Onderzoeksrapport Nr. 7818

FUEL ADJUSTMENT MECHANISMS

AND

ECONOMIC EFFICIENCY

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March 1978

Revised May 1978

Wettelijk Depot : D/1978/2376/27.

Forthcoming Journal of Industrial Economics

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ABSTRACT

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Fuel adjustment clauses (FAC's) provide for automatic adjustments in the output price of electricity in response to changes in the factor prices of fuels. The principal arguments against FAC's are that they dampen the incentive for the choice of the least-cost fuel supply and for the substitution of other inputs for fuel.

Given an average cost adjustment formula, the former is shown to be a problem only when the firm has decreasing returns to scale, while the latter results in a greater fuel-capital ratio when the real price of fuel is anticipated to increase with probability one.

FUEL ADJUSTMENT MECHANISMS AND ECONOMIC EFFICIENCY

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I. Introduction

Fuel adjustment mechanisms used in electricity and natural gas pricing are formulae that provide for automatic adjustments in output prices in response to changes in the factor prices of boiler fuels and wellhead gas, respectively. Because these adjustments are made automatically, regulatory commissions do not exercise direct review of the appropriateness of the adjustments although they do generally have authority to determine the form of the formulae used.¹ The purpose of this paper is to investigate the implications of these mechanisms for economic efficiency, and the analysis will focus on fuel adjustment clauses for electricity rates, since they have been the subject of the most concern in the U.S.²

Fuel adjustment mechanisms were first utilized in the U.S. during World War I to enable the regulatory process to function in response to the rapid increase in coal prices.³ "By 1958, the vast majority of electric utilities had adopted fuel clauses. ... most fuel clauses, however, were limited to

commercial and industrial users... The percentage of utilities having residential fuel clauses rose from 35 percent in 1970 to 65 percent in 1973. [19, p. 5]."

As an indication of the pervasiveness of these mechanisms, they are currently allowed in all but five states, Montana, Oregon, Utah, Washington and Wyoming, and in Idaho and Nevada "FAC's are not used or are denied to some categories of utilities. [20, p. VI]."

Of the 82 electric utilities responding to an October 3, 1974 questionnaire of the Edison Electric Institute, 81 reported that a FAC was included in their tariffs [8].

"An FPC survey as of January 1, 1974 showed that 65 % of the larger privately owned utilities had fuel adjustment clauses in their residential schedules, 77 % had such clauses in their commercial schedules, and 83 % in their industrial schedules." [13, p. 315].

The House Subcommittee on Oversight and Investigation [19] has estimated the magnitude of the rate increases resulting from fuel adjustments as follows :

"In 1974, following the decision of the Organization of Petroleum Exporting Countries (OPEC) to raise the price of oil, utility fossil fuel costs increased 86.8 percent, an increase of nearly \$6.2 billion over 1973. (p. 2)"

"The price of electricity rose \$8 billion in 1974. Automatically two-thirds of that increase was incurred through automatic fuel adjustment clauses. (p. 1)"

A study prepared by the Congressional Research Service for the Senate Subcommittee on Intergovernmental Relations and the Subcommittee on Reports, Accounting, and Management indicated that in 1976 electric utilities received rate increases estimated to amount to "\$8.5 billion - \$6 billion through FAC's and \$2.5 billion through formal rate cases. [20, p. V]"

the magnitude of these cost increases and the fact that they were made without public review has led to strong criticism of this regulatory instrument. The House Subcommittee on Oversight and Investigations has concluded :

"... the Subcommittee finds that fuel adjustment clauses, in any form, are unwise, unnecessary, unworkable, and unfair. Fuel clauses, in the Subcommittee's view, moreover, may be the forerunner of a campaign to undermine utility regulation by means of a full range of automatic adjustment clauses that will render utility commissions virtually powerless while reducing utility management to the not so fine art of adjusting monthly consumer electric bills to reflect the industry's unchecked cost increases. [19, p. 1]"

The proponents of automatic adjustment mechanisms argue that these mechanisms are necessary to enable utilities to maintain financial viability and to raise capital. The objective of a fuel adjustment clause as stated by the FPC [18] is as follows : "... our purpose is protection of the consumers while keeping utilities whole for increases in fuel costs..."⁴ Utilities appear to interpret this objective as meaning that fuel adjustment clauses should operate to enhance rates of return rather than to simply match revenues with increases in fuel costs. For example, in response to charges by Silvia M. Siegel that Southern California Edison and Pacific Gas and Electric Company had overcollected on their FAC's, a P.G. and E. spokesman stated

"P.G. and E's other cost increases more than offset any 'profits' that it might have gained from short run overcollection under the fuel clause."

