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Regulatory Effectiveness in The Electric Utility Industry: An Empirical Analysis

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REGULATORY EFFECTIVENESS IN THE ELECTRIC UTILITY INDUSTRY: AN EMPIRICAL ANALYSIS*

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Abstract

An established result in the theory of the regulated firm is that an effective rate-of-return constraint induces the firm to employ larger proportions of capital inputs to noncapital inputs than would be the case in the absence of the regulatory constraint. This overcapitalization, often referred to as the Averch-Johnson effect, has been the subject of several recent empirical studies of the electric utility industry. The present study adds to this body of literature. It seeks to test for the effectiveness of utility regulation in the context of a cost minimization model which includes the allowed rate of return as an explanatory variable and permits arbitrary elasticities of substitution for any pair of inputs.

1. INTRODUCTION

1.1 PURPOSE OF THE STUDY

This study will concern itself with an empirical examination of the effectiveness of rate-of-return regulation in the electric utility industry. It is characterized by the use of a production function which is "flexible" in the sense that it places few a priori restrictions on the technological parameters of the production structure for steam electric generation. Empirical analysis of the production structure provides information which may be used to assess the general effectiveness of regulation. In particular, as the discussion below will point out, the presence of an effective regulatory constraint in the profit maximizing activities of the firm is manifested in the form of certain distinct parameters and comparative static properties of the profit maximizing model.

1.2 IMPLICATIONS OF EFFECTIVE REGULATION: THE AVERCH-JOHNSON HYPOTHESIS

The simple static model of a profit maximizing firm subject to rate-of-return regulation was first analyzed by Averch and Johnson (2). The firm, producing a single output with capital and labor inputs, is regulated to the extent that the earned rate of return on productive capital may not exceed a "fair" rate of return prescribed by a regulatory commission. In the static model it is assumed that the firm earns exactly the allowed rate of return; the allowed rate of return is assumed to exceed the market cost of capital but is less than the rate which the firm might earn in the absence of regulation.

The most significant conclusion of the Averch-Johnson analysis is that the effectively regulated firm maximizes profits by choosing a capital-labor ratio which exceeds the ratio that would be chosen

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in the absence of regulation. A brief examination of the model illustrates the distorted choice of inputs. Let

$Q = \Phi(K,L)$ = the firm's (well-behaved) production function.
$R(Q) = R[\Phi(K,L)]$ = the firm's total revenue function.
K = the amount of capital input.
L = the amount of labor input.
P_K = the implicit rental price per unit of capital.
P_L = the unit price of labor.
s = the allowed rate of return (assumed to exceed the cost of capital).

The firm seeks to maximize profits

$$R[\Phi(K,L)] - P_L L - P_K K \quad (1)$$

subject to the rate of return and production constraints,

$$R[\Phi(K,L)] - P_L L \leqq sK \quad (2)$$
$$Q \leqq \Phi(K,L) \ . \quad (3)$$

The Lagrangian expression is given by

$$Z = R[\Phi(K,L)] - P_L L - P_K K - \lambda\{R[\Phi(K,L)] - P_L L - sK\} - \Theta\{Q - \Phi(K,L)\} \ . \quad (4)$$

Differentiation of (4) with respect to the choice variables Q, K and L yields the necessary conditions for profit maximization:

$$R'(1-\lambda) - \Theta \leqq 0 \quad (5)$$
$$R'\Phi_K(1-\lambda) - P_K + \lambda s + \Theta\Phi_K \leqq 0 \quad (6)$$
$$R'\Phi_L(1-\lambda) - P_L(1-\lambda) + \Theta\Phi_L \leqq 0 \quad (7)$$
$$\Theta \geqq 0,\ \lambda \geqq 0,\ Q \geqq 0,\ K \geqq 0,\ L \geqq 0 \quad (8)$$
$$\lambda\{R[\Phi(K,L)] - P_L L - sK\} = 0 \quad (9)$$
$$\Theta\{Q - \Phi(K,L)\} = 0 \ . \quad (10)$$

where subscripts on the symbol Φ denote partial derivatives of the production function and R' denotes the derivative of the revenue function with respect to Q.

