an influence on total fuel costs when total nonfuel costs are held constant. Second, it is inappropriate to model total operating costs as influencing total fuel costs when total nonfuel costs, unrelated to the conversion of fuel into electricity, are not held constant. To show this, consider a change in nonfuel costs prompted by an improvement in the performance of operations unrelated to the conversion of fuel into electricity. Perhaps, the utility has adopted better management practices in personnel administration. Obviously, the effect of this management decision on total fuel costs is negligible. Third, it may be inappropriate to model total operating costs as influencing total fuel costs when nonfuel costs, related to the conversion of fuel into electricity, are not held constant. To make this claim more clear, consider a change in nonfuel costs prompted by the adoption of better engineering practices. When these new practices do not cause changes in the utility's economic dispatch or its ability to convert fuel to electricity, total fuel costs do not change. The same amount of fuel is required to produce the same amount of electricity. Now suppose that the adoption of better engineering practices causes a change in the economic dispatch of the utility's generation units. Let these new practices increase the running time of low cost generation units, and decrease the running time of high cost generation units. The effect of these better practices is to reduce total fuel costs when the level of electricity production is left unchanged. Yet, it is apparent that the change in total fuel costs is not caused by a change in total operating cost. Instead, the change in total fuel costs is a result of a change in a specific type of nonfuel cost.

Another distinguishing feature of this econometric model is that fuel-related incentives are modelled as an exogenous variable that affects a utility's fuel and total operating costs. This modelling choice is justified by the Hausman test conducted in the second section of this chapter. Recall that the version of the Hausman test used in this research failed to reject the hypothesis that the adoption of fuel-related incentives is an exogenous variable.

Neither equation (5-11) nor equation (5-12) models the effects of fuel-related incentives on the price of electricity. The decision to omit a price equation is based on the following reasoning. The adoption of these fuel-related incentives is embedded within rate-of-return regulation. Under rate-of-return procedures, the prices for different types of electricity service tend to be set after the utility's costs have been identified and approved. As a result, the price equation is mainly an extension of the total operating cost equation.[13]

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[13] At best, there is a weak simultaneity relationship between prices and costs in a market subject to rate-of-return regulation. Prices may affect costs through quantities demanded of different services. Following is a brief sketch of how this feedback mechanism works. The utility makes an estimate of the quantity demanded of a particular service. A typical method is to use a projection of prices to forecast the quantity demanded of the service. The demand forecast is used to predict the utility's costs. The cost prediction is divided by the demand forecast to obtain service prices. Hopefully, consumers will elect to buy the forecasted quantities demanded at these prices. When prices are not consistent with quantities demanded, a feedback loop arises because prices, costs, and quantities demanded must be adjusted until they are within reasonable tolerance of each other.

A perhaps unusual aspect of equations (5-11) and (5-12) is the selection of the Producer Price Index as an exogenous variable. It is included because the nominal costs of production are meaningfully affected by inflation effect. To make this point, consider a wage increase without an accompanying increase in productivity. Assuming for convenience that the utility's production is unchanged, the effects of this wage increase are lower profits and higher nominal costs. Now suppose that instead of a wage increase there is an increase in the price of fuel without any increase in the efficiency at which fuel is converted to electricity. Assuming that the utility's generation is unchanged, the higher nominal fuel prices cause an increase in the utility's nominal total fuel costs. Similarly, an increase in nominal total fuel costs without a productivity increase elsewhere causes an increase in the utility's nominal total operating costs when its total sales are unchanged.

The decision to use nominal costs instead of real costs rests on the observation that we are examining a regulatory decision to change public policy. Many regulators view inflation as something that is beyond their control, but nevertheless as something that influences their decisionmaking. When prices for everything are rising, regulators attempt to keep the prices for electricity, telecommunications, gas, and water services low in a nominal sense. Although it is certainly true that these regulators should feel a sense of accomplishment when they have prevented increases in the inflation-adjusted cost of producing electricity, most of their constituents know little to nothing of the economic relevance of the inflation-adjusted costs of producing a regulated service. Instead, their constituents know how much of their monthly pay checks go to electric utilities, and hence, these constituents worry about the nominal cost of producing electricity.

Because constituents are concerned about rising nominal costs, regulators often consider changes in public policy that are expected to lower these nominal costs. In particular, they open dockets and hold hearings relating to the adoption of various types of programs that have the potential to reduce the utility's nominal costs of producing electricity. One of these programs is fuel-related incentives. Under this regulatory format, utilities face performance-based incentives that are expected to lower their nominal fuel costs.

