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A TEST OF TWO VIEWS OF THE REGULATORY MECHANISM: AVERCH-JOHNSON AND JOSKOW

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I. Introduction

The impact of regulation on the production decisions of electric utilities was first described by Averch and Johnson (1962). They argued that rate-of-return regulation gives utilities the incentive to overcapitalize, that is, to employ a capital-labor ratio that is larger than one that minimizes costs for a given output level.[1] Courville (1974), Spann (1974), Petersen (1975), and Cowing (1978), for example, find evidence of an overcapitalization bias using variations of the Averch and Johnson (A-J) model.[2]

The major challenge to the A-J model concerns the nature of the regulatory environment. Implicit in the A-J model is a regulator that constantly monitors capital returns and adjusts electricity prices to keep capital returns equal to their "fair" levels. Joskow (1974) argues that regulators are more concerned with nominal electricity prices than with the rate of return on capital. As long as nominal electricity prices are not increasing, regulators will not actively enforce the rate-of-return constraint, thereby eliminating the source of the A-J bias. As evidence in favor of his view, Joskow finds a positive relationship between changes in the average cost of electricity production and the frequency of rate hearings initiated by utilities. He also argues that the implementation of fuel-cost-adjustment clauses and environmental regulations in the 1970s reflects his more general view of regulators as political entities rather than as Averch and Johnson's strict rate-of-return enforcers.

The total impact of these and other constraints on electric utility production decisions was examined by Atkinson and Halvorsen (1984). They developed a generalized cost model that includes the impact of additional regulatory constraints and found empirical evidence of these impacts in a cross-section sample of electric utilities. However, they did not include Joskow's view of the regulatory process in their model.

The purpose of this paper is to test Joskow's view of the regulatory mechanism by estimating a modified version of the Atkinson and Halvorsen model. The modifications are of two sorts. The first allows for different regulatory impacts over time as argued by Joskow. The second permits the use of panel data and the estimation of total factor productivity (TFP) and its returns-to-scale and technical-change components. Joskow argues that when the A-J bias occurs, utilities have less incentive not only to employ an efficient team of production inputs, but also to innovate or to maintain a high rate of technical change. Nelson and Wohar (1983) attempted to examine the impact of regulation on utility technical change, but they could not estimate a direct regulatory impact on technical change. Our procedure yields such an estimate.

Our data are a panel sample of the seven major electric utilities in Ohio over the period 1965 to 1982.[3] The advantage of this sample is that the technologies employed by these utilities should be fairly similar; these Ohio utilities are all privately owned, coal-burning plants and are subject to the same regulator. Thus, the estimation of a common cost structure for these utilities should yield a smaller potential for specification bias than is true of previous studies of electric utilities, whose samples include utilities that employ varying technologies or face different regulators.

Our results square with Joskow's view. We find considerable circumstantial evidence in Ohio consistent with Joskow's more general regulatory mechanism. Our estimation results show that these utilities produce electricity less efficiently during the years when Joskow expects regulatory constraints to be more binding, and that regulation significantly retards the rate of technical change implemented by these utilities. Thus, the emphasis that regulators and economists place on efficient production using a given capital stock appears to be misplaced; the retardation of the rate of technical change implemented by these utilities appears to be an important source of bias. However, contrary to Joskow's view, we find that regulation retards the technical change implemented by these utilities to a lesser extent during the years when regulatory constraints are more tightly binding.

The next section of this paper contrasts the Averch-Johnson and Joskow views of the regulatory mechanism. After that, the rate hearing experience in Ohio over the 1965 to 1982 period is discussed and is found to correspond quite well with Joskow's view of the regulatory mechanism. The fourth part presents the model and outlines the testing procedures; the fifth section describes the empirical results. The final section provides summary and concluding remarks.

II. Averch-Johnson and Joskow Views of the Regulatory Process

It is useful to view the regulatory process in two parts: 1) the mechanics of setting a utility's electricity price structure, and 2) the events that initiate a rate hearing or a review of a utility's electricity price structure. There is little disagreement among economists about the first part. What brings a utility to a rate hearing and what motivates a regulator are open questions in the empirical literature. The predominant answers to these questions were influenced by Averch and Johnson. They investigated the optimal response of a cost-minimizing utility in static equilibrium to a "fair" rate of return on capital regulatory constraint. They showed that when the rate of return on capital constraint is binding, and when the "fair" rate of return is larger than the cost of capital, a utility has the incentive to overcapitalize, that is, to employ a capital-labor ratio that is larger than one that minimizes costs for the chosen output level.[4]

Implicit in the A-J model are two assumptions about the behavior of the regulator. One is that the motivating factor behind regulatory action is the rate of return on capital; in the A-J model, the constraint on a utility's profit-maximization actions is that the actual rate of return on capital earned by a utility is no greater than the "fair" rate. The second is that an <u>active</u> regulator continually monitors utility returns and pounds on a utility with a "visible hand" to maintain the equality of a utility's profits with its "fair" profits. This follows from Averch and Johnson's assumption of static equilibrium. When a utility's profit is less than its "fair" level of profits, the regulator calls a rate hearing to raise the "fair" return and, hence, the utility's price of electricity. When a utility's profits are above the "fair" level, the regulator calls a rate hearing to lower its "fair" return and the price of electricity.

With minor amendments, this view of regulatory behavior predominates in the economics literature, especially in empirical studies of electric utility behavior, with the exception of Joskow (1974).[5] Joskow agrees that rate-of-return regulation will give a utility the incentive to employ an inefficient mix of input factors, but he argues that the A-J bias may not always occur in a dynamic world. In Joskow's view, regulators are political institutions whose objective is to minimize "conflict and criticism," not to keep the rate of return on capital equal to the "fair" rate.

One important source of conflict and criticism is an increase in the nominal price of electricity. Consumers will agitate against increases in electricity prices because they typically view these increases as price-gouging. If electricity prices are not increasing, and especially if they are falling, consumers are indifferent to the profits earned by a utility. Thus, Joskow argues that utilities that are able to adjust their production and investment decisions to raise their earned rates of return without raising electricity prices will not be thwarted by the regulator. In this case, there may be little A-J bias. On the other hand, Joskow argues that regulators do not initiate any actions to raise the rate of return on a utility's capital when it is below the "fair" rate unless requested to do so by the utility. Before a rate increase is granted, the utility will earn a return on capital below the "fair" return. In this case, an A-J bias may appear.

Thus, in contrast to the active A-J regulator, the Joskow regulator is passive, adjusting the rate of return on a utility's capital only when requested to do so by a utility or by a consumer advocate. Earned profits may deviate from "fair" profits over time if input prices, electricity demand, and other factors change, but the regulator does not institute a price change to re-equate earned profits with "fair" profits until the next rate hearing. In the meantime, a utility can alter its production and investment decisions in ways opposite to those predicted by the A-J model; The "fair" rate of return in Joskow's view is a means to an end (uncontroversial electricity prices), not an end in itself. After reviewing the regulatory experience across the U.S. between the 1950s and early 1970s, Joskow concludes that:

> Contrary to the popular view, it ***does not*** appear that regulatory agencies have been concerned with regulating rates of return per se. The primary concern of regulatory commissions has been to keep ***nominal prices from increasing.*** Firms which can increase their earned rates of return without raising prices or by lowering prices (depending on changing cost and demand characteristics) have been permitted to earn virtually any rate of return that they can. ***Formal regulatory action in the form of rate of return review is primarily triggered by firms attempting to raise the level of their rates or to make major changes in the structure of their rates.*** The rate of return is then used to establish a new set of ceiling prices which the firm must live with until another regulatory hearing is triggered. General price ***reductions*** do not trigger regulatory review, but are routinely approved without formal rate of return review.