A Southern California Edison official, in response to Ms. Siegel's allegations, concluded that "The ultimate test of the fairness of the fuel clause should be the level of rate of return earned by the utility." [19, p. 6]"

Whether fuel adjustment clauses are intended to match revenue changes with cost changes or to enhance rates of return, the desire for these automatic adjustment mechanisms results from the processing lag⁵ inherent in the rate review process. In approving a comprehensive adjustment mechanism for the Public Service Company of New Mexico, the New Mexico Public Service Commission clearly stated this view.

"In short, the utility has lost all stability and reliability of common stock earnings in the view of investors, and the restoration of his allowed level of earnings, which can be prospective only and not retroactive, must await the outcome of yet another protracted and expensive general rate proceeding, at the conclusion of which the dismal cycle of declining earnings begins again. [18, p. 129]"

The length of the processing period varies among jurisdictions, and according to the Edison Electric Institute

"Recent data, however, suggest that the average time period necessary to complete a rate case from initial filing to the effective date of the new rates, may have stabilized. From just under 9.5 months for cases decided in 1971, the average lag grew to 10 months in 1972 and to nearly 10.5 months in 1973. In 1974, the average case "life" was also just under 10.5 months. [19, p. 112]"

Opponents of automatic adjustment mechanisms argue that the adverse effects on a firm's financial strength that result during the processing lag period can be diminished without abdicating regulatory responsibility not only by reducing the processing lag but also by granting interim rate relief and by using future test periods. "Nearly, 38 % of the cases for which final decisions were rendered in 1974 involved interim increases prior to the concluding actions. [19, p. 112]" For cases settled between January 1, 1976 and March 31, 1977, 45 of the 166 cases (27 %) involved interim

rates in effect while the case was in progress.⁶ A future test period "permits rates to be established on the basis of estimated costs which will be incurred at the time the rates go into effect as opposed to the more common practice of establishing rates based on costs incurred in the past." [19, p. 113] There is however little normative theory to guide a commission in determining the amount of an interim rate increase and many commissions are reluctant to grant rates based on forecasts as is necessary with the use of future test periods.⁷

A second criticism of fuel adjustment clauses is that they can be manipulated by utilities to the detriment of consumers. While there are some instances of manipulation cited by the House Subcommittee on Oversight and Investigations [19] and by the Consumers Union [7], FPC audits, according to W.W. Lindsay, "do not reveal any widespread effort to "rip off" American consumers of electricity by way of improper administration of fuel clauses. [12, p. 10]"

A third argument against fuel adjustment clauses is that they may result in increases in output prices due to higher fuel costs even though average costs are decreasing because of, for example, productivity gains. This, however, appears to be more of a problem of the inability of a commission, and perhaps the unwillingness of the utility, to adjust prices in response to costs that change over time. Even without a fuel adjustment mechanism this problem is likely to be present.⁸

A fourth criticism is that the adjustments have been extended to more than just the factor price of fuel and thus represent the automatic pass through of endogenous operating costs rather than exogenous factor price changes. A Congressional Research Service survey indicated that of the 36 commissions that provided information on the costs included in the FAC's under their jurisdiction⁹

"... in addition to changes in fossil fuel charges, 11 commissions included nuclear fuel costs in the calculation of their FAC's ; 2 commissions included hydro-power ; 1 commission included geothermal ; 25 included purchased power ; 22 included line losses ; 18 commissions included transportation charges ; 14 had an efficiency factor ; 6 commissions included taxes and fees ; 6 included fuel handling costs ; 3 FAC's included fuel-related salaries and labor ; 1 included wheeling charges ; 1 included an allowance for uncollectable expenses ; and 1 included a lag correction factor. [20, p. 21]."

It is clear that although these costs may be incurred in relation to the usage of fuel, they are endogenous rather than exogenous costs.