If we assume that the problem has a solution at a positive level of output, then (5) through (7) are satisfied as equalities.* Substituting for Θ in (6) and (7) and dividing (6) by (7) yields

$$\Phi_K/\Phi_L = P_K'/P_L \ ,$$

where $P_K' = (P_K - \lambda s)/(1-\lambda)$.

It is seen that the ratio of the marginal products is equal to the ratio of input prices (i.e. the choice of inputs is efficient) only if $\lambda = 0$ (i.e. only if the regulatory constraint is not binding). If $\lambda \neq 0$ then the choice of inputs is inefficient; it can be shown that the capital-labor ratio chosen in this case exceeds that which maximizes profit in the absence of regulation.

This overcapitalization, often referred to as the Averch-Johnson thesis, results from an effective subsidy to capital in the form of a positive difference between the allowed rate of return and the market cost of capital. Since regulation is in terms of the rate of return on the firm's stock of productive capital, the firm will maximize its profits by using a larger capital-labor ratio than the unregulated firm.

Thus an empirical analysis of regulatory effects is effectively a test for the presence of overcapitalization. It is to this issue that the present study is addressed.

Despite the potential importance of the Averch-Johnson thesis for energy policy, it is only within the past two years that empirical studies have appeared. The first to appear were by Courville (9) and Spann (31). These were followed by Petersen (27), Cowing (10) and, most recently, Hayashi and Trapani (17) and Boyes (6). These studies, employing a variety of testing procedures, generally affirm the existence of the Averch-Johnson effect in the electric utility industry. Space limitations prevent a detailed critical appraisal of these studies. The interested reader is referred to Zimmer (36), where the above papers are criticized on two grounds. First, the models employed rest on restrictive assumptions which could be eliminated by the use of alternative specifications. Second, inadequate attention is paid to proper measurement of the implicit rental price of capital equipment employed in power generation. The present study is an attempt to examine the Averch-Johnson hypothesis by means of a test which is free of these shortcomings.

Concern with the effects of utility regulation has provided the impetus for numerous other studies focusing on aspects of the problem which are not considered in this study. Stigler and Friedland (32), in a study of early attempts at regulation, conclude that the price of electricity was not significantly affected by regulation. Westfield (34) argues that regulation induces utilities to acquiesce to higher prices on new capital equipment. More recently a study by Moore (23) is an attempt to test for the effectiveness of regulation by means of comparing input choices of investor-owned and public utilities. This requires the assumption that public firms adhere to optimization procedures identical to those of private firms. Such an assumption is difficult to accept on an a priori basis, and its verification is deemed beyond the scope of the present study; hence the Moore study does not receive direct consideration in the literature currently under review.

*Baumol and Klevorick (4) show that $0 \leqq \lambda < 1$. Therefore it must be true that $\Theta \neq 0$, since in (5) a zero value for Θ implies $\lambda = 1$. Thus the firm operates on its production possibilities frontier.

Joskow (19) constructs a model which assumes that the behavior of regulatory commissions is directed primarily at preventing increases in nominal electricity rates. Thus any nominal rate of return is permitted so long as the firm does not request a rate increase. On the basis of this model Joskow argues that utility regulation is effective.

Since these studies are not directly relevant to the questions currently under investigation, they receive no further consideration in the following sections. Instead the present study focuses on the Averch-Johnson model as outlined in this section.

1.3 PROPOSED METHODOLOGY

The methodology proposed in this study rests on the notion that electric utilities minimize costs of production subject to the regulatory constraint as well as the constraint imposed by the production function. The firm is assumed to minimize the objective function

$$C = P_L L + P_K K + P_F F \qquad (11)$$

subject to

$$R - P_L L - P_F F = sK \qquad (12)$$

and

$$\Phi(K,L,F) = Q, \qquad (13)$$

where R is revenue resulting from the sale of (exogenous) generated power Q; Φ is a twice-differentiable quasi-concave production function with positive marginal products. The production process is such that each input is necessary for production. Note that output is assumed to be exogenous; this is certainly tenable in the case of the electric utility industry. In most cases electric utilities are required to satisfy the demand for power at existing (regulated) prices. In addition it is assumed that factor prices are exogenous to the firm. These assumptions suggest that estimation of the cost function (which has as explanatory variables the level of output and factor prices) is desirable as a means of studying the production structure of the electric utility industry.*