> This regulatory process is therefore extremely passive. Regulators take no action regarding prices unless major increases or structural changes are initiated by the firms under its jurisdiction. In short, it is the firms themselves which trigger a regulatory rate of return review. There is no "allowed" rate of return that regulatory commissions are continuously monitoring and at some specified point enforcing. (Joskow, 1974, p. 298)

Because they work in a political environment, public utility commissions face other sources of conflict and criticism, which have resulted in two additional constraints on utility behavior. First, in the mid-1970s, when energy costs increased rapidly, utilities requested rate hearings in greater numbers than in the past. This increased caseload put a large burden on these regulatory agencies, who were accustomed to only a few hearings in a year. The time lag between the request for a rate hearing and a change in electricity prices increased, and many utilities were forced to request another rate hearing immediately after their previous hearing. In order to shorten this lag and to appease utilities, regulators instituted fuel-cost-adjustment clauses that permitted utilities to pass higher fuel costs to consumers without the need for a formal rate hearing. Second, environmental advocates successfully agitated public utility commissions to establish limits on the amount of pollution emitted by fossil-fueled utilities. These two constraints complicate the analysis of the impact of a rate-of-return constraint on utility behavior.

III. Rate Hearings and Average Costs of Ohio Utilities: 1965 to 1982

Some evidence consistent with Joskow's view of the regulatory mechanism is found in the history of rate hearings in Ohio between 1965 and 1982. To put this evidence into perspective, refer to the figure on page 26, which shows the behavior of the average price per kilowatt-hour of electricity charged, and the quantity of kilowatt-hours sold, by the seven major Ohio electric utilities.

For the purposes of this discussion, three distinct periods of different nominal electricity price and consumption behavior can be seen: 1965 to 1968, 1969 to 1975, and 1976 to 1982.[6] Within each period, the directions of change in price and quantity were the same for each utility in the sample. During the 1965 to 1968 period, the average price of electricity changed very little and electricity sales rose considerably. During the 1969 to 1975 period, theaverage annual growth rate of electricity sales slowed, while that of prices increased greatly. Between 1976 and 1982, electricity sales declined for the first time in Ohio's history, while prices increased at their fastest average annual percentage rate.

The figure also shows the percentage of the seven utilities requesting rate hearings in each year. In the first period, utilities rarely requested rate hearings, and their average costs were falling. This behavior corresponds with Joskow's first proposition: "During periods of falling average cost we expect to observe virtually no regulatory rate of return reviews" (p. 299). The average price of electricity also was falling during this period, consistent with Joskow's second proposition: "During periods of falling average costs we expect to observe constant or falling prices charged by regulated firms" (p. 299). Given that there were few rate hearings in this period, it is plausible that utility returns on capital were greater than or equal to what the "fair" returns the Public Utilities Commission of Ohio (PUCO) would have defined'had they been requested to do so.[7] According to Joskow, if actual returns were lower than the "fair" return, then the utilities would have asked for price increases. Hence Joskow's third proposition: "During periods of falling average costs we expect to observe rising or constant (profit maximizing) rates of return" (p. 299).

During the 1969 to 1975 period, average costs increased slightly, triggering a modest increase in the frequency of hearings, while during the 1976 to 1982 period, the average costs increased tremendously. Production costs increased in the late 1960s because of inflation stimulated by economic policies; they increased very quickly and unexpectedly in the mid-1970s because of inflation engendered by worldwide food shortages and by the Arab oil embargo. For a given electricity price, such increases in operating costs drove utility profits below their "fair" levels. Utilities promptly responded to these cost increases by requesting electricity price increases that, in most cases, were granted by the PUCO. The frequency of hearings increased sharply as utilities had trouble keeping up with the effects of the rapid rise in costs. Viewing the 1969 to 1975 period as a transition from a period of falling average costs to one of rising average costs, the modest increase in rate hearings during this period is consistent with Joskow's fifth proposition:

> The transition from a period of falling average costs to one of rising average costs for a particular regulated industry will at first yield no observable increase in the number of rate of return reviews filed by the regulatory agency, but as cost increases continue more and more rate of return reviews are triggered as firms seek price increases to keep their earned rates of return at least at the level that they expect the commission will allow in a formal regulatory hearing. (p. 300)

For estimation purposes, the 1965 to 1982 interval was divided into two periods: 1965 to 1973 and 1974 to 1982. Testable hypotheses of the A-J and Joskow views deal with the absolute and relative production inefficiencies of the utilities in these two periods. The near absence of regulatory hearings in the first period would suggest, to both Joskow and A-J, that earned rates of return of these utilities were at least as great as "fair" rates of return. Averch and Johnson would argue that earned rates of return were lower than monopoly rates of return and, hence, that the A-J bias should exist in the first period. On the other hand, Joskow would argue that earned rates of return may have been close to monopoly rates. If this were true, then because monopoly rates are consistent with efficient production, there may have been very little A-J bias in the first period. Indeed, as Joskow argues in his seventh proposition, production may have been very efficient in the first period because reducing costs would have contributed to higher earned rates of return that were not taken away by regulators:

> During periods of falling or constant nominal average cost firms have an incentive to produce efficiently since all profits may be kept as long as prices stay below the level established by the regulatory commission in the last formal rate of return review. (p. 303)

The high frequency of hearings in the 1974 to 1982 period suggests that earned rates of return for these utilities were lower than "fair" rates of return for most of the period. Because these earned rates were even further away from monopolistic rates of return, Joskow would argue that it is more likely that there are inefficiencies of the A-J type in the second period. His proposition eight says: "During periods of rising average cost A-J type biases may begin to become important" (p. 304). He does not exclude the possibility that firms may continue to try to be as efficient as they were in the first period in order to earn greater than "fair" rates of return. However, he argues that:

> Unless the direction of the cost path can be changed, however, the continuous interaction of firms and regulators in formal regulatory hearings, resulting from the necessity to raise output prices, is exactly the situation for which the A-J type model (with some modifications) would hold. I would therefore expect that it is under this situation of continuously rising output prices, triggering rate of return reviews that the A-J type models and the associated results are most useful. (p. 304)

Thus, Joskow would argue that utilities would try to organize their production more efficiently in the first period than in the second period. His concept of production efficiency includes the static notion of employing currently available production inputs in the least-cost way for any given level of output (that is, employing the least-cost combination of inputs along a given isoquant) and the dynamic notion of investing in more productive capital and management techniques over time (to push the family of isoquants toward the origin). Averch and Johnson deal only with the static notion of productive inefficiency because their model analyzes a static equilibrium. They would argue that the amounts of this static inefficiency are the same in both periods because they assume a regulator who maintains the earned rate of return on capital at its "fair" rate.

The distinction between the static and dynamic notions of production efficiency is important. When a public utility commission conducts a rate hearing, it pays attention only to the static notion of production efficiency. Indeed, most models of regulatory impact deal only with the static notion. However, it is conceivable that regulation also affects the rate of technical change implemented by utilities; if regulation biases the amount of capital employed by a utility, it also may bias the type of capital employed. Regulatory impacts on overall inefficiency and on the rate of technical change are estimated below.

IV. Empirical Model

A. The Generalized or Shadow Cost Model

The A-J and Joskow views are examined using a modified version of the Atkinson and Halvorsen (1984) generalized long-run cost function approach with capital (K), labor (L), and fuel (F) as inputs.[8] Atkinson and Halvorsen argued that the long-run neoclassical cost-function approach is incorrect for a regulated firm because it assumes the firm is minimizing cost in a perfectly competitive world constrained only to produce a given level of output.[9] When the firm is subject to a number of regulatory constraints, the marginal product of each input does not equal the market price of the input, but the market price of the input plus the marginal changes in the additional constraints weighted by their Lagrange multipliers. Atkinson and Halvorsen use the term "shadow" prices to refer to these modified market input prices. The exact specification of these shadow prices depends on the exact form of the additional constraints. Atkinson and Halvorsen approximated these shadow prices by simple proportional relationships with market prices; that is, the shadow price of input i $P_i^s = k_i P_i$, where P_i is its market price and k_i is a constant.