Equations (5-13) and (5-14) describe the second econometric model used in this research.

$$c_{sf} = a_1p_o + a_2p_g + a_3p_c + a_4L + a_5H + a_6I + a_7G_s + a_8K + e \tag{5-13}$$

$$c_{stp} = b_1I + b_2c_{sf} + b_3c_{o\&m} + b_4H + b_5S + b_6L + b_7K + b_8u + e \tag{5-14}$$

The first equation contains nominal fuel costs incurred to produce steam as the endogenous variable. The exogenous variables are load factor, a measure of energy conversion, H, peak demand, total steam generation, an indicator variable for fuel-related incentives, and prices for oil, coal, and natural gas. The endogenous variable in the second equation is total steam production costs. Total steam fuel costs, total sales, load factor, peak load, a measure of energy conversion, an indicator variable for fuel-related incentives, and the duration of these incentives are exogenous variables in the second equation.

This second econometric model is more disaggregated than the first econometric model. Instead of using the Producer Price Index as a proxy for the utility's price of fuel, actual fuel prices are included in the specification of the second model. In addition, a measure of the efficiency at which energy is converted to electricity has been inserted into the second model. This new variable supplies some information about the engineering practices of the utilities. The other variables are essentially the same as found in the first econometric model.

Concluding Remarks

Two econometric models are estimated in the next chapter. Panel data are used to determine the effects of fuel-related incentives on nominal fuel and production costs. The estimation strategy for both models is neither simultaneous nor recursive. Instead, the fuel cost and production cost equations are treated as separate and unrelated to each other. In particular, each model has the following characteristic. A change in the level of a utility's fuel costs influences total costs, but a change in the level of a utility's total costs does not affect its fuel costs.

CHAPTER 6

ESTIMATION OF TWO ECONOMETRIC MODELS: THE EFFECTS OF FUEL-RELATED INCENTIVES ON UTILITY COSTS

The purpose of this chapter is to estimate the parameters of the two econometric models described in the preceding chapter. This task begins with the selection of an estimation strategy, continues on with the selection of estimation techniques, and ends with the estimation and testing of the models' parameters.

The next section discusses the estimation strategy. The following section contains the estimation techniques and provides the reasons why they are selected. The next-to-last section presents the results of the empirical testing of the models. Concluding remarks are made in the final section.

Estimation Strategy

The estimation strategy is to find, if possible, an efficient estimate of the incentives parameter. An efficient estimate has the smallest variance of all unbiased estimates.[1] An unbiased estimate is on average equal to the true value of the parameter.[2]

The alternative strategy is to find a consistent estimate of the effects of the adoption of fuel-related incentives on a utility's costs. Consistent estimates often are the next best thing when efficient estimates cannot be obtained for whatever reason. Wonnacott and Wonnacott loosely describe a consistent estimate as one that becomes

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[1] T. W. Mirer, *Economic Statistics and Econometrics* (New York: MacMillan Publishing Company, 1983): 249.

[2] Ibid., 248.

better and better as the size of the data set increases.[3] "Better" is interpreted as a reduction in the spread of the probability distribution of the estimate about the true value of the parameter. The measure of this spread is the mean squared error (MSE), which is the sum of the sample variance of the estimate and the square of the estimator's bias.[4] The best possible MSE is zero, and a consistent estimate achieves this best possible value as the size of the data set increases to infinity. Therefore, a consistent estimate has the characteristics that any sample variance and bias head toward zero as the sample size increases.

Although a consistent estimate is useful for econometric work, it does have its drawbacks. In addition to the possibility of a large variance, a consistent estimate may also be biased when sample sizes are finite. A biased estimate is on average too high or too low.[5] When substantial bias is present, an unbiased and inconsistent estimator may be preferred to a biased and consistent estimator.

Estimation Technique

Panel data for several investor-owned electric utilities are used to estimate the models' parameters. These data are best described as a time series of cross-sectional information. The decision to pool these data has been made because time-series-related exogenous variables such as duration of incentive regulation, u, profit margin, M, sales, S, and peak load, K, are included in our data set.[6] Because we are using pooled data, the problem of selecting an estimation technique becomes the problem of finding

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[3] Ronald J. Wonnacott and Thomas H. Wonnacott, *Econometrics* (New York: John Wiley & Sons, Inc., 1970): 45.

[4] Mirer, *Statistics and Econometrics*, 249.

[5] Ibid., 248-50.