A fifth and perhaps most damaging criticism of fuel adjustment mechanisms is that they weaken incentives for efficiency, since if utilities can pass on all fuel cost increases, they may have no incentive to choose the least-cost fuel supply. Critics argue that a solution to this incentive problem is to allow utilities to pass on only a portion of the fuel price increases. With respect to this issue the FPC in Order No. 517 opposed this approach stating

"Other comments suggested that utilities be permitted to recover only a portion of increased fuel costs in order to provide an incentive to bargain for lower cost fuel. It should be noted that to the extent that only a portion of changes in fuel costs are permitted to be reflected in rates, the purposes of the fuel clause (namely to pass on to customers the increases or decreases in the fuel costs actually incurred by the utility) is to that extent defeated [18, p. 40583]."

Proponents of FAC's argue however that a "collection lag" provides incentives for the choice of the efficient fuel. The FPC states this view as follows :

"In addition, the lag in collection for fuel expenses inherent in a typical fuel cost adjustment clause provides some incentive for companies to bargain for favorable prices during periods of rising fuel costs. [18, p. 40583]"

The October 3, 1974 Questionnaire on Fuel Adjustment Revenue administered by the Edison Electric Institute indicates that of the 81 responding utilities with FAC's in operation, three had their fuel adjustment calculated on a "current month estimated" basis, 16 on the prior month base, 43 on the second preceding month, 15 on an average of prior months, and 12 on other bases. The respondents also indicated that during 1973 or 1974, 26 of the 81 had the lag reduced, presumably at the request of the utilities. Since the length of the collection lag is subject to the jurisdiction of a commission, it can be adjusted to strengthen or weaken the incentive for the choice of the efficient fuel. As will be indicated in Section IV, this incentive problem will be shown to be present only when the firm has decreasing returns to scale which is not likely to be the situation for most electric utilities. When this efficiency problem is present, the collection lag will be shown to be a sufficient regulatory instrument to induce the efficient choice among fuel supply sources.

Another potential source of inefficiency involves the substitution of other factor inputs for fuel. An increased factor price should not only lead to the substitution of other fuels for the fuel whose price has increased, but also to the substitution of other factor

inputs for fuel. The principal substitution possibility is between capital and fuel, and a substitution of capital for fuel would be anticipated in response to changing relative prices. The limit to this substitution at the generation stage is that "Lead times [are] of from 6 years for a coal-fired plant to 10 years for a nuclear station ... [19, p. 144]" While at the ex ante or design stage a utility has the opportunity to substitute capital for fuel, for example, by investing in transmission equipment to reduce line losses or by purchasing more efficient generation equipment, once the capital is in place the technology of the plant is largely invariable. Ex post substitution is thus limited.¹⁰

In addition to the issue of the abdication of regulatory responsibility, the principal arguments against the use of automatic adjustment mechanisms center on their impact on economic efficiency. The objective of this study is to investigate the efficiency of both the fuel supply decision and the choice of technology. As will be demonstrated in Section III, predicting the direction of this bias is complicated. For example, if a factor price increase is anticipated with probability one, a fuel adjustment clause results in a bias toward the overutilization of fuel. If, however, the factor price is uncertain but has an expected value equal to the current factor price, the technology chosen by the firm will involve the underutilization of fuel when, for example, the firm has constant returns to scale. The model utilized to investigate the efficiency issue is introduced

in the next section, and the choice of a technology is analyzed in Section III. The fuel choice decision is considered in Section IV, and conclusions are offered in the final section.

II. The Model

Prior to developing the model of the firm, the nature of the regulatory environment in which the firm operates will be considered. A central feature of a fuel adjustment clause (FAC) is that it acts directly on the output price without a specific consideration of its effect on the rate of return earned by the firm once the adjustment has been made. While at a later date the earned rate of return may be reviewed and the output price adjusted appropriately, no rate of return constraint is imposed at the time the terms of the fuel adjustment mechanism are exercised. Consequently, a model of regulation of the Averch-Johnson [2] variety with a continually-imposed rate of return constraint is not an appropriate description of the regulatory process. A better description of the regulatory process is that a commission sets (or approves) an initial price for a firm's output, with rate of return objectives in mind, but after an adjustment in the price via a fuel adjustment clause, the firm may or may not earn its allowed return. The model will therefore assume that the regulator sets the initial price and changes from the price can occur only through the FAC. To facilitate the analysis, a single factor price change will be considered, and the output price will be adjusted only in response to that change.