The generalized or shadow cost function is simply the neoclassical cost function with P_i^s substituted for P_i:

$$C^s = C^s\left(P_i^s, Q, T\right) \tag{1a}$$

where C^s is the shadow total cost of electricity production;

P_i^s is the shadow price of input factor i, i = K, L, F;

Q is output of electricity; and

T is time.

Instead of minimizing long-run actual costs, a utility is assumed to minimize long-run <u>shadow</u> costs by equating the <u>shadow</u> marginal cost of each input with the amount of the input used. If the additional constraints are not binding, then the k_i equal one and minimizing shadow costs is equivalent to minimizing actual costs. If the k_i do not equal one, then the firm is not operating at the lowest point of its long-run average cost curve.

An observable cost function based on the shadow cost function can be derived as follows. First, recall the accounting identity for actual cost:

$$C^a = \sum_i P_i X_i$$

where X_i is the quantity of input i used in production. Similarly, the accounting identity for shadow cost is:

$$C^s = \sum_i P_i^s \cdot X_i . \tag{1b}$$

The shadow cost share equations:

$$M_i^s = \frac{P_i^s \cdot X_i}{C^s} \qquad \text{for } i = K, L, F$$

can be rewritten as:

$$P_i X_i = \frac{C^s M_i^s}{k_i} \qquad \text{for } i = K, L, F \tag{2}$$

and summed over all i to obtain:

$$\text{(3a)} \qquad C^a = C^s \cdot \sum_i \left(\frac{M_i^s}{k_i} \right).$$

Taking logarithms of both sides of (3a) yields:

$$\text{(3b)} \qquad \ln(C^a) = \ln(C^s) + \ln\left[\sum_i \left(\frac{M_i^s}{k_i} \right) \right].$$

That is, the logarithm of actual cost equals the logarithm of shadow cost plus the logarithm of the sum of the shadow cost shares each weighted by the inverse of its respective k_i.

To express each shadow cost share as a function of its corresponding actual cost share, first divide both sides of (2) by C^a:

$$\text{(4)} \qquad \frac{P_i X_i}{C^a} = M_i^a = \left(\frac{C^s}{C^a} \right) \cdot \left(\frac{M_i^s}{k_i} \right) \quad \text{for } i = K, L, F$$

and substitute (3a) into (4):

$$\text{(5)} \qquad M_i^a = \frac{\left(\frac{M_i^s}{k_i} \right)}{\sum_i \left(\frac{M_i^s}{k_i} \right)} \qquad \text{for } i = K, L, F.$$

Atkinson and Halvorsen estimate a system comprising (3b) and two of the three equations in (5) but without a time trend because they use cross-section data. We add the appropriate time variables to the shadow cost equation and add a shadow TFP (TFP^s) equation to our system in order to improve the efficiency of the shadow cost equation coefficient estimates. Actual TFP is measured as the change in the average cost of production that is not due to changes in input prices. It reflects the overall productivity of all inputs rather than the productivity of a single input such as labor. The neoclassical approach to the measurement of TFP assumes an optimal distribution of production resources in a firm, which may be an inappropriate assumption for regulated electric utilities. The generalized cost-function approach yields a shadow estimate of TFP that is consistent with regulated behavior. The most important variable for the purposes of examining Joskow's view on productivity behavior is the pure technical change component of TFP. Gollop and Roberts (1981), among others, argue that this component is a better measure of productivity than TFP.

The TFP^s equation is derived as follows. First, take the time derivative of (1a):

$$(6) \qquad \frac{dC^s}{dT} = \sum_i \left(\frac{\partial C^s}{\partial P_i^s} \cdot \frac{dP_i^s}{dT} \right) + \frac{\partial C^s}{\partial Q} \cdot \frac{dQ}{dT} + \frac{\partial C^s}{\partial T} \,.$$

According to Shephard's Lemma, the elasticity of actual total cost with respect to the market price of input i is equal to the share of input i in total cost:

$$(7) \qquad M_i^a = \frac{\partial \ln(C^a)}{\partial \ln(P_i)} \quad \text{for } i = K, L, F.$$

A modified Shephard's Lemma for the shadow cost function is:

$$(8) \qquad M_i^s = \frac{\partial \ln(C^s)}{\partial \ln(P_i^s)} \quad \text{for } i = K, L, F.$$

Dividing both sides of (6) by C^s and using (8) yields a functional relationship between the percentage change in shadow cost and the percentage changes in the P_i^s, Q, and T:

$$(9) \qquad \dot{C}^s = \sum_i \left(M_i^s \cdot \dot{P}_i^s \right) + v_Q^s \dot{Q} + v_T^s$$

where a dot over a variable indicates the rate of change, v_Q^s is the elasticity of shadow cost with respect to output $(\partial \ln C^s / \partial \ln Q)$, and v_T^s is the rate of change in shadow cost, holding all other variables constant $(\partial \ln C^s / \partial T)$. $(1 - v_Q^s)$ is a measure of shadow returns to scale, and $-v_T^s$ is the measure of shadow technical change of interest in this paper.

Next, following the traditional definition of actual TFP as a Divisia index of factor inputs, the rate of change in TFP^s (W^s) can be defined as:

$$(10) \qquad W^s = \sum_i \left(M_i^s \cdot \dot{X}_i \right).$$

Totally differentiating the accounting identity (1b) with respect to time and using Shephard's Lemma yields:

$$(11) \qquad \dot{C}^s = \sum_i \left(M_i^s \cdot \dot{X}_i \right) + \sum_i \left(M_i^s \cdot \dot{P}_i^s \right) .$$

Equations (10) and (11) imply:

$$(12a) \qquad W^s = \dot{C}^s - \sum_i \left(M_i^s \cdot \dot{P}_i^s \right)$$

and using (9):

$$\sum_i \left(M_i^s \cdot \dot{X}_i \right) = v_Q^s \dot{Q} + v_T^s .$$

Finally, because $\sum_i M_i^s = 1$, the above expression can be rewritten in terms of one of the $\dot{X}_i$, say $\dot{X}_L$:

$$(12b) \qquad \dot{X}_L = \sum_{i=K,F} M_i^s \left(\dot{X}_L - \dot{X}_i \right) + v_Q^s \dot{Q} + v_T^s .$$

Equation (12a) cannot be used for estimation purposes because W^s is not observed. It can be used to obtain an equation explaining the actual rate of change in TFP as a function of W^s, but (12b) is easier to estimate.

The general specification of our estimation model includes the total cost equation (3b), the M_K^a and M_F^a share equations from (5), and the TFP equation (12b). The estimation model is based upon the translog functional form. The translog shadow cost function is:

$$(13) \qquad \ln C^s = \alpha + \sum_i \left(\beta_i \ln P_i^s \right) + \beta_Q \ln Q + \beta_T T + \frac{1}{2} \sum_j \sum_i \left(\gamma_{ij} \ln P_i^s \ln P_j^s \right) +$$

$$\sum_i \left(\gamma_{iQ} \ln P_i^s \ln Q \right) + \sum_i \left(\gamma_{iT} \ln P_i^s \right) T + \frac{1}{2} \gamma_{QQ} (\ln Q)^2 +$$

$$\gamma_{QT} (\ln Q) T + \frac{1}{2} \gamma_{TT} T^2 ,$$

with $P_i^s = k_i P_i$ and the usual linear homogeneity restrictions:

$$\sum_i \beta_i = 1,$$

$$\sum_i \gamma_{iQ} = 0,$$

$$\sum_i \gamma_{iT} = 0,$$

$$\sum_i \sum_j \gamma_{ij} = 0, \text{ and}$$

$$\gamma_{ij} = \gamma_{ji} \quad \text{for all } i \text{ and } j.$$

Using Shephard's Lemma (8), the shadow cost share equations are:

$$(14) \qquad M_i^s = \beta_i + \sum_j \gamma_{ij} \ln P_j^s + \gamma_{iQ} \ln Q + \gamma_{iT} T.$$