Furthermore, recent advances in duality theory enhance the appeal of the cost function approach.** The satisfaction of certain regularity conditions guarantees that a given production function implies a particular cost function, and vice versa. Every cost function in turn implies a set of derived demand equations. These may be obtained by application of Shephard's Lemma to a particular cost function.*** Given the cost function C(Q,P) where Q is output and P is an n-dimensional vector of factor prices, Shephard's Lemma may be stated as

$$\partial C/\partial P_i = X_i \ , \ i = 1 \ , \ \ldots, \ n$$

where X_i denotes the profit maximizing (cost minimizing) amount of factor i. Since the derived demand equations are obtained by differentiating the cost function, they generally do not give rise to additional unrestricted regression coefficients. Thus the inclusion of the derived demand equations with the cost function provides a means of increasing the efficiency of parameter estimates. This is particularly important in the case of "generalized" cost functions, which typically contain a relatively large number of regressors.****

The cost minimization model (11)-(13) may be used to derive a cost function of the general form

$$C = C(Q,P_L, P_F, P_K, s) \qquad , \qquad (14)$$

while application of Shephard's Lemma yields factor demand equations

$$K = K(Q,P_L, P_F, P_K, s) \qquad (15)$$

$$F = F(Q, P_L, P_F, P_K, s) \qquad (16)$$

$$L = L(Q, P_L, P_F, P_K, s) \qquad (17)$$

Equations (14)-(17) constitute the basis for empirical analysis. If the "regulated" cost minimization model is a meaningful explanation of the behavior of electric utilities, then the cost and factor demand equations should exhibit the general properties of equations (14)-(17). In particular the allowed rate of return, s, should appear as a significant explanatory variable in relationships explaining the firm's costs and its optimal input mix. This suggests that a suitable testing procedure consists of estimating the set of equations

*This is the general approach used in the previously discussed paper by Petersen (27), as well as papers by Christensen and Greene (7) and Nerlove (24).

**A lucid survey of these developments is given by Diewert (13).

***See, for example, Shephard (29). This result was also recognized by Samuelson (28), pp. 68-69.

****For a further discussion on this point see Christensen and Greene (7). Another means of improving efficiency is to estimate the cost function alone from pooled cross section and time series data.

first as it would appear if the regulatory constraint were not binding (i.e., with all coefficients associated with the allowed rate of return restricted to zero) and second with no such restrictions imposed. A likelihood ratio test may then be applied as a test for general effectiveness of regulation.* The test may then be viewed as one which seeks to determine whether the firm's effective cost function includes the allowed rate of return as an explanatory variable.

1.4 DESCRIPTIONS OF DATA AND SAMPLE

A detailed discussion of the data used in the study is given in Zimmer (36).

The purpose of this section is to describe the general characteristics of the sample.

The analysis will be confined to privately-owned utilities primarily engaged in steam electric generation from fossil fuelled plants. Inclusion of public firms would make it necessary to justify the hypothesis that public enterprises are cost minimizers, a task which is beyond the scope of this study. Concentration on fossil-fuelled steam generation is intended to provide a sample of firms with access to reasonably homogenous production technology. The sample is a reasonable representation of the electric power industry, since private firms using fossil-fuelled technology account for about seventy-five percent of all generated power in the United States.

Moreover, it is reasonable to concentrate on the generation phase of the production process, since as Courville (9) has shown, the transmission and distribution phases are probably characterized by fixed proportions and hence offer few opportunities for factor substitution.

Empirical analysis in this study is conducted for a sample of annual observations at the firm level for sixty-two private utilities for each of the years 1968 through 1972.

The use of observations from the 1968-1972 period is motivated by a desire for recent data while recognizing that circumstances which prevailed after 1972, notably the oil embargo beginning in October, 1973, and the rapid escalation of the price level, present problems for empirical analysis which are beyond the scope of this study.