[6] Robert S. Pindyck and Daniel L. Rubinfeld, *Econometric Models and Economic Forecasts*, 2nd ed. (New York: McGraw-Hill Book Company, 1981): 253.

estimators that are suitable for handling data with time series and cross-sectional variation.

Pindyck and Rubinfeld note that the ordinary least squares (OLS) estimator is consistent and unbiased when there is neither time series variation nor cross-sectional variation in the data set. When OLS is selected for pooled data, one sufficient assumption is that each element of the pooled data should be treated identically because the models' intercepts are constant over time and over utilities.[7] Another sufficient assumption for the selection of the OLS estimator is that the models' intercepts vary systematically over time and over utilities.[8] Obviously then, the selection of the OLS estimator is questionable when the intercepts vary randomly.[9]

A candidate for consistent and unbiased estimation when intercepts vary randomly is the "error components" estimator. This particular estimator is consistent and unbiased when the time series error component, the cross-sectional error component, and the combined time series and cross-sectional error components are uncorrelated with each other, and when they are not autocorrelated across utilities or time periods.[10] However, the error components approach, under the assumptions noted above, does have shortcomings. The assumed absence of time series autocorrelation means that the

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[7] Ibid., 253.

[8] Ibid., 255, 257.

[9] Ibid., 257.

[10] P. Balestra and M. Nerlove, "Pooling Cross-Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," *Econometrica* 34 (1966): 585-612; T. D. Wallace and A. Hussain, "The Use of Error Components Models in Combining Cross Section with Time Series Data," *Econometrica* 37 (1969): 55-72; M. Nerlove, "Further Evidence on the Estimation of Dynamic Economic Relations from a Time Series of Cross Sections," *Econometrica* 39 (1971): 359-81. See also, W. A. Fuller and G. E. Battese, "Estimation of Linear Models with Crossed-Error Structure," *Journal of Econometrics* 2 (1974): 67-78; George G. Judge, R. Carter Hill, William E. Griffiths, Helmut Lutkepohl, and Tsoung-Chao Lee, *Introduction to the Theory and Practice of Econometrics*, 2nd ed. (New York: John Wiley & Sons, 1988), 484; Pindyck and Rubinfeld, *Econometric Models*, 256-57.

statistical properties of the time series error component do not depend on the passage of time.[11] Yet, it may actually be the case that the time series error component is autoregressive. For example, the time series error component in the last period of the analysis may be influenced by the error component in the next-to-last period, and so on. The assumed absence of cross-sectional autocorrelation means that the statistical properties of the cross-sectional error component do not depend on differences in the utilities' operations.[12] When this assumption is relaxed, the obvious alternative is that differences in the utilities's operations in a given year affect the statistical properties of the cross-sectional error component.[13] Another statistical issue that is not addressed by the error components approach is the possibility of time series and cross-sectional heteroscedasticity for each utility.[14]

An alternative estimation technique may be substituted for the error components technique for any of the above reasons. A nonautoregressive technique focuses on the statistical problems of heteroscedasticity and cross-sectional correlation. The autoregressive technique is concerned primarily with the time series aspect of the random errors associated with the pooled data. Usually, the time series aspect of the random errors is assumed to first-order autocorrelation, which means that an error in any time period is influenced by the error in the immediately preceding time period.

Pindyck and Rubinfeld show that efficient estimates can be extracted from a first-order autoregressive model when the remaining error structure is assumed to be homeoscedastic without cross-sectional correlation.[15] A more general error structure for

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[11] Pindyck and Rubinfeld, *Econometric Models*, 258. See also, Judge, et al., *Theory and Practice of Econometrics*, 480.

[12] Judge, et al., *Theory and Practice of Econometrics*, 480.

[13] Pindyck and Rubinfeld, *Econometric Models*, 258.

[14] Ibid., 258.

[15] Ibid.

for an autoregressive model using pooled data is suggested by Parks.[16] The error structure assumes cross-sectional heteroscedasticity, cross-sectional correlation for each year, and first-order autocorrelation. Park's has shown that his estimator is consistent. Greene provides a consistent estimator for the case of first-order autocorrelation and cross-sectional heteroscedasticity.[17]

Exploratory runs of both models were made to test for autocorrelation, cross-sectional heteroscedasticity, and cross-sectional correlation.[18] The restriction of cross-sectional correlation was rejected for both models. However, the restrictions of first-order autocorrelation and cross-sectional heteroscedasticity were accepted for both models. Consequently, the OLS and error components techniques are not suitable for our data set. Instead, the best estimation technique accounts for first-order autocorrelation and cross-sectional heteroscedasticity.