Substituting (13), (14), and the definition of P_i^s into (3b) yields an estimable cost equation. Substituting (14) and the definition of P_i^s into (5) yields estimable cost share equations. Finally, an estimable TFP equation is obtained by substituting (14) and the following v_Q^s and v_T^s expressions into (12b):

$$(15) \qquad v_Q^s = \beta_Q + \sum_i \gamma_{iQ} \ln k_i P_i + \gamma_{iQ} \ln Q + \gamma_{QQ} \ln Q$$

$$v_T^s = \beta_T + \sum_i \gamma_{iT} \ln k_i P_i + \gamma_{iT} T + \gamma_{TT} T.$$

Two modifications are made to these equations. First, separate values for the k_i coefficients were estimated for the 1965 to 1973 and 1974 to 1982 periods in order to estimate a shift in regulatory impact. The k_i coefficient estimates for the 1974 to 1982 period are denoted with a subscript "S"

Second, k_L and k_{LS} were normalized to one because the shadow cost system is homogeneous of degree zero in the k_i. This means that only relative price efficiency can be examined using the k_i, by testing $k_i = k_j = 1$ and $k_{iS} = k_{jS} = 1$ for i,j = K,F. Differences in absolute price efficiency between the two periods, relevant for a test of Averch-Johnson versus Joskow, cannot be tested using differences between k_i and k_{iS}.

Nevertheless, the model can serve to test Averch-Johnson against Joskow, as described below.[10]

These translog equations form a nonlinear, seemingly unrelated regression system. It is similar to that of Gollop and Roberts (1981), only generalized to allow for the impact of all types of regulation on utility behavior. The maximum likelihood LSQ option of TSP, version 4.0E, was used to estimate this translog system.

B. Data

Data for labor input and the price of labor are taken from Financial Statistics of Selected Electric Utilities, 1982, Department of Energy (DOE/EIA-0437(82)), February 1984. The quantity of labor is the number of electric department employees, with a part-time worker counted as one-half of a full-time worker. The labor price is defined as the ratio of labor expense to the quantity of labor, where labor expense is total salaries and wages charged to electric operation.

The fuel price data come from Standard and Poor's Compustat Services, Inc., Utility Compustat II. Fuel operation expense is the total cost of fuel used exclusively for the production of electricity. The price of fuel is the average cost of fuel per million Btu, which is the total cost of fuel used for electricity production divided by its total Btu content in millions. The quantity of fuel input is millions of Btu, defined as the ratio of fuel operating expenses to the average cost per million Btu.

The data for the capital price and capital stock come from various issues of Statistics of Privately Owned Electric Utilities in the United States, U.S. Federal Power Commission. The capital price measure is the conventional market price of capital, which is a function of the long-term debt interest rate, the required return on equity capital, the preferred stock dividend rate, the depreciation rate, and the Handy-Whitman index. The capital stock is computed using a perpetual inventory method.[11] The depreciation rate is based on a 30-year average service life.[12] The product of capital price and capital stock is the total capital costs.

Total cost is the sum of labor, fuel, and capital costs.

V. Empirical Evidence

A. Model Characteristics

The results of estimating the model over the 1965 to 1982 period are shown in table 1. Before testing the regulation bias hypotheses, it is useful to examine the sense of the estimated model. A quick glance at the t-statistics shows that the explanatory variables are just that -- only two of the 25 estimated coefficients have t-statistics less than 2 in absolute value. Apart from the k_i, the statistical significance of the coefficients does not necessarily provide strong evidence about the adequacy of the estimated model. Instead, characteristics of the production technology implied by the coefficients provide better clues of model plausibility. The estimated returns to scale are a good check of model adequacy for utilities because utilities ought to display increasing returns to scale given the large fixed costs required to supply electricity over an extensive geographic market.

Table 2 reports the estimates of the elasticity of cost with respect to output averaged over all firms for each year. The shadow estimate is the elasticity of shadow cost with respect to output from (15). The actual estimate is the shadow elasticity adjusted for the difference between actual and shadow costs:

$$(16) \qquad v_Q^a = v_Q^s + \frac{\sum_i \frac{\gamma_{iQ}}{k_i}}{\sum_i \frac{M_i^s}{k_i}}$$

If returns to scale are increasing, then the cost elasticity is less than one. As shown in table 2, the cost elasticities averaged over firms indicate increasing returns to scale over the whole sample period. Both the shadow and the actual elasticities behave similarly over time: the size of the increasing returns to scale grows moderately over the first period and shrinks over the second, and returns to scale are greater on average in the second period. These results are consistent with the behavior of output over these periods. In the first period, as output was increasing, these utilities were operating on lower portions of their average cost curves, where returns to scale are lower. In the second period, as output grew more slowly and eventually fell, these utilities operated on higher portions of their average cost curves, where returns to scale are higher. These results are the opposite of those of Gollop and Roberts (1981), who do not allow for a regulatory bias. They find an increase in returns to scale in the first period and a drop in returns to scale in 1974-75, the last years of their sample.

As further evidence, constant returns to scale and homogeneity of the cost function are tested. Homogeneity means that scale economies are the same for firms of all sizes in all years, and constant returns to scale means that there are no cost savings to increasing plant size. Homogeneity requires that

$$\gamma_{LQ}=\gamma_{FQ}=\gamma_{TQ}=\gamma_{QQ}=0;$$

constant returns requires homogeneity plus $\beta_Q=1$. Both homogeneity and constant returns to scale are rejected at better than the 0.5 percent significance level.

The estimated actual and shadow cost shares for the inputs are shown in tables 3a and 3b, respectively. The actual cost shares show that capital was the largest component of actual cost in the first period, and that labor became the largest cost component in the second period; fuel was the smallest cost component in both periods. The shadow cost shares show that capital and labor were the largest and smallest cost components, respectively, in both periods. The difference between the actual and shadow cost shares is rather dramatic, and again reflects the ratio of shadow to actual cost from (4) and (5). The large difference suggests that looking at the actual cost shares will give a misleading picture of the reaction of these utilities to changes in regulated prices.

Table 4 shows the decomposition of the growth rate of actual average cost into its components. This decomposition is similar to that for the growth rate of shadow cost (11):

$$(17) \qquad \dot{C}^a - \dot{Q} = \sum_i M_i^s \dot{P}_i + (v_Q^a - 1)\dot{Q} + v_T^a.$$

The first column of table 4 shows the average growth rate of actual average cost for each year. The next three columns are the $M_i^s \dot{P}_i$ terms for the three inputs; the fifth column shows the contribution of the returns to scale term $(v_Q^a - 1)\dot{Q}$ using v_Q^a from (16) ; the sixth shows the contribution of the technical change term v_T^a:

$$(18) \qquad v_T^a = v_T^s + \frac{\sum_i \frac{\gamma_{iT}}{k_i}}{\sum_i \frac{M_i^s}{k_i}}.$$

The last column is simply the difference between the first column and the sum of the next five. This remainder is not zero, because the five components on the right-hand side of (17) are estimated. Note that this remainder is not derived from any of the estimated regression equations.

Every cost component except scale economies on average added to the growth of average costs in both periods. Capital and fuel were the largest contributors to average cost growth in both periods, and capital and technical change accounted for much of the increase in the growth rate of average costs between the two periods. The remainder is about one-sixth the size of the average growth rate of average costs in the first period, but it is very small in the second. This suggests that the shadow cost model fits the second period much better than the first.

Estimated values for actual and shadow TFP and its components are shown in tables 5a and 5b. The shadow TFP measure is the partial derivative of shadow average cost with respect to time, which is the sum of two terms, the first reflecting scale economies and the second representing technical change:

$$(19)\quad TFP^{s} = (1-v^{s}_{Q})\dot{Q} \cdot v^{s}_{T}.$$

Actual TFP (TFP^{a}) comes from (19) but with v^{a}_{Q} from (16) replacing v^{s}_{Q}, and v^{a}_{T} from (18) replacing v^{s}_{T}. The results in table 5a show that scale economies have boosted TFP^{a} growth in every year except 1980, though the gain was significantly less in the second period. However, technical change was negative in every year but 1965, pulling the growth of TFP^{a} down, especially in the second period. The results for TFP^{s}, shown in table 5b, are qualitatively similar to those of TFP^{a} and its components, though it is interesting that v^{s}_{T} was slightly positive on average in the first period.