Estimation of equations (14)-(17) requires data by firms and plants on each of the factor inputs and their unit prices as well as total production costs and the allowed rate of return. With the exception of the rental price of capital, these data are available from a variety of publications of the Federal Power Commission. In this study the rental price of capital will be estimated for each firm in the sample; the rental price is defined as it commonly appears in the Investment literature:

$$P_K = B\{\frac{r(1 - tw)}{(1 - t)} + \frac{d(1 - tv)}{(1 - t)}\}$$

where B is a measure of equipment costs; r is the "cost of capital"; d is the rate of depreciation on capital equipment; t is the tax rate on corporate income; w is the proportion of total capital service charges deductible as interest for tax purposes; and v represents the proportion of replacement investment deductible as depreciation.**

It is seen that the "cost of capital," defined as the minimum prospective yield expected by the firm's current owners on future investment projects, is imbedded in the capital rental price. Since the other components of the rental price may be measured without systematic error, it is the cost of capital which creates potential for measurement error. For purposes of this study the cost of capital has been estimated by means of the two-stage instrumental variable technique introduced by Miller and Modigliani (21). The reader is referred to Zimmer (36) for a more detailed discussion of these estimates and their properties.

2. EMPIRICAL ANALYSIS OF REGULATORY-EFFECTIVENESS

2.1 THE GENERAL MODEL AND CHOICE OF FUNCTIONAL FORM

It is desirable that the specific functional form for the cost function (14) correspond to a production structure which places few a priori restrictions on the technological production parameters. The functional form chosen for this study is Diewert's Generalized Leontief cost function:

$$\begin{aligned} C = Q[&a_{FF}P_F + a_{KK}P_K + a_{LL}P_L + a_{ss}s \\ &+ 2a_{FK}(P_FP_K)^{1/2} + 2a_{FL}(P_FP_L)^{1/2} \\ &+ 2a_{KL}(P_KP_L)^{1/2} + 2a_{FS}(P_Fs)^{1/2} \\ &+ 2a_{KS}(P_Ks)^{1/2} + 2a_{LS}(P_Ls)^{1/2}] \end{aligned} \quad (18)$$

*It will be recalled that this is the general procedure adopted by Cowing (10) for estimated profit functions. It has also been employed by Christensen and Greene as a means of testing for homotheticity in steam electric generation. (7)

**The definition used in this paper is taken from Jorgenson (18). It is presumed that net capital gains on the disposal of equipment are negligible.

where all symbols are as defined before.* Applying Shephard's Lemma to (18) yields the factor demand equations

$$L = Q[a_{LL} + a_{FL}(P_F/P_L)^{1/2} + a_{KL}(P_K/P_L)^{1/2} + a_{LS}(s/P_L)^{1/2}] \quad (19)$$

$$F = Q[a_{FF} + a_{FK}(P_K/P_F)^{1/2} + a_{FL}(P_L/P_F)^{1/2} + a_{FS}(s/P_F)^{1/2}] \quad (20)$$

$$K = Q[a_{KK} + a_{FK}(P_F/P_K)^{1/2} + a_{KL}(P_L/P_K)^{1/2} + a_{KS}(s/P_K)^{1/2}] \quad (21)$$

where again all symbols are as previously defined. Equation (18) is a form which is well suited for empirical analysis of steam-electric generation since it allows the corresponding production function to attain an arbitrary set of elasticities of substitution at a specified vector of inputs and input prices.** Thus the use of a "generalized" specification places no restrictions on the technology of factor substitution. This is desirable in an analysis of regulation, since it permits flexibility in factor substitution in response to changes in regulatory parameters.

Diewert (12) has shown that under the restriction that all parameters in equation (18) are nonnegative the cost function C satisfies the following properties (to be referred to as the "well-behaved" properties):

(1) C is positive, real-valued and finite for all finite nonzero levels of output and factor prices;

(2) C is nondecreasing and left-continuous in output;

(3) C is nondecreasing and concave in factor prices for positive levels of output;

(4) C is homogenous of degree one in factor prices.