Fuel adjustment clauses typically are designed to increase the output price by an amount equal to the increase in average cost. In practice, the formula for the adjustment depends on a variety of factors such as fuel mix and line losses and may be based on the kilowatt hours delivered, the kilowatt hours generated, Btu's of fuel consumed, or other bases. The formula to be considered here is based on the fuel cost increase per unit of output at the time that the factor price changes. If initially p_1 is the output price, c_1 the factor price of fuel, f_1 the quantity of fuel used, and $Q(p_1)$ the output, the change in average cost due to a real factor price change to c_2 is $(c_2 - c_1)f_1/Q(p_1)$. The adjusted output price p_2 is thus given by

$$p_2 = p_1 + (c_2 - c_1)f_1/Q(p_1).$$

As indicated in Section I, opponents of fuel adjustment clauses have argued that the adjustment should be multiplied by a constant $\xi < 1$ in order to induce the efficient choice of a fuel, but consideration of such a regulatory instrument will be reserved for Section IV.

Both the future factor price c_2 and the time at which the change occurs will be assumed to be uncertain. To represent the timing of the factor price change, let $1 - F(t)$ denote the probability that the price has not changed prior to time t . The conditional probability density function for a price change at time t , given that it has not changed prior to t , is thus $k(t) = \dot{F}(t)/(1 - F(t))$, which is referred to as the hazard rate.¹¹ In order to facilitate the analysis, the random variables c_2 and t are assumed to be

statistically independent, and the hazard rate will be assumed to be a constant k which implies that $1 - F(t) = \exp(-kt)$, so that the time at which the factor price will change is exponentially distributed.¹²

When a factor price change occurs, the firm may not be permitted to collect the adjusted price until after some collection lag τ . As indicated in Section I, the average collection lag is likely to be less than two months and varies from a "current month estimated" basis to a lag of a few months. A "current month estimated" basis could, for example, be represented by $\tau = 0$, while a prior month's base would correspond to $\tau > 0$.¹³ The length of the lag is assumed to be known, since the lag is typically specified in the tariff. In practice, the collection lag is due to inherent delays in obtaining accounting data, but it may also be used as a regulatory instrument in order to improve efficiency incentives, as considered in Section IV.

The time frame of the model can be thought of as consisting of three intervals. During the initial interval $(0, t)$ the output price p_1 is in effect and the factor price is c_1 . At time t the factor price changes to c_2 , and during the collection lag period $(t, t + \tau)$ the output price remains at p_1 . The third interval begins at $t + \tau$ when the output price is adjusted to p_2 , and to simplify the analysis, the factor price and the output price are assumed to remain at those levels thereafter. The following Figure 1 illustrates the time intervals and the prices in effect at each time.¹⁴

The production possibilities of the firm will be represented by a simple technology involving two inputs, capital and fuel. An electric utility does not have perfect flexibility with respect to its choice of technology, since, for example, the lead time for the construction of a new plant may range from six years for a coal-fired plant to ten years for a nuclear plant. To represent this situation, the firm will be assumed to have a putty-clay technology so that at time zero the firm can freely choose its fuel-capital ratio, but thereafter the ratio is fixed.

The ex ante production function will be specified as homothetic, and while homothetic production function specifications have generally been utilized in empirical studies of the electric utility industry, there have been few tests of this assumption. One such test is that of Atkinson and Halvorsen [1] who explicitly tested for homotheticity using a translog specification and concluded that "the production function is predominately homothetic." The ex ante production function is specified by $Q_i = H(G(K_i, f_i))$, where H is a strictly increasing function and G is a production function that is homogeneous of degree one and i denotes the time interval.¹⁵ The function H thus reflects returns to scale, and taking the inverse and dividing by K_i yields

$$H^{-1}(Q_i)/K_i = G(K_i, f_i)/K_i = G(1, \gamma) = 1/g(\gamma),$$

where γ is the fuel-capital ratio. For notational convenience let $\varphi \equiv H^{-1}$, and since H is strictly increasing, so is φ . Also g is strictly decreasing in γ , since G is a strictly increasing function.¹⁶ The marginal

rate of technical substitution is

$$MRTS = \frac{\partial Q_i / \partial K_i}{\partial Q_i / \partial f_i} = -(g(\gamma) + \gamma g'(\gamma)) / g'(\gamma) > 0,$$

which implies that $g(\gamma) + \gamma g'(\gamma) > 0$.