The most notable characteristic about both technical change estimates is their strong downward trend.[13] This rather uniform decline is due to the strong estimated time trend γ_{TT}. That shadow input prices have little influence on technical change is not surprising, because electricity production offers little input substitutability in the short and medium runs.

B. Regulatory Impact

The estimation results in table 1 show that all of the $\log(k_i)$ are individually significantly different from zero at better than the 0.5% significance level. The joint test of the statistical insignificance of all four of the $\log(k_i)$ is rejected at better than the 0.5 percent significance level. Thus, relative price efficiency is rejected over the whole sample, and the neoclassical cost function approach for regulated firms employed by Gollop and Roberts (1981) and others is inappropriate for this sample.[14]

A test of the A-J view and a test of the implications of Joskow's view is whether production inefficiencies due to regulation differ in the 1965 to 1973 and the 1974 to 1982 periods. The A-J view is that the inefficiencies should be the same in each period, while the Joskow view is that there should be greater inefficiencies in the second period than in the first. The true cost of regulation, and hence the magnitude of the inefficiencies created by regulation, cannot be estimated, because there is no evidence to suggest how the utilities would have organized their production had regulation not existed over the sample period. For example, the activities of production and distribution might have been separated, different amounts of capital might have been employed, and different technologies might have been chosen.[15] Hence, it is impossible to know what these firms' cost functions and associated returns to scale and productivities would have been.

However, "instantaneous" tatal and dynamic inefficiency estimates can be computed. The total measure compares actual utility costs predicted by the estimated model with the actual costs predicted by the model, but with k_K and k_F set equal to one in both periods. That is, current production costs for actual levels of output, which are generated by current production techniques and regulatory constraints, are compared with the costs generated with the same production techniques and for the same actual output levels, but without the regulatory constraints. This estimate, also examined by Atkinson and Halvorsen, measures movement along the isoquant to the efficient input mix.

An estimate of the dynamic notion of inefficiency can be obtained by examining the technical change experienced by these utilities with and without regulation. As above, technical change with regulation is that implied by the estimated model; technical change without regulation is that implied by the estimated model, but with all k_i set equal to one. The difference does not have a real-world counterpart or explanation, but it does indicate the direction of regulatory bias.

Note that our measure of the regulatory impact on technical change is different from that of Nelson and Wohar (1983). In their model, TFP is the sum of the technical-change term, the returns-to-scale term, and a separate regulatory impact. Without regulation, TFP is the sum of only the returns-to-scale and technical-change terms. This naturally begs the question of how regulation affects TFP if it does not affect the components of TFP. Obviously, Nelson and Wohar cannot test for a regulatory impact on technical change. Their measures of a regulatory impact on technical change are purely hypothetical, based on the difference between different TFP values calculated using assumed, not estimated, values for the regulatory impact coefficient, and their returns-to-scale and regulatory impact terms. The reader is left to wonder why the authors believed that regulation does not affect the returns-to-scale term.

Two sets of measures can be examined for a regulatory impact: actual and shadow. As shown in Israilevich and Kowalewski (1987), the actual cost and the actual and shadow returns-to-scale and technical-change equations are homogeneous of degree zero in the k_i, while the shadow cost equation is not. Thus, either the actual or the shadow returns-to-scale and technical-change measures can be used to examine the regulatory bias. The regulatory bias to the translog shadow measures is a constant for each variable in each period. This can be seen by subtracting the translog shadow equation for any of these variables from the same equation, but with the k_i set equal to one. The reason is that the cost-minimization model is set in a static equilibrium framework. The regulatory biases to the actual variables are not constant because they differ from the shadow measures by a proportional function of the ratio of shadow to actual cost. This ratio, and hence the degree of regulatory bias, varies over time. We prefer to use the actual measures to examine the regulatory bias for this reason and because the shadow measures have no real-world meaning.

Our inefficiency estimates reject Averch and Johnson's view and do not reject Joskow's view. As shown in table 6, the total inefficiency measure differs between the two periods, contrary to Averch and Johnson's view. Moreover, the direction of change between the two periods is what Joskow would expect -- total inefficiency is about 16 percentage points greater in the second period. In the first period, total inefficiency steadily increases from about 61.5 percent to 73.8 percent and averages about 66.6 percent. In the second period, it steadily increases from 74.9 percent to 87.4 percent and averages about 82.6 percent.

These total inefficiency estimates give the appearance of being overly large in magnitude. Atkinson and Halvorsen find much smaller inefficiency losses (9.0 percent) in their cross-section sample of 1970 firms, which includes two of our firms.[16] However, the Atkinson and Halvorsen result captures only the static portion of total inefficiency costs because they do not use time variables in their cost equation. Our estimates include the dynamic inefficiency costs, and hence are more representative of the total costs of regulation.

The difference between the Atkinson and Halvorsen result and ours suggests that the dynamic inefficiency may be quite large. Indeed, as shown in table 7, we find that regulation may have retarded the growth of technical change on average by about 0.64 percentage point <u>per year</u> in the first period and by 0.44 percentage point <u>per year</u> in the second. This an important result, and one that has been neglected by economists and regulators alike. Regulation not only affects the efficient utilization of existing production inputs, but it also affects the implementation of efficient capital and management techniques over time. Unlike our total inefficiency estimates, the dynamic portion of our total inefficiency estimate rejects Joskow's view of greater regulatory bias in the second period.

This regulatory bias on technical change is opposite to the casual impression given by the trends in actual and shadow technical change shown in tables 5a and 5b. The strong downward trends in both technical change measures, especially given the total inefficiency cost estimates shown in table 6, might lead some analysts to infer that tighter regulatory constraints contributed to the slowdown in technical change in the second period. However, table 7 shows that the regulatory bias on technical change was less in the second period.

Finally, an interesting result in table 7 is that regulation biased returns to scale upward on average in both periods. Contrary to Joskow's view, the regulatory bias on returns to scale is smaller in the second period. Netting out the two components, TFP was biased down by 0.46 percentage point per year in the first period and by about 0.33 percentage point per year in the second. This result also rejects Joskow's view of greater dynamic inefficiency in the second period.