However, the nonnegativity conditions required to assure these properties are unduly restrictive, since they constrain all pairs of factors to be substitutes. This is because, as Diewert (13) has shown, the elasticity of substitution between factors i and j is of the same sign as the parameter a_{ij}; thus the restriction $a_{ij} \geq 0$, although sufficient to guarantee these properties for the cost function, precludes complementarity between factors i and j. In this study these restrictions are not imposed, and recourse has been made to certain available procedures to determine the extent to which the cost function estimated without nonnegativity restrictions still retains the well-behaved properties.*** In any case, as Diewert has shown, the Generalized Leontief cost function provides a second order Taylor series approximation to an arbitrary twice differentiable cost function which satisfies conditions (1) through (4).****

2.2 REVISION OF THE MODEL

Equations (18)-(21) form the basis for empirical testing of regulatory effects. The test may be conducted by estimating first the set of equations in its present form and then under the restriction

$$a_{FS} = a_{KS} = a_{LS} = a_{SS} = 0 \quad (22)$$

A likelihood ratio test may then be conducted to test for the significance of the regulatory coefficients.

*See Diewert (12). Other empirical applications of this form are Parks (25) and Woodland (35).

**Equation (18) describes the case in which the production function exhibits constant returns to scale. The more general case obtains when Q is replaced by h(Q), where h is a monotonic nondecreasing function of Q.

Denny demonstrates that the Generalized Leontief cost function is a special case of a still more general form

$$C = \sum_i \sum_j (a_{ij} P_i^{\beta\gamma} P_j^{\beta(1-\gamma)})^{1/\beta} \cdot h(Q),\ h'(Q) \geq 0 .$$

He also demonstrates the relationship between the Generalized Leontief and conventional forms:

a) Setting $\gamma = 1/2$ and $\beta = 1$ yields the Generalized Leontief form.
b) Setting $\gamma = 1/2$ and $a_{ij} = 0$, $i \neq j$ yields the CES cost function.
c) Setting $\gamma = 1/2$, $\beta = 0$ and $a_{ij} = 0$, $i \neq j$ yields the Cobb-Douglas cost function.

***Further discussion of this point is found in Zimmer (36). It is concluded that the cost function estimated without restrictions adheres reasonably to the well-behaved properties.

****See Diewert (13, p. 115 and Appendix).

There are, however, two impediments to the direct implemention of this procedure to the model described in this study. The first problem is that Shephard's Lemma is not applicable to a model which explicitly accounts for regulation by the inclusion of a rate-of-return constraint. In such a case it is necessary to adopt a modified Shephard's Lemma to account for the additional constraint.* A complete derivation of this version is provided in Zimmer (36); the results may be summarized as

$$K = \partial C/\partial P_K \qquad (23)$$

$$F = (\partial C/\partial P_F \cdot \partial C/\partial P_K)/(\partial C/\partial P_K + \partial C/\partial s) \qquad (24)$$

$$L = (\partial C/\partial P_L \cdot \partial C/\partial P_K)/(\partial C/\partial P_K + \partial C/\partial s)\ . \qquad (25)$$

It is necessary, therefore, to modify equations (19)-(21) in accordance with the modified Shephard's Lemma. It will be seen that this modification results in a nonlinear set of equations equivalent to (18)-(21).

The second difficulty with the procedure in this study concerns the singularity of the covariance matrix of disturbances for equations (18)-(21). Since the dependent variable in the cost equation is a linear combination of the dependent variables in the factor demand equations, the corresponding distrubances are also collinear, resulting in a singular disturbance covariance matrix.** In order to insure the nonsingularity of this matrix one of the factor demand equations must be deleted from the model. In this study the equation to be removed is the labor demand equation.***