Although the estimator associated with this technique is consistent, it may produce biased estimates of the effects of fuel-related incentives on a utility's costs. Additionally, the estimator is likely to yield estimates with inflated standard deviations because the data sets are finite.[19] Consequently, there are problems with the use of this estimator because we want to gain insights into the causal properties of the relationships between

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[16] R. W. Parks, "Efficient Estimation of a System of Regression Equations when Disturbances Are Both Serially and Contemporaneously Correlated," *Journal of the American Statistical Association* 62 (1967): 500-09.

[17] William H. Greene, *Econometric Analysis* (New York: MacMillan, 1990). For example, abnormally large variances for the parameter estimates are one of the problems that arise when the possibility of autocorrelated error terms is not recognized. Failure to correct for autocorrelation improperly decreases the value of "t-statistic," which is used to determined the statistical significance of the regression coefficients. As the t-statistic falls, there is a greater chance of incorrectly accepting the null hypothesis that the exogenous variable does not influence the endogenous variable.

[18] These computer runs are available on request.

[19] Mirer, *Statistics and Econometrics*, 264.

fuel-related incentives, fuel costs, and production costs. The potentially biased and potential imprecise nature of the estimates makes it difficult to determine what the effect of the adoption of fuel-related incentives has been on a utility's costs. However, the limitations of econometric estimation are an unavoidable fact of life with respect to empirical work in economics. It is seldom the case that the error term is so well-behaved that the estimator is efficient. Multicollinearity among the exogenous variables inflates the standard deviations, and thereby increases the imprecision of the estimates. When the values of the exogenous variables are measured imperfectly, this limitation creates biased estimates. Each of these problems plagues econometric analysis to one degree or another, and the analysis contained in this report is no exception.

Estimation Results

The results of the autoregressive estimation of the two econometric models are shown in equations (6-1), (6-2), (6-3), and (6-4). The estimate of main interest is the regression coefficient representing the effects of fuel-related incentives on a utility's costs. The estimates for the first model are shown in equations (6-1) and (6-2).

$$\begin{array}{l} c_{tf} = \underset{(2.887)^{*}}{21.680\ I} + \underset{(5.229)^{*}}{.00419\ G} - \underset{(-8.464)^{*}}{83.182\ L} + \underset{(6.764)^{*}}{.40420\ P} + \underset{(11.599)^{*}}{.04325\ K} \end{array} \tag{6-1}$$

$$c_{to} = \underset{(14.898)^{*}}{1.3464\ c_{tf}} - \underset{(-.839)}{16.286\ I} + \underset{(2.594)^{*}}{.00730\ S} - \underset{(-5.572)^{*}}{213.25\ L} - \underset{(-1.900)}{.02337\ K} + \underset{(14.209)^{*}}{3.3459\ P} + \underset{(1.145)}{6.4698\ u} \tag{6-2}$$

The fuel cost equation, equation (6-1), features the somewhat surprising result that the adoption of fuel-related incentives increases the utility's total fuel cost. One possible explanation is that these incentives are inducing a utility to opt for higher priced fuel in an attempt to meet performance objectives. Perhaps, a utility might be dedicating more labor and other variable resources to the support of fuel-related activities. For example, more effort may be expended to negotiate lower priced fuel purchases. However, the increased variable costs may outweigh the reduction in fuel costs. Finally, the incentive to substitute purchased power for in-house generation might be driving fuel prices up as a utility makes it easier to find substitution opportunities. Each and every one of the possibilities has to be considered as possible because the positive incentive coefficient is statistically significant at the 95 percent confidence level.[20]

The statistical significance of all the other exogenous variables in equation (6-1) is encouraging. It appears that the specified model is performing reasonably well. Also encouraging is that all signs of these variables are as expected. More in-house generation seems to result in higher fuel prices. The obvious explanation is that fuel costs are not declining, and more fuel is being used to produce more electricity. Growth in the utility's peak load appears to increase its fuel costs. The explanation is conventional. More peaking units come on line as peak load increases. The operation of these peaking units tends to drive up fuel costs because these units tend to use higher priced fuels. Increases in the Producer Price Index, representing a proxy for increases in fuel prices, surfaces as a factor that swells a utility's fuel costs. Only improvements in a utility's in-house generation as a percent of potential in-house generation, hereafter called load factor, emerges as an influence for lower fuel costs.