VI. Summary and Conclusions

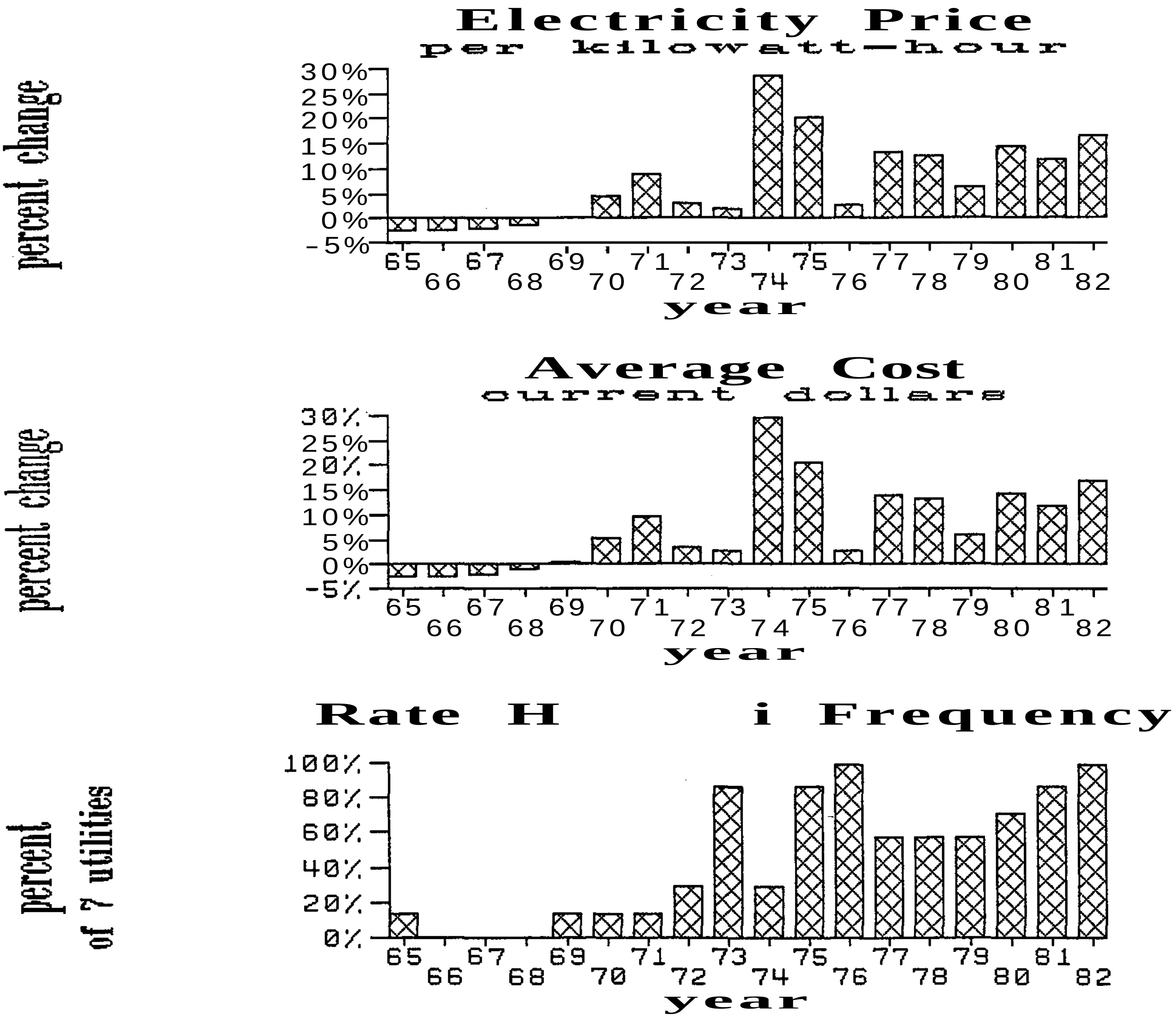
Electric utility regulators attempt to maintain a competitive price for electricity by adjusting the rate of return on a utility's capital. At first blush, this price-setting scheme appears sensible. It seems reasonably efficient to allow utilities to pass along operating costs and to cover their cost of capital. However, there are potentially serious problems with this type of regulation related to consumer reactions to price increases and to the types of incentives given to utilities. First, price increases may lower the consumption of electricity, which may reduce earned rates of return below "fair" rates and trigger a price increase, which in turn may lower consumption and trigger another price increase, and so on. That is, the proper response to falling utility profits because of lower demand may not be to raise prices.

Second, utilities may be able to effect price increases by using "too much" capital, that is, by overcapitalizing, which inflates their rate base. Indeed, rate increases lower the risk of capital investment below the risk level of unregulated industries, clearly giving utilities the incentive to overcapitalize. This potential bias was recognized by Averch and Johnson, and many empirical studies that adopted their model found an overcapitalization bias.

Finally, the ability to pass along operating cost increases that originated from productivity declines suggests that utilities may not have the incentive to raise productivity. This dynamic source of inefficiency was recognized by Joskow, who also argued that the regulatory mechanism is more complicated than that assumed by Averch and Johnson.

This paper is the first, to our knowledge, to explicitly test the Averch-Johnson view against Joskow's more general view. Using a modified version of the generalized long-run cost function derived by Atkinson and Halvorsen and a sample of the seven major electric utilities in Ohio over the 1965 to 1982 period, substantial evidence is found against the A-J view. Our total inefficiency measure shows that regulatory constraints were more binding during the years in which Joskow expects them to be more binding. We also find that regulation substantially retards the rate of technical change experienced by these utilities. However, the retardation in technical change is greater during the years when Joskow expects regulation to be less binding. This is the first demonstration of a regulatory impact on technical change. It clearly suggests that regulators ought to pay closer attention to the incentives they give utilities to innovate.[17]

PRICE, AVERAGE COST, AND RATE HEARING FREQUENCY



SOURCE: The authors.

TABLE 1

COEFFICIENT ESTIMATES

Coefficient	Estimate	Std. Error	T-Statistic
$\log(k_K)$	2.309321	.1192982	19.35756
$\log(k_{KS})$	2.408440	.1239441	19.43167
$\log(k_F)$	2.504495	.2273822	11.01447
$\log(k_{FS})$	1.756207	.2103573	8.348686
α	-7.593048	1.780928	-4.263535
β_L	.1308763	.2288987D-01	5.717650
β_F	-.5894347	.7871482D-01	-7.488230
β_T	-.8838121D-01	.2978847D-01	-2.966960
β_Q	2.149072	.3934191	5.462553
γ_{LK}	.3794210D-01	.5171896D-02	7.336208
γ_{FK}	-.1025558	.1416839D-01	-7.238348
γ_{FL}	-.3669283D-02	.4092725D-02	-.8965380
γ_{LQ}	-.6479785D-02	.1919976D-02	-3.374931
γ_{FQ}	.9260517D-01	.9527101D-02	9.720184
γ_{LT}	.1460668D-02	.4497358D-03	3.247836
γ_{FT}	-.2607712D-02	.9782291D-03	-2.665748
γ_{QT}	.8006320D-02	.3311198D-02	2.417953
γ_{QQ}	-.1572125	.4352119D-01	-3.612320
γ_{TT}	.2782344D-02	.5384827D-03	5.167008

COEFFICIENTS COMPUTED FROM PARAMETER RESTRICTIONS

Coefficient	Estimate	Std. Error	T-Statistic
β_K	1.4586	8.0374E-02	18.1472
γ_{KK}	6.46143-02	1.69563-02	3.8108
γ_{FF}	1.06233-01	1.40533-02	7.5588
γ_{LL}	-3.42733-02	5.43513-03	-6.3058
γ_{KQ}	-8.61253-02	9.5677E-03	-9.0017
γ_{KT}	1.14703-03	1.05543-03	1.0869

TABLE 2

ESTIMATED ELASTICITY OF COST WITH RESPECT TO OUTPUT
(averaged over firms)

Year	Actual	Shadow
1965	0.7838	0.7250
1966	0.7731	0.7151
1967	0.7747	0.7166
1968	0.7618	0.7045
1969	0.7598	0.7027
1970	0.7699	0.7135
1971	0.7736	0.7188
1972	0.7659	0.7120
1973	0.7601	0.7070
1974	0.6832	0.6937
1975	0.6825	0.6926
1976	0.6726	0.6826
1977	0.6644	0.6742
1978	0.6767	0.6865
1979	0.6749	0.6847
1980	0.6901	0.6998
1981	0.6871	0.6967
1982	0.6992	0.7088
1965-1973	0.7692	0.7128
1974-1982	0.6812	0.6911

NOTE: The elasticity of shadow cost with respect to output is computed using v_Q^s from equation (15). The elasticity of actual cost is computed from equation (16).