When these modifications are incorporated into equations (18)-(21) the model becomes

$$\begin{aligned} C/Q = {} & a_T T + a_{KK}P_K + a_{LL}P_L + a_{FF}P_F + a_{SS}s \\ & + 2a_{KL}(P_K P_L)^{1/2} + 2a_{FK}(P_F P_K)^{1/2} \\ & + 2a_{FL}(P_F P_L)^{1/2} + 2a_{FS}(P_F s)^{1/2} \\ & + 2a_{KS}(P_K s)^{1/2} + 2a_{LS}(P_L s)^{1/2} \end{aligned} \qquad (26)$$

$$\begin{aligned} K/Q = {} & a_{KK} + a_{FK}(P_F/P_K)^{1/2} + a_{KL}(P_L/P_K)^{1/2} \\ & + a_{KS}(s/P_K)^{1/2} \end{aligned} \qquad (27)$$

$$\begin{aligned} F/Q = {} & [(a_{KK}a_{FF} + a_{FK}a_{FK}) + a_{KK}a_{FK}(P_K/P_F)^{1/2} \\ & + a_{FK}a_{FF}(P_F/P_K)^{1/2} \\ & + (a_{KK}a_{FL} + a_{KL}a_{FK})(P_L/P_F)^{1/2} \\ & + (a_{KK}a_{FS} + a_{KS}a_{FK})\ (s/P_F)^{1/2} \\ & + a_{KS}a_{FF} + a_{FK}a_{FS})\ (s/P_K)^{1/2} \\ & + (a_{KL}a_{FF} + a_{FL}a_{FK})(P_L/P_K)^{1/2} \\ & + (a_{KL}a_{FS} + a_{KS}a_{FL})(P_L s/P_K P_F)^{1/2} \\ & + a_{KL}(P_L P_L/P_K P_F)^{1/2} \\ & + a_{KS}a_{FS}(ss/P_K P_F)^{1/2}]/[(a_{KK} + a_{SS}) \\ & + a_{FK}(P_F/P_K)^{1/2} + a_{KL}(P_L/P_K)^{1/2} \\ & + a_{KS}(s/P_K)^{1/2} + a_{FS}(P_F/s)^{1/2} \\ & + a_{KS}(P_K/s)^{1/2} + a_{LS}(P_L/s)^{1/2}] \end{aligned} \qquad (28)$$

*For further discussion on this point in the context of a regulated profit function see Cowing (10).

**For a discussion on this point, see Berndt and Savine (5).

***Barten (3) has shown that maximum likelihood estimates of a set of equations are invariant with respect to the equation which is deleted. Since the estimation procedure to be used in this study results in maximum likelihood estimates, the equation deleted is of no consequence so far as the parameter estimates are concerned. The only real consequence is a loss in efficiency.

where all symbols are as defined before and T represents the age of plant. Note that both sides of the original equations have been divided by output, so that the equations to be estimated are unit cost and factor demand equations.* In addition, an index of technology, measured as the average age of productive plant, has been included in the cost equation.

Equations (26)-(28) comprise the final form for the model to be estimated in testing for regulatory effectiveness. The estimating procedure employed in this study is an iterative scheme described, for example, by Eisenpress and Greenstadt (14). It uses the Gauss-Newton computational method and is known to converge to maximum likelihood. The results of estimation and likelihood ratio tests are discussed in the following sections.

2.3 RESULTS OF ESTIMATION

Estimates of the parameters of equations (26)-(28) for a sample of 62 utilities are presented in Table 1.

While the results for years 1970 through 1972 indicate a number of significant coefficients, the results for 1968 and 1969 are less satisfactory. It will be observed that during all years there is evidence of interaction between fuel and capital inputs; in particular, the coefficient a_{FK} is significant at the five percent level (or nearly so) in all years, and its positive sign is evidence of the substitutability between fuel and capital equipment in steam generation. Thus there is convincing evidence that the appropriate way to model the electric power industry is by means of a generalized model which permits flexible factor substitution. The coefficient of the rental price of capital is significant in all years, while the technology index is significant only for 1972.

Before proceeding with the likelihood ratio tests, two qualifications are in order with respect to the results in Table 1.

First, it should be recalled that one of the assumptions underlying the Averch-Johnson model of the regulated firm is that the firm earns a rate of return in excess of its market cost of capital.** Comparison of the cost of capital estimates with earned rates of return reveals that this assumption is generally upheld with the exception of the 1970 sample; during 1970 nearly one fifth of the sample firms failed to earn rates of return in excess of the cost of capital, while the proportion is negligible for all other years. Thus the sample observations for 1970 tend to violate one of the assumptions of the model and the corresponding estimates should accordingly be viewed with a degree of caution.