Most of the signs displayed in equation (6-2) are expected. The positive and statistically significant sign for fuel costs indicates that higher fuel prices contribute toward increased total operating costs. This result is extremely reasonable because sales, peak load, and load factor are being held constant in this equation. Another extremely rational result is that an increase in the Producer Price Index causes an increase in total operating costs. A rising Producer Price Index, which in this instance represents an increase in the nonfuel costs of production, is expected to contribute to escalating

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[20] Looking at the positive coefficient for incentives from another direction, it appears that fuel-related incentives have not induced productivity improvements. A utility may not be substituting low-cost fuel for high-cost fuel. Moreover, a utility may not be getting more useable heat out of the same quality fuel.

operating costs when sales and fuel costs are held constant.[21] Of course, this cost growth may be due completely to pure inflation, or it may be due to some combination of inflation and an elevation in the use of the nonfuel factors of production. Finally, the positive sign on sales is easily explained by the fact that more sales implies either more in-house production or more purchased power or both. More in-house production expands the utility production costs. More purchased power boosts the utility's administrative cost. Either type of cost growth increases operating costs.

The unexpected result is that total operating costs rise as fuel-related incentives are kept in place for longer periods of time. Conceivably, a utility may be becoming more accustomed to the incentives as time wears on. This familiarity may breed a disdain for the incentives, which is reflected in steadily rising operating costs. This explanation is not totally unrealistic because sales, load factor, and peak load growth are held constant in this equation. But whatever the possible explanation for the positive sign for the incentive duration variable, it is the case that the estimate of the effect of incentive duration on total operating costs is statistically insignificant.

Most of the negative-signed parameters in this equation also are expected. It seems that the adoption of fuel-related incentives contributes toward the more efficient operation of the utility. Perhaps, the utility is aware that regulators are watching its operations more carefully. However, the disappointing aspect of this estimate is that it is statistically insignificant, which implies that the adoption of fuel-related incentives has no impact, either positive or negative, on the utility's total operating costs. A rather surprising negative sign is the suggestion that growth in peak load causes a reduction in total operating costs. One possible explanation lies with the dual restrictions of constant load factors and peak loads. As peak load grows, the load factor deteriorates. This

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[21] A rising PPI may be thought of as higher operating costs when fuel cost is held constant. For example, imagine that the per unit cost of producing 100 kilowatthours (kWhs) of electricity is $0.05 per kWh, and $0.10 per kWh for the production of 200 kWhs. Assume both of these costs are observed before the PPI increases 10 percent. The per unit cost of producing 100 kWhs becomes $0.055 per kWh for 100 kWhs, and $0.11 per kWh for 200 kWhs. Consequently, operating cost has increased as a result of an increase in the PPI because fuel costs have been held constant.

suggests that base load units are operating for shorter periods of time. The reduced operation of these base load units may explain the observed decline in total operating costs. But once again, statistical significance is lacking for this estimate. Therefore, the foregoing rather convoluted explanation of the effect of peak load growth on total operating costs may not be necessary.

The combination of the statistical significance of the incentive variable in the fuel cost equation and its statistical insignificance in the total operating cost equation manifests a somewhat comforting interpretation of the effects of fuel-related incentives on a utility's costs. Although fuel costs do not decline as a result of the adoption of these incentives, the implementation of these incentives does not seem to have resulted in a rise in total operating costs. This result suggests, but does not demonstrate, that a utility makes some performance adjustment outside of the fuel cost areas in response to the adoption of fuel-related incentives. Consequently, it appears that a utility is manipulating the fuel-related incentives. However, this manipulation is not affecting either the utility's quality of service or its costs of production. At the very worst in this regard, the rise in fuel costs is no greater than the decline in nonfuel costs. The potential problem, of course, is that the utility may be receiving a reward for meeting performance incentives without a contemporaneous reduction in the costs of production. Hence, it may be the case that the price of electricity is rising as a result of the adoption of the fuel-related incentives.

Table 6-1 summarizes the expected and actual signs for the exogenous variables. This summary table furnishes a picture of how changes in a utility's environment causes changes in its fuel and total operating costs. Assume as a result of some unspecified cause that regulators adopt fuel-related incentives. Utility behavior induced by these incentives causes a swell in fuel costs on the one hand, while they cause improvements in operating efficiency on the other hand. The efficiency improvements serve to hold total operating costs steady in spite of the rising fuel costs. Consequently, sales may not increase as a result of the adoption of the fuel-related incentives. In fact, sales may actually fall because the rewards for meeting performance objectives may inflate the price of electricity.