TABLE 3a

ESTIMATED ACTUAL COST SHARES
(averaged over firms)

Year	Capital	Labor	Fuel
1965	0.5494	0.2824	0.1682
1966	0.5381	0.2938	0.1681
1967	0.5345	0.2932	0.1723
1968	0.5245	0.3047	0.1707
1969	0.5154	0.3085	0.1761
1970	0.4981	0.3203	0.1816
1971	0.4790	0.3433	0.1777
1972	0.4668	0.3572	0.1760
1973	0.4536	0.3694	0.1770
1974	0.3635	0.3738	0.2626
1975	0.3503	0.4045	0.2452
1976	0.3508	0.4131	0.2362
1977	0.3426	0.4358	0.2215
1978	0.3436	0.4305	0.2260
1979	0.3406	0.4395	0.2200
1980	0.3401	0.4386	0.2213
1981	0.3379	0.4551	0.2070
1982	0.3439	0.4614	0.1947
1965-1973	0.5066	0.3192	0.1742
1974-1982	0.3459	0.4280	0.2261

NOTE: The actual cost shares are computed using equation (7).

TABLE 3b

ESTIMATED SHADOW COST SHARES
(averaged over firms)

Year	Capital	Labor	Fuel
1965	0.7076	0.0372	0.2552
1966	0.7021	0.0389	0.2590
1967	0.6957	0.0386	0.2657
1968	0.6915	0.0405	0.2680
1969	0.6815	0.0410	0.2774
1970	0.6665	0.0430	0.2905
1971	0.6605	0.0476	0.2919
1972	0.6569	0.0508	0.2923
1973	0.6483	0.0532	0.2985
1974	0.6829	0.0634	0.2537
1975	0.6833	0.0713	0.2454
1976	0.6891	0.0734	0.2375
1977	0.6920	0.0798	0.2282
1978	0.6891	0.0780	0.2329
1979	0.6903	0.0805	0.2292
1980	0.6884	0.0804	0.2313
1981	0.6957	0.0846	0.2198
1982	0.7076	0.0856	0.2067
1965-1973	0.6790	0.0434	0.2776
1974-1982	0.6909	0.0774	0.2316

NOTE: The shadow cost shares are computed using equation (14).

TABLE 4

ESTIMATED COMPONENTS OF THE RATE OF CHANGE IN ACTUAL AVERAGE COST

(percentage change, averaged over firms)

Year	Average Cost	Capital	Labor	Fuel	Scale Econ.	Tech. Change	Remainder
1966	-2.435%	3.210%	0.103%	0.516%	-2.888%	0.038%	-3.413%
1967	-0.066	0.217	0.155	1.083	-2.012	0.362	0.129
1968	2.337	5.040	0.190	0.733	-2.963	0.719	-1.384
1969	1.974	2.412	0.176	2.046	-2.418	1.054	-1.296
1970	11.563	6.503	0.294	6.117	-1.353	1.327	-1.326
1971	19.067	10.720	0.283	4.822	-0.742	1.587	2.397
1972	9.920	8.679	0.319	2.512	-2.250	1.912	-1.253
1973	9.714	8.069	0.405	3.689	-2.857	2.241	-1.833
1974	32.748	12.848	0.475	16.299	-0.616	2.305	1.437
1975	24.425	17.295	0.481	4.342	-0.717	2.567	0.457
1976	8.196	7.204	0.607	-0.316	-1.865	2.909	-0.343
1977	15.661	11.864	0.145	1.642	-1.394	3.214	0.191
1978	14.324	6.564	1.526	3.977	-0.192	3.498	-1.049
1979	10.493	6.614	0.505	1.038	-1.372	3.806	-0.097
1980	12.059	4.348	0.869	2.776	0.560	4.065	-0.558
1981	17.481	12.365	0.858	1.848	-0.537	4.360	-1.413
1982	17.609	6.431	1.039	0.857	1.741	4.610	2.931
1966-1973	6.509	5.606	0.240	2.690	-2.185	0.992	-0.997
1974-1982	16.999	9.504	0.723	3.607	-0.488	3.481	0.173

NOTE: These figures are computed using equation (17). The sum of the capital, labor, fuel, scale economies, and technical change columns is the estimated percentage change in actual average cost. The difference between the average cost column and this estimated percentage change is the remainder.

TABLE 5a

ESTIMATED ACTUAL TOTAL FACTOR PRODUCTIVITY AND COMPONENTS

(percentage change, averaged over firms)

Year	Total Factor Produc.	Scale Econ.	Tech. Change
1965	2.5797%	2.2673%	0.312%
1966	2.8500	2.8876	-0.038
1967	1.6501	2.0123	-0.362
1968	2.2433	2.9627	-0.719
1969	1.3636	2.4177	-1.054
1970	0.0256	1.3526	-1.327
1971	-0.8451	0.7419	-1.587
1972	0.3383	2.2503	-1.912
1973	0.6156	2.8567	-2.241
1974	-1.6893	0.6161	-2.305
1975	-1.8499	0.7169	-2.567
1976	-1.0434	1.8654	-2.909
1977	-1.8196	1.3943	-3.214
1978	-3.3061	0.1916	-3.498
1979	-2.4337	1.3723	-3.806
1980	-4.6240	-0.5596	-4.065
1981	-3.8231	0.5366	-4.360
1982	-6.3510	-1.7409	-4.610
1965-1973	1.2023	2.1943	-0.992
1974-1982	-2.9933	0.4881	-3.481

NOTE: Actual total factor productivity and its two components are computed from equation (19) but with v_Q^a from (16) replacing v_Q^s and v_T^a from (18) replacing v_T^s.

TABLE 5b

ESTIMATED SHADOW TOTAL FACTOR PRODUCTIVITY AND COMPONENTS

(percentage change)

Year	Total Factor Produc.	Scale Econ.	Tech. Change
1965	3.1640%	1.7794%	1.3841%
1966	3.3126	2.2927	1.0200
1967	2.3547	1.6574	0.6974
1968	2.6819	2.3561	0.3259
1969	1.9193	1.9313	-0.0121
1970	0.7850	1.0827	-0.2976
1971	-0.0224	0.5651	-0.5876
1972	0.8984	1.8291	-0.9304
1973	1.0881	2.3624	-1.2743
1974	-1.0104	0.6339	-1.6441
1975	-1.1941	0.7356	-1.9299
1976	-0.3551	1.9217	-2.2766
1977	-1.1613	1.4370	-2.5986
1978	-2.6797	0.1993	-2.8786
1979	-1.7847	1.4091	-3.1936
1980	-4.0267	-0.5744	-3.4520
1981	-3.2077	0.5494	-3.7574
1982	-5.8026	-1.7951	-4.0074
1965-1973	1.7980	1.7618	0.0362
1974-1982	-2.3580	0.5018	-2.8598

NOTE: Shadow total factor productivity and its components are computed using equation (19).

TABLE 6

TOTAL REGULATORY IMPACT ON ACTUAL COST

Year	Estimated Actual Cost	No Regulation Actual Cost	Regulatory Impact
1965	102.614	63.958	61.529%
1966	114.387	70.675	62.980
1967	121.560	75.208	62.872
1968	140.683	86.073	64.390
1969	156.215	95.322	64.921
1970	185.397	111.908	66.579
1971	223.909	132.645	69.875
1972	267.667	157.020	71.987
1973	329.468	191.387	73.815
1974	449.484	260.410	74.864
1975	583.524	330.424	79.143
1976	673.849	378.174	80.442
1977	822.803	452.890	83.831
1978	963.641	532.468	82.845
1979	1119.011	614.231	84.148
1980	1260.033	689.946	83.929
1981	1532.749	829.544	86.420
1982	1672.927	899.412	87.417
1965-1973	182.433	109.355	66.550
1974-1982	1008.669	554.167	82.560

TABLE 7
REGULATORY IMPACT ON ACTUAL TOTAL FACTOR PRODUCTIVITY
(percentage change)

Year	Total Factor Produc.	Scale Econ.	Tech. Change
1965	-0.4696%	0.2141%	-0.6837%
1966	-0.4120	0.2571	-0.6691
1967	-0.5156	0.1557	-0.6713
1968	-0.4020	0.2553	-0.6573
1969	-0.4514	0.2024	-0.6539
1970	-0.5337	0.1071	-0.6409
1971	-0.5463	0.0650	-0.6113
1972	-0.4313	0.1623	-0.5936
1973	-0.3850	0.1939	-0.5789
1974	-0.3443	0.1349	-0.4791
1975	-0.3133	0.1416	-0.4549
1976	-0.0026	0.4483	-0.4509
1977	-0.0709	0.3629	-0.4337
1978	-0.3737	0.0634	-0.4371
1979	-0.1324	0.2983	-0.4307
1980	-0.5391	-0.1080	-0.4311
1981	-0.3020	0.1187	-0.4207
1982	-0.8671	-0.4460	-0.4211
1965-1973	-0.4608	0.1792	-0.6400
1974-1982	-0.3273	0.1127	-0.4399

NOTE: The columns show the difference between the estimated actual measures and the estimated actual measures with the k_i all set equal to one.