The firm is assumed to be required to supply any level of demand, and the ex post fuel and capital inputs required to produce an output Q_i are determined by the fuel-capital ratio chosen ex ante. The inputs are given by

$$K_i(Q_i, \gamma) = g(\gamma) \varphi_i, \quad i = 1, 2$$

$$f_i(Q_i, \gamma) = \gamma K_i(Q(p_i), \gamma) = \gamma g(\gamma) \varphi_i, \quad i = 1, 2$$

where $\varphi_i \equiv \varphi(Q(p_i))$ and $Q_i \equiv Q(p_i)$. Consequently, once the fuel-capital ratio has been determined ex ante, the ex post inputs are constrained to be on a ray in the (K, f) -plane.¹⁷ The profit $\pi_i, i = 1, 2, 3$ earned by the firm in each interval is thus

$$\pi_1 = p_1 Q_1 - c_1 f_1 - v K_1 = p_1 Q_1 - \varphi_1 M_1$$

$$\pi_2 = p_1 Q_1 - \varphi_1 M_2$$

$$\pi_3 = p_2 Q_2 - \varphi_2 M_2,$$

where v is the real cost of capital and $M_i = c_1 \gamma g(\gamma) + v g(\gamma)$. The objective of the firm is assumed to be the maximization of the expected discounted profit V which is given by

$$V = \int_0^\infty \dot{P}(t) \{ \int_0^t e^{-rt^0} \pi_1 dt^0 + \int_t^{t+\tau} e^{-rt^0} E \pi_2 dt^0 + \int_{t+}^\infty e^{-rt^0} E \pi_3 dt^0 \} dt,$$

where E denotes the expectation with respect to c_2 and r is the discount rate. Integrating with respect to t^0 and then t yields

$$V = (r\pi_1 + k(1 - e^{-rT})E\pi_2 + ke^{-rT}E\pi_3)/(r(r+k)),$$

since t and c_2 are statistically independent.

III. Technical Efficiency with a Fuel Adjustment Mechanism

For a given initial price p_1 and a specified fuel adjustment clause, the firm maximizes V and hence its optimal γ^* satisfies

$$(1) \quad \frac{\partial V}{\partial \gamma} = - [r\varphi_1 M_{1\gamma} + k(1 - e^{-rT})\varphi_1 E M_{2\gamma} + ke^{-rT}(E(\varphi_2 M_{2\gamma}) - \frac{\partial \pi_3}{\partial p_2} \frac{dp_2}{d\gamma})] / (r(r+k)) =$$

where $M_{i\gamma} = \partial M_i / \partial \gamma$. The second-order condition will be assumed to be satisfied at γ^* . The term $(\partial \pi_3 / \partial p_2) / (dp_2 / d\gamma)$ represents the price effect of γ on the post-adjustment profit π_3 , and the effect of γ on p_2 through the FAC is

$$(2) \quad \frac{dp_2}{d\gamma} = (c_2 - c_1) \varphi(Q(p_1)) (g(\gamma) + \gamma g'(\gamma)) / Q(p_1).$$

The technically efficient fuel-capital ratio depends on the output prices in the three time intervals and hence, technical efficiency must be defined relative to a given price schedule over time. The technically efficient fuel-capital ratio γ^0 corresponding to the prices p_1 and

$$p_2 = p_1 + (c_2 - c_1) \varphi(Q(p_1)) \gamma^* g(\gamma^*) / Q(p_1),$$

thus satisfies (1) with $\partial \pi_3 / \partial p_2 = 0$. The nature of the bias in technology thus depends on the sign of the term

$$(3) \quad E\left(\frac{\partial \pi_3}{\partial p_2} \frac{dp_2}{d\gamma}\right) = \left[E\left(\frac{\partial \pi_3}{\partial p_2}\right)E(c_2 - c_1) + \text{cov}\left(\frac{\partial \pi_3}{\partial p_2}, c_2\right)\right] (g(\gamma^*) + \gamma^* g'(\gamma^*)) \varphi_1 / Q_1.$$

Since $g(\gamma^*) + \gamma^* g'(\gamma^*)$ is positive, the direction of the technical bias caused by the fuel adjustment clause is determined by the sign of the term in brackets in (3).