TABLE 6-1

EXPECTED AND ACTUAL SIGNS OF EXOGENOUS VARIABLES: MODEL 1

	Fuel Cost		Operating Cost	
	Expected	Actual	Expected	Actual
Fuel Cost			+	+
Generation	+	+		
Incentives	-	+	-	-
Incentive Duration			-	+
Peak Load	+	+	+	-
Producer Price Index	+	+	+	+
Load Factor	-	-	-	-
Sales			+	+

The estimates for the second model are displayed in equations (6-3) and (6-4).

$$\begin{aligned} c_{sf} = {} & \underset{(2.525)^*}{154.35\, p_g} + \underset{(.413)}{3.0433\, p_c} - \underset{(-.173)}{1.0100\, p_o} - \underset{(-1.956)^*}{2076.3\, L} + \underset{(.672)}{26.948\, H} - \underset{(-.015)}{4.6938\, I} \\ & + \underset{(5.194)^*}{14.025\, G_s} + \underset{(4.707)^*}{.32826\, K} - \underset{(-.717)}{38.0781\, u} \end{aligned} \tag{6-3}$$

$$\begin{aligned} c_{stp} = {} & \underset{(6.243)^*}{.28744\, c_{sf}} + \underset{(50.585)^*}{.75137\, c_{o\&m}} - \underset{(-1.954)^*}{191.00\, I} + \underset{(2.707)^*}{29.852\, H} + \underset{(1.559)}{2.2255\, S} - \underset{(-4.049)^*}{1097.7\, L} \\ & - \underset{(-2.375)^*}{.13971\, K} + \underset{(1.464)}{28.738\, u} \end{aligned} \tag{6-4}$$

The use of the second more disaggregated data set to estimate the fuel cost equation produced the following results. All in all, the changes in delivered fuel prices did not have the expected effects on the utility's cost of fuel used to generate steam. The estimates of the effects of coal and oil prices are statistically insignificant, which suggests that changes in these fuel prices do not affect a utility's fuel costs. Of course, it was expected that increases in the prices of either of these fuels would have inflated fuel costs. However, the expected effect did occur with respect to the impact that changes in gas prices have on a utility's fuel costs. A rise in the price of gas induces statistically significant growth in fuel costs.

The adoption of fuel-related incentives, the duration of incentive regulation, and changes in heat rate do not have statistically significant effects on the fuel costs incurred by the utility to generate steam. These results suggest that performance-based incentives in the fuel and efficiency areas have no visible impact on a utility's operations. Still on the other hand, the absence of statistical significance implies that the adoption of either type of incentive does not materially harm consumers. Another comforting aspect of these results is that the signs for these variables are as expected. The signs for the incentives and duration variables are negative, suggesting that the adoption of fuel-related incentives could reduce fuel costs. Meanwhile, the sign for the heat rate variable is positive, which means that improvements in the efficiency of converting fuel to electricity could lower a utility's fuel costs.

Growths in peak load and in-house electricity generation create increases in the fuel costs that a utility incurs to generate steam. Once again, improvements in a utility's load tend to lower these fuel costs. The explanations for these results have already been given in the discussion of equation (6-1).

The estimation of the total production cost equation produced the most policy relevant results. The estimate of the effect of fuel-related incentives on total production costs is negative and statistically significant. The regulators' decision to adopt these incentives appears to have resulted in lower production costs, despite the observation that the adoption of fuel-related incentives does not seem to have affected the level of the fuel costs incurred by the utility to generate steam. It appears, somewhat unexpectedly, that these incentives encourage the utility to be more efficient with respect to the operation of its generation and related facilities. Perchance, a utility is aware that regulators are watching its operations more carefully.

Two other policy relevant results are that the duration of incentive regulation does not appear to have a material effect on a utility's total production costs, and improvements in a utility's ability to convert energy into electricity serves to lower its production costs. The lack of a material effect on production costs due to the longevity of incentive regulation suggests that regulators do not have to fear the "familiarity result" found in the estimation of the econometric model based on the ready availability of aggregated data.[22] Furthermore, the statistical significance of the energy conversion variable suggests that more efficient fuel conversion practices can reduce the need for nonfuel resources.

The positive signs and statistical significance of the fuel cost variable and operations and maintenance costs variable are expected. Obviously, higher fuel costs bring on higher total production costs when sales and the efficiency of energy conversion are held constant. The same explanation carries over to the statistical relationship between total production costs and changes in operations and maintenance costs. Another unexceptional result is the negative and statistically significant sign with respect to the load factor variable.