A second qualification relates to the presence of negative coefficients in Table 1. It will be recalled that the Generalized Leontief cost function satisfies the well-behaved properties under the restriction that all coefficients are nonnegative. Diewert (12) has developed a set of conditions on the sample data which are sufficient to guarantee that the cost function satisfies these properties even in the presence of negative coefficients. A check of these conditions reveals that they are violated (i.e., that the well-behaved properties *may* not hold) only for a small proportion of the sample observations. Therefore it appears that the presence of negative estimated coefficients poses virtually no threat to the well-behaved properties of the cost function (and hence the corresponding production function) under examination in this study.

2.4 LIKELIHOOD RATIO TESTS

It will be recalled that in order to conduct the test for general regulatory effectiveness estimation of the set of equations (26)-(28) is repeated under the restriction

$$a_{FS} = a_{KS} = a_{LS} = a_{SS} = 0 \ ,$$

and the log-likelihood statistics may be used to test the above restriction as a null hypothesis. It is well known that the quantity $-2\ln L$, where L represents the ratio of the likelihood functions for the restricted and unrestricted models, has an approximate Chi-Square distribution with degrees of freedom equal to the number of restrictions imposed.

The results of this test are presented in Table 2. Models I and II are the restricted and unrestricted versions respectively. Comparison of the computed statistics with the tabular Chi-Square

*Dividing by output offers not only convenience in estimation, but also serves as a correction for possible heteroscedasticity in the disturbance terms of each equation. Denoting the disturbance for equation j and observation k by u_{jk}, u_{jk} is assumed to obey the properties:

$$E(u_{jk}) = 0$$

$$E(u_{jk})^2 = \sigma_j^2 Q_k^2 \ .$$

Dividing equation j by output changes in the disturbance term to $v_{jk} = u_{jk}/Q_k$, so that

$$E(v_{jk})^2 = E(u_{jk}^2/Q_k^2) = \sigma_j^2 \ ,$$

giving equation j a homoscedastic error term.

**See section 1.2.

critical value reveals that the null hypothesis of ineffective regulation may be rejected at the one percent level of significance for all years under observation with the exception of 1971. It it not surprising that these results are obtained for 1971. It is generally conceded that the utility industry was significantly affected by the recession of 1970, and this is substantiated by the previously discussed comparison of earned rates of return and the estimated cost of capital for that year. Consequently the recovery period of 1971 probably witnessed levels of earnings which were rising but well within the constraints of regulation.

Thus while these results tend to indicate a picture of general regulatory effectiveness, it may not be inferred that the regulatory constraint is binding during all periods of time. It follows that the major implication of effective regulation namely the Averch-Johnson overcapitalization effect, draws general support but may not be operative during all periods of time.

TABLE I

ESTIMATED COST FUNCTION PARAMETERS*

Parameter	1972	1971	1970	1969	1968
a_T	0.114 (2.53)	0.073 (1.12)	-0.035 (-1.47)	-0.001 (-0.01)	0.018 (0.97)
a_{FF}	0.963 (7.97)	0.268 (1.01)	0.072 (0.90)	0.309 (1.32)	0.505 (2.03)
a_{KK}	0.093 (5.89)	-0.187 (-3.36)	-0.061 (-2.69)	-0.142 (-3.05)	-0.309 (-6.87)
a_{LL}	3.929 (5.82)	7.601 (2.89)	-4.48 (-3.98)	0.835 (0.57)	-0.550 (-0.03)
a_{SS}	0.145 (2.52)	0.105 (1.39)	-0.205 (-2.60)	0.051 (0.86)	-0.028 (-0.79)
a_{FK}	0.124 (5.15)	0.079 (3.53)	0.042 (1.92)	0.117 (3.24)	0.116 (4.24)
a_{FL}	-1.560 (-5.63)	-1.569 (-2.58)	0.675 (3.10)	-0.217 (-0.51)	-0.527 (-0.88)
a_{FS}	-0.180 (-4.30)	0.399 (2.36)	-0.165 (-3.00)	-0.033 (-0.70)	-0.097 (-1.43)
a_{KL}	0.033 (0.37)	0.021 (0.21)	0.051 (0.60)	-0.013 (-0.12)	0.317 (3.53)
a_{KS}	-0.116 (-4.22)	0.021 (0.94)	-0.004 (-0.20)	0.006 (0.25)	-0.022 (-1.33)
a_{LS}	-0.042 (-0.24)	-1.290 (-2.18)	1.00 (3.43)	-0.122 (-0.49)	0.340 (1.73)

*Figures in parentheses are t-ratios.