If regulation is effective in maintaining the output price below the price that a firm employing the technology γ^* would set if unregulated, then $\partial \pi_3 / \partial p_2 > 0$ and $E(\partial \pi_3 / \partial p_2) > 0$. The covariance is negative (positive) if $(\partial \pi_3 / \partial p_2)$ is a decreasing (increasing) function of c_2 , but in general, monotonicity may not be present. Differentiation yields

$$\begin{aligned}
 (4) \quad \frac{\partial^2 \pi_3}{\partial p_2 \partial c_2} &= \frac{\partial^2 \pi_3}{\partial p_2^2} \frac{\partial p_2}{\partial c_2} - \varphi_2' Q_2' \gamma g(\gamma) \\
 &= \frac{\partial p_2}{\partial c_2} \left[\frac{\partial^2 \pi_3}{\partial p_2^2} - \varphi_2' Q_2' Q_1 / \varphi_1 \right] \\
 &= \frac{\partial p_2}{\partial c_2} \left[\frac{\partial^2 \pi_3}{\partial p_2^2} - \frac{Q_2' \varphi_2' \eta_1}{\varphi_1} \right],
 \end{aligned}$$

where $\eta_1 \equiv \varphi_1' Q_1 / \varphi_1$ is the returns to scale measure at the initial output level. By the assumed strict concavity of π_3 at p_2 the first term in brackets is negative, but the second term is positive, so the sign of the covariance in (3) is ambiguous. Consequently, only limited results regarding the nature of the bias can be given. The following results can be established.¹⁸

Proposition 1 : a) If regulation is effective and a factor price increase (decrease) is anticipated with probability one, that is,

$\Pr(c_2 \geq c_1) = 1$ ($\Pr(c_2 \leq c_1) = 1$) with the strict inequality holding with positive probability, then $\gamma^* > (<) \gamma^0$.

b) If $E(c_2) = c_1$, technical efficiency will result if $\partial\pi_3/\partial p_2$ is constant in c_2 , or in general if the case in which the functional form of π_3 is such that $\text{cov}(\partial\pi_3/\partial p_2, c_2) = 0$.

Proof : a) If $\Pr(c_2 \geq c_1) = 1$, then $dp_2/d\gamma$ in (2) is nonnegative for all c_2 and positive for some values of c_2 with positive probability. Since $\partial\pi_3/\partial p_2 > 0$ when regulation is effective, the bias term is the expectation of two nonnegative functions which is strictly positive if $\Pr(c_2 > c_1) > 0$. An analogous argument holds for an anticipated price decrease.

b) If $E(c_2) = c_1$, the sign of the bias term given in (3) is the same as that of the term $\text{cov}(\partial\pi_3/\partial p_2, c_2)$. This will equal zero only if $\partial\pi_3/\partial p_2$ is constant in c_2 which requires that the term in brackets in (4) be zero for all c_2 . This will be zero only for special functions π_3 .

This characterization of the bias in the choice of technology caused by the fuel adjustment clause is not complete, but several interesting conclusions can be drawn. First, if a fuel such as natural gas or oil is anticipated to rise in price in the future, then the fuel adjustment clause would encourage the overconsumption of that fuel through a technology biased in favor of the employment of that fuel. At a time when the conservation of these fuels is being encouraged, a fuel adjustment clause would hinder the achievement of that goal. This also suggests that

an electric utility would have less incentive to convert to alternate fuel sources when that conversion is costly, so the use of legislation requiring conversion from oil to coal might be justified to promote efficiency. Second, if the real price of a fuel is "expected" to be stable (e.e. $E(c_2) = c_1$), then the fuel-adjustment clause may lead to the use of a fuel-capital ratio that is less than the technically efficient ratio. This reflects the effect of factor price uncertainty, the covariance term, on the marginal profit of the firm which results from the adjustment.

As an example, suppose that the firm has constant returns to scale and that the initial price p_1 was set equal to average cost M_1 . The price p_2 is then

$$p_2 = p_1 + (c_2 - c_1) \gamma g(\gamma) = M_2.$$

Evaluating (4) yields

$$\frac{\partial^2 \pi_3}{\partial p_2 \partial c_2} = \frac{\partial p_2}{\partial c_2} [Q_2' + (p_2 - M_2)Q_2''] = \frac{\partial p_2}{\partial c_2} Q_2',$$

which is negative for any demand function. Consequently, if the expected factor price change is zero and the firm has constant returns to scale, the firm will choose a fuel capital ratio that is lower than the technically efficient level. While this example cannot be extended to a general proposition, it does suggest that the use of a fuel adjustment clause when factor prices are anticipated to be stable "on average" would lead to the underutilization of fuel.