An explanation is that residual nonfuel costs are systematically related to load factor when fuel costs and operations and maintenance costs are held constant. Perhaps, the utility is using less nonfuel resources in an effort to compensate for the lack of influence of fuel-related incentives on fuel costs.

An unforeseen result is the statistical insignificance of the sales variable. It was anticipated that higher sales would create an environment that could be reasonably associated with higher production costs when a utility's ability to convert energy into

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[22] However, it should in fairness be noted that the sign of the duration variable is positive, which suggests that a utility's total production costs might increase as it becomes more familiar with incentive regulation.

electricity is held constant. Perhaps, it is the case that rising sales do not have a material effect on total production costs because the utility has extended its efforts to improve the efficiency of its actions and procedures in the nonfuel areas.

The most confounding result is the statistical significance of the negative sign on the peak load variable. It seems that growth in peak load reduces total production costs when load factor and sales are held constant. One possible explanation may be found in the substitution opportunities between in-house generation and purchased power. Recall that some of the firms in the second sample face an incentive to increase their use of purchased power. When there is growth in the peak load and the load factor is held constant, there is necessarily an increase in the number of kilowatthours produced by the utility. When sales are held constant, the increase in the production of in-house generation is compensated for by a reduction in purchased power. However, a reduction in purchased power would not be viewed favorably by regulators, if it is not associated with a decline in total production costs. Consequently, fuel-related incentives could induce a utility to expend more effort in its cost-reducing efforts when its peak load is growing.

Overall, there is reason to believe that consumers can benefit from the adoption of fuel-related incentives. Although the costs incurred to generate steam have not been affected by these incentives, it has been revealed that total production costs have declined. Under rate-of-return regulation, these cost declines are flowed through to consumers in the form of lower prices for electricity. As long as the decline in total costs is larger than the reward for meeting performance objectives, consumers benefit after the adoption of fuel-related incentives.

Table 6-2 summarizes the signs for the exogenous variables. Like the summary before it, this summary paints a favorable picture of how the adoption of fuel-related incentives affects a utility's costs. These incentives have lowered the utility's total production costs even though they do not materially affect the utility's fuel costs. Moreover, the utility's cost reduction efforts do not appear to be badly influenced by the duration of this incentive regulation.

TABLE 6-2

EXPECTED AND ACTUAL SIGNS OF EXOGENOUS VARIABLES: MODEL 2

	Fuel Cost		Operating Cost	
	Expected	Actual	Expected	Actual
Fuel Cost			+	+
Operation and Maintenance Cost			+	+
Steam Generation	+	+		
Heat Rate	+	+	+	+
Incentives	-	-	-	-
Incentive Duration	-	-	-	
Peak Load	+	+	+	-
Price of Oil	+	-		
Price of Coal	+	+		
Price of Gas	+	+		
Load Factor	-	-	-	-
Sales			+	+

Concluding Remarks

In this chapter, the cost-reducing effects of fuel-related incentives have been estimated. Two observations stand out as a result of the estimation of the two econometric models developed in prior chapters. First and surprisingly, the adoption of these incentives does not have the expected effect on fuel costs. With respect to the first econometric model which uses aggregated data, the existence of fuel-related incentives seem to have raised the utility's expenditures on all types of fuel used for all types of in-house generation. The adoption of these incentives fared somewhat better in the second econometric model, although they still do not perform as expected. With respect to the second model, the utility does not seem to respond materially to these fuel-related incentives in the fuel areas. Second and somewhat comforting, the adoption of fuel-related incentive does not have adverse effects on either total operating costs or total costs incurred in the production of steam generation. The results of the aggregated data model, which related these incentives to total operating costs, indicate that total operating costs are not materially affected by the adoption of fuel-related incentives. Meanwhile, the results obtained from the estimation of the disaggregated data model suggest that these incentive reduce total production costs.

No attempt has been made in this chapter to discover how fuel-related incentives might affect profits. This analytical path has not been traveled because the control of a utility's profits is neither a regulatory nor an economic objective associated with the introduction of these incentives. Rising or falling profits are indirect effects of the regulators' intention to improve a utility's productivity. Instead, the objective associated with the adoption of fuel-related incentives is to reduce a utility's cost per unit of output.