TABLE 2

TESTS FOR GENERAL REGULATORY EFFECTIVENESS*

		Log Likelihood	log L	-2 log L
1972	Model I	-678.60	-11.99	23.98
	Model II	-666.61		
1971	Model I	-666.03	-0.37	0.74
	Model II	-676.66		
1970	Model I	-608.52	-15.82	31.64
	Model II	-592.70		
1969	Model I	-620.29	-8.88	17.76
	Model II	-611.41		
1968	Model I	-595.76	-19.87	39.74
	Model II	-575.89		

*Chi-Square value for 4 d.f. is 13.28 at the one percent significance level.

3. SUMMARY AND CONCLUSIONS

This study adds to the empirical evidence on the effectiveness of rate-of-return regulation in the electric utility industry. It represents an improvement over previous studies in this area to the extent that it rests on fewer restrictive assumptions than other studies. In addition, the generalized specification used is fully consistent with the simple static Averch-Johnson model of the regulated firm.

The main conclusion of the study is that rate-of-return regulation was effective during most years of the period 1968-1972. This is consistent with the results of previous empirical studies of utility regulation. In the context of the Averch-Johnson model, the condition that regulation is effective is sufficient to guarantee the existence of input choice inefficiency in the form of overcapitalization.* It follows, therefore, that the firms during the years under investigation in this study were generally characterized by overcapitalization attributable to regulatory effects.

The principal implication of this result is that the intended benefits of rate-of-return regulation are not achieved at zero cost. The imposition of an effective rate-of-return constraint induces the firm to choose inefficient input combinations, and these inefficiencies should be included in cost-benefit analyses of regulation. Indeed, in view of these results it is desirable to render new assessments of the benefits of utility regulation. For if regulation fails to result in increased production of power at lower prices to such an extent as to at least offset the costs of overcapitalization, then it is undesirable from the standpoint of efficient resource allocation.

This suggests that regulatory policy should be formulated to enable the utility industry to come as close as possible to efficient use of inputs. Recent proposals for regulatory reform have stopped short of advocating deregulation of the industry. Instead the focus is on revisions of the existing regulatory process designed to encourage efficiency. For example, Klevorick (20) suggests that the allowed rate of return should not be constant but instead related to the size of the firm's capital stock. It is contended that if the maximum allowable rate of return is permitted to decrease with successive increments in the capital stock, the inefficiencies of overcapitalization are attenuated. In another proposal Sherman (30) suggests that a policy through which noncapital inputs are subsidized while a tax is imposed on capital inputs would result in efficient input choice.

Empirical analysis in this study is based on a generalized cost function which includes the allowed rate of return as a regulatory variable and permits flexible substitution among productive factors. Statistical results give strong support to the existence of capital-fuel substitution in power generation, indicating that it is appropriate to model the electric power industry by means of a generalized specification.

Useful refinements in the model of the regulated firm might include a more sophisticated treatment

*It should be noted that effective regulation is not a necessary condition for overcapitalization. Other sufficient conditions are delineated by Chenery (8); thus, for the years in which regulation is inferred to be effective it may not be asserted that regulation provides the sole impetus for overcapitalization.

of the role of uncertainty. This has been suggested by Peles and Stein (26), who assert that the conclusions of the Averch-Johnson analysis are not insensitive to the manner in which uncertainty enters the model. In addition, the increasing use of fuel adjustment clauses might have significant implications for regulatory policy. Work on incorporating adjustment clauses into the Averch-Johnson model has been initiated by Atkinson and Halvorsen (1).

There is a need to extend this line of inquiry into other areas of regulation. While it is unlikely that the methodology employed in this study has general applicability to analysis of other regulated industries, there do exist numerous viable opportunities for meaningful research.

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