The significance of this example lies in the recent empirical results of Christensen and Greene [6] who have concluded using 1970 data that 45 % of the electricity generated by the 114 utilities included in their sample was in a region of "no significant economies or diseconomies" of scale. Since the fuel price changes since the time of the oil boycott have been relatively stable in nominal terms, anticipation of such stability in the future could result in the underutilization of fuel.

The length τ of the collection lag can be used by a regulator to affect the firm's choice of technology, since an extension of the lag diminishes the time over which the firm receives the adjusted price. To characterize the relationship between γ^* and τ , differentiation of (1) yields

$$(5) \quad \frac{d\gamma^*}{d\tau} = (-rk e^{-r\tau} [E((\varphi_2 - \varphi_1)M_{2\gamma}) - E(\frac{\partial \pi_3}{\partial p_2} \frac{dp_2}{d\gamma})]) / D,$$

where $D = (\partial^2 V / \partial \gamma^2) r(r + k)$ is proportional to the second-order condition $\partial^2 V / \partial \gamma^2$ which is negative by assumption. The following proposition characterizes the sign of $d\gamma^* / d\tau$ for the case of an anticipated factor price increase.

Proposition 2 : If a factor price increase is anticipated, the optimal fuel-capital ratio is a decreasing function of τ .¹⁹

Proof : First, the sign of $E((\varphi_2 - \varphi_1)M_{2\gamma})$ will be established. For the case of an anticipated factor price increase assume that $EM_{2\gamma} \leq 0$. Then, since $M_{2\gamma}$ is increasing in c_2 , $EM_{2\gamma} \geq M_{1\gamma}$ because $\Pr(c_2 \geq c_1) = 1$. This implies that the first two terms in (1) are nonpositive. The term $E(\varphi_2 M_{2\gamma})$ may be evaluated as

$$E(\varphi_2 M_{2\gamma}) = E(\varphi_2)E(M_{2\gamma}) + (\gamma^* g'(\gamma^*) + g(\gamma^*)) \text{cov}(\varphi_2, c_2).$$

The covariance is negative, since φ_2 is a decreasing function of c_2 , so $E(\varphi_2 M_{2Y}) < 0$. Finally, from Proposition 1, $E(\frac{\partial \pi_3}{\partial p_2} \frac{dp_2}{dY}) > 0$ when a factor price increase is anticipated. Hence, $\frac{\partial V}{\partial Y} \Big|_{Y = Y^*} < 0$ which contradicts the optimality of Y^* , so $EM_{2Y} > 0$.

The term $E((\varphi_2 - \varphi_1)M_{2Y})$ may be evaluated as

$$E((\varphi_2 - \varphi_1)M_{2Y}) = E(\varphi_2 - \varphi_1)E(M_{2Y}) + (\gamma^* g'(\gamma^*) + g(\gamma^*)) \text{cov}(\varphi_2, c_2) < 0,$$

since $\varphi_2 \leq \varphi_1$ for all $c_2 \geq c_1$, $E(M_{2Y}) > 0$, and $\text{cov}(\varphi_2, c_2) < 0$. Proposition 1 implies that the last term $(-E(\frac{\partial \pi_3}{\partial p_2} \frac{dp_2}{dY}))$ in (5) is negative, which establishes $dY^*/d\tau < 0$. ■

The collection lag can thus be utilized to decrease the use of fuel when a factor price increase is anticipated, but this does not imply that the technological bias $(\gamma^* - \gamma^0)$ is a decreasing function of π , since γ^0 is also a decreasing function of π .

The use of an average cost fuel adjustment formula is based on the presumption that the firm is being regulated under an average cost pricing rule. That is, if the initial price p_1 is equal to average cost,²⁰ then the adjustment in response to a factor price change is simply equal to the average cost of producing the initial quantity. The output price adjustment however changes the level of output, and unless the firm has constant returns to scale, average cost at the adjusted price will differ from the average cost at the initial output. A firm with increasing returns to scale will thus have an adjusted price below (above) average cost when the factor price increases (decreases), while the opposite relationship will hold for a firm with decreasing returns to scale.