Lastly, the autoregressive, single equation estimation of the effects of fuel-related incentives on a utility's costs yields results that are consistent with the Averch-Johnson theory of regulation without incentives. The Averch-Johnson model of regulation points in the direction of higher fuel and operating costs, as a utility is not rewarded in the long term for reducing either of these expense categories. This X-inefficiency occurs because of the cost-plus nature of rate-of-return regulation, and despite the potential for rate-of-return regulation to cause a utility to inflate its capital/labor ratio in an effort to achieve maximum profits under conventional regulation. In both models, the estimates of the effects of fuel-related incentives on a utility's costs suggest that their adoption reduces this X-inefficiency.

CHAPTER 7

CONCLUSIONS AND POLICY

Two expected effects on utility behavior due to the adoption of fuel-related incentives are introduced in Chapter 3 of this report. The first effect implies that fuel and other more inclusive measures of a utility's costs will decline because these incentives have the effect of relaxing the rate-of-return constraint. The second effect suggests that the Averch-Johnson effect becomes less of a problem because a utility is allowed to earn increasingly higher rates of return. Only the cost reduction hypothesis is examined in this report.

The principal result of Chapter 4 is that the cost reduction hypothesis is testable without first obtaining measures of how much the relaxation of the rate-of-return constraint affects a utility's profits. What makes this analytical approach possible is the assumption that a utility does not earn actual profits that exceed a maximum profit level predetermined by regulators. As a result, any rate-of-return measure can be replaced by a measure consisting of the prices and quantities of a utility's outputs and inputs.

Before the cost reduction hypothesis can be tested, it is necessary to dispose of the question of the endogenity of incentive regulation. The Hausman test is used to answer this question. It is found in Chapter 5 that the utility's current cost performance does not sway the regulators' decision to adopt fuel-related incentives. A possible explanation for this conclusion is that regulators know that they face a substantial information asymmetry as they attempt to evaluate the factors affecting a utility's costs. In response to this obstacle, they adopt an incentive program on the basis of an ex ante belief that consumers may benefit if a utility is subject to the rigors of performance-based incentives.

Because the adoption of fuel-related incentives was found to be an exogenous variable, nonsimultaneous systems of econometric equations are used to model the cost reduction potential of these incentives. The parameters of these systems are estimated in Chapter 6. The primary conclusion therein is that the adoption of fuel-related incentives does not reduce fuel costs. However, a notable secondary conclusion is that the adoption of these incentives can cause reductions in either the total costs incurred to generate steam or costs incurred outside of the fuel area. Several actions by the utility may have contributed to the failure of fuel-related incentives to reduce fuel costs. The fuel cost reduction might not have occurred because the utility is unable to get more out of the same quality fuel. Perhaps, the adoption of incentive regulation has not induced the utility to institute programs that enhance the management of its fuel. Maybe, it has not become more careful in its handling of the receipt of fuel. For example, the firm might not be spending more time comparing the invoice weights with the weights as delivered.

Still, a utility does seem to react in an overall constructive manner to these incentives. The failure to reduce fuel costs is compensated for by reductions in other cost areas. Such utility behavior is consistent with the earlier finding that the adoption of fuel-related incentives is an exogenous variable. An implication derived from the exogenity of incentives is that a utility shifts costs and resources among its activities after regulators have adopted these incentives. The observed decline in total production costs incurred to generate steam suggests that a utility does not shift effort and resources in the direction that are targeted by the incentives. Therefore, it appears that the utility is responding to the regulators' ex ante beliefs that the utility can do better if given a positive incentive to do so.

Our analysis does not support the standard criticisms of fuel-related incentives. With respect to the utilities examined in this report, they have not increased either operating costs or total steam production costs in order to reduce fuel costs or improve capacity factors. Instead, they have kept these costs down after the adoption of fuel-related incentives. Perhaps, they have chosen to strengthen their engineering procedures and to substitute cost-saving capital investment for operating and production expenses. In practice, the adoption of these incentives seems to have created a more efficient utility by making it economically worthwhile for a utility to perform more adroitly.

The conclusions presented in this chapter suggest that it might be appropriate for regulators to adopt fuel-related incentives because they appear to improve a utility's overall efficiency. Of course, this observation is provisional for two reasons. First, the adoption of fuel-related incentives may not represent optimal regulatory behavior. The analysis in this report has not demonstrated that fuel-related incentives are the best way to reduce a utility's costs when compared to other forms of incentives such as price-cap or yardstick regulation. Second, it might be the case that the adoption of fuel-related incentives may induce a utility to substitute capital resources for noncapital resources, thereby increasing any capital bias of rate-of-return regulation.