FOOTNOTES

[1] This interpretation of the Averch-Johnson result is due to Baumol and Klevorick (1970).

[2] That is, Courville (1974), Spann (1974), Petersen (1975), Cowing (1978), and Nelson and Wohar (1983), for example, test only for an overcapitalization bias against an alternative hypothesis of no bias. Of these papers, only Nelson and Wohar do not find an overcapitalization bias.

[3] The seven major electric utilities in Ohio are Ohio Power; Cincinnati Gas and Electric; Cleveland Electric Illuminating; Columbus and Southern Ohio Electric; Dayton Power and Light; Ohio Edison; and Toledo Edison. Over the 1965 to 1982 period, they accounted for about 90 percent of electric power sales in Ohio.

[4] Actually, Baumol and Klevorick (1970) argue that Averch and Johnson did not prove this as a general-result. Note that if there are additional production factors, then the amount of capital relative to these other inputs also will be higher than for the cost-minimizing firm.

[5] A slight modification to the Averch-Johnson regulatory process was the introduction of a "regulatory lag"; see, for example, Bailey and Coleman (1971) and Baumol and Klevorick (1970).

[6] The average price shown in the figure is not the regulated price, but the ratio of average total revenue for the seven utilities to their average total sales. In general, different consumers face different regulated price schedules, and utilities serving different geographic markets may be allowed to charge different prices for the same category of consumer.

[7] It can never be known whether earned returns were greater than "fair" returns because there were no rate hearings for all firms during these years.

[8] Other production inputs, such as materials, managerial skills, and available infrastructure, for example, are excluded because there are no reliable data for these factors.

[9] Nevertheless, some authors, for example Gollop and Roberts (1981, 1983), use the neoclassical approach to study electric utilities.

[10] A strict test of Averch and Johnson's view using the k_i is k_F not equal to 1 and k_{FS} not equal to one, because Averch and Johnson consider only a rate-of-return regulatory constraint. If these hypotheses cannot be rejected, then Nelson and Wohar (1983) and other papers that test only this constraint are potentially incorrect.

[11] See Cowing, Small, and Stevenson (1981) for the equations used to compute the capital stock and capital price variables.

[12] *Capital Stock Estimates for Input-Output Industries: Methods and Data*, Bulletin 2034, U.S. Department of Labor, Bureau of Labor Statistics, 1979.

FOOTNOTES

[13] A strong downward trend in the rates of technical change experienced by utilities also was found by Nelson and Wohar (1983), Gollop and Roberts (1981), and Gollop and Jorgenson (1980), all of whom used samples that ended in the 1970s. Thus, the results reported here confirm these earlier findings for the late 1970s and early 1980s.

[14] The strict test of Averch and Johnson's view is rejected; k_F and k_{FS} are jointly statistically different from zero at better than a 0.5 percent significance level.

[15] Under the current regulatory environment, the production and distribution of electricity must be handled by each utility. Moreover, the transferal of electric power across state lines also is impeded.

[16] It is likely that our estimates are more accurate for Ohio because our sample includes only Ohio firms, which are fairly similar in a number of important respects, as mentioned earlier.

[17] The poor technical-change performance also may be due to increased investment in nuclear power plants over this period, which drew funds away from conventional power-generation capital investments.

REFERENCES

Atkinson, Scott E., and Robert Halvorsen. "Parametric Efficiency Tests, Economies of Scale, and Input Demand in U.S. Electric Power Generation," International Economic Review, vol. 25, no. 3 (October 1984), 647-62.

Averch, Harvey, and Leland L. Johnson. "Behavior of the Firm under Regulatory Constraint," American Economic Review, vol. 52, no. 5 (December 1962), 1052-69.

Bailey, E.E., and R.D. Coleman. "The Effect of Lagged Regulation in an Averch-Johnson Model," The Bell Journal of Economics and Management Science, vol. 2, no. 1 (Spring 1971), 278-92.

Baumol, William J., and Alvin K. Klevorick. "Input Choices and Rate-of-Return Regulation: An Overview of the Discussion," The Bell Journal of Economics and Management science, vol. 1, no. 2 (Autumn 1970), 162-90.

Berndt, Ernst R., and Melvyn A. Fuss. "Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium," Journal of Econometrics, vol. 33, no. 1/2 (October/November 1986), 7-30.

Christensen, L.R., and Dale W. Jorgenson. "U.S. Real Product and Real Factor Input, 1929-1967," The Review of Income and Wealth, series 16, no. 1 (March 1970), 19-50.

Courville, Leon. "Regulation and Efficiency in the Electric Utility Industry," The Bell Journal of Economics and Management Science, vol. 5, no. 1 (Spring 1974), 53-74.

Cowing, Thomas G. "The Effectiveness of Rate-of-Return Regulation: An Empirical Test Using Profit Functions," in M. Fuss and D. McFadden, Eds., Production Economics: A Dual Approach to Theory and Application, Amsterdam: North Holland Publishing Company, 1978.

Cowing, Thomas G., Jeffery Small, and Rodney E. Stevenson. "Comparative Measures of Total Factor Productivity in the Regulated Sector: The Electric Utility Industry," in T.G. Cowing and R.E. Stevenson, Eds., Productivity Measurement in Regulated Industries, New York: Academic Press, 1981.

Fare, Rolf, and James Logan. "Shephard's Lemma and Rate of Return Regulation," Economics Letters, vol. 12 (1983), 121-25.

Gollop, Frank M., and Dale Jorgenson. "U.S. Productivity Growth by Industry, 1947-1973," in J.W. Kendrick and B.N. Vaccara, Eds., Studies in Income and Wealth, National Bureau of Economic Research, Chicago: University of Chicago Press, 1980.

Gollop, Frank M., and Mark J. Roberts. "The Sources of Economic Growth in the U.S. Electric Power Industry," in T.G. Cowing and R.E. Stevenson, Eds., Productivity Measurement in Regulated Industries, New York: Academic Press, 1981.

Gollop, Frank M., and Mark J. Roberts. "Environmental Regulations and Productivity Growth: The Case of Fossil-Fueled Electric Power Generation," Journal of Political Economy, vol. 91, no. 4 (August 1983), 654-74.

Israilevich, Philip and K.J. Kowalewski. "Estimating Total Factor Productivity in a Generalized Cost System," Federal Reserve Bank of Cleveland Working; Paper 8702, March 1987.

Joskow, Paul L. "Inflation and Environmental Concern: Structural Change in the Process of Public Utility Price Regulation," The Journal of Law and Economics, vol. 17 (October 1974), 291-327.

Nelson, Randy A., and Mark E. Wohar. "Regulation, Scale Economies, and Productivity in Steam-Electric Generation," International Economic Review, vol. 24, no. 1 (February 1983), 57-79.

Petersen, H. Craig. "An Empirical Test of Regulatory Effects," The Bell Journal of Economics and Management Science, vol. 6, no. 1 (Spring 1975), 111-26.

Spann, R.M. "Rate of Return Regulation and Efficiency in Production: An Empirical Test of the Averch-Johnson Thesis," The Bell Journal of Economics and Management Science, vol. 5, no. 1 (Spring 1974), 38-52.