If returns to scale are increasing as has been indicated by many empirical studies of electricity production,²¹ an automatic adjustment mechanism that passes on the average cost increase based on the current output level will thus yield an insufficient return when the current regulated price equals average cost including an allowed rate of return. Consequently, if the regulated price was such that the firm was able to earn its allowed return prior to the fuel price increases in the early 1970's, the fuel adjustment clauses that were used to pass on those factor price increases would be insufficient to allow the firm to earn its allowed return after the adjustment. This would then require a rate revision request by the firm and a subsequent formal rate hearing which is the situation that fuel adjustment clauses are intended to avoid. During the fifteen month period from January 1, 1976 to March 31, 1977, 145 electric utility rate cases were concluded in the U.S.²² involving firms that had fuel adjustment clauses in effect. While these rate cases were likely to be largely due to factor price increases associated with non-fuel inputs, the effect of average cost fuel adjustment clauses coupled with increasing returns to scale may also have contributed to the deterioration in the firms' earned return, thus requiring rate revision requests.

IV. Fuel Adjustment Clauses and the Incentive to Purchase the Efficient Fuel

One of the principal arguments against fuel adjustment clauses is that they dampen incentives for the choice of the least-cost fuel supply. This section investigates the case in which a long-term fuel supply source is selected at the time at which the technology of the firm is chosen. The choice of technology may, for example, determine the type of fuel to be utilized, so the fuel supply decision involves the choice from among alternative long-term supplies of that fuel. Ex post conversion from one type of fuel to another will not be considered here.²³

To investigate the fuel supply decision, assume that there are two fuels that are perfect substitutes, so that $f_i = f_i^1 + f_i^2$, where f_i^j is the quantity of fuel j consumed in interval i . While perfect substitutes would normally sell at the same price, market imperfections such as those created by government regulations can cause the prices to differ. For example, the price per Btu for interstate natural gas is below the price per Btu for intrastate gas. Similarly, the prices on high- and low-sulfur coal may differ in a state because of variations among state pollution control laws and their enforcement. The initial price of each fuel will be assumed to be c_1 and at the same time t their prices will increase to c_2^2 and c_2^1 . To facilitate the analysis, the second fuel is assumed to be the more costly after time t in the sense that $\Pr(c_2^2 \geq c_2^1) = 1$. The second fuel is thus anticipated to be the more costly although the cost difference is uncertain. Letting $\psi \in (0,1)$ denote the proportion (f_i^1/f_i) of the total fuel supply represented by the first fuel, the amounts of each fuel consumed are

$$f_i^1 = \psi f_i = \psi g(Y) \varphi_i$$

$$f_i^2 = (1 - \psi) f_i = (1 - \psi) g(Y) \varphi_i.$$

The fuel cost in the interval (t, ∞) then is $f_2(c_2^2 + \psi(c_2^1 - c_2^2))$, and the adjusted price is

$$p_2 = p_1 + (\psi(c_2^1 - c_2^2) + c_2^2 - c_1) f_1 / Q_1.$$

The firm determines its optimal fuel mix ψ according to the sign of the term

$$(6) \quad \frac{\partial V}{\partial \psi} = -kE[(1 - e^{-r\tau})(c_2^1 - c_2^2)f_1 + e^{-r\tau}((c_2^1 - c_2^2)f_2 - \frac{\partial \pi_3}{\partial p_2} \cdot (c_2^1 - c_2^2)f_1 / Q_1)] / (r(r + k)),$$

where E denotes the expectation with respect to the joint distribution of the factor prices. The efficient fuel choice ($\psi = 1$) will be made if $\partial V / \partial \psi \geq 0$ for all $\psi \in [0, 1]$.

To evaluate $\partial V / \partial \psi$, let A denote the term in brackets in (6) and substitute for $\partial \pi_3 / \partial p_2$ to obtain

$$EA = E\{(c_2^1 - c_2^2)[(1 - e^{-r\tau})f_1 Q_1 + Q_1 Q_2 e^{-r\tau}(f_2 / Q_2 - f_1 / Q_1) - e^{-r\tau}(p_2 - \varphi_2' M_2) Q_2' f_1]\} / Q_1.$$

Since factor price increases will occur, $Q_2 < Q_1$ for all factor price levels. Then, the term

$$f_1/Q_1 = (\varphi_2/Q_2 - \varphi_1/Q_1)\gamma^* g(\gamma^*),$$

(negative) (constant) as returns to scale are increasing (constant). Consequently, if the firm has nondecreasing scale and p_2 is at least as great as marginal cost (φ'_M) as able, EA is negative and the efficient fuel choice will all $\tau \geq 0$. If the firm has decreasing returns to scale, the likely to be below marginal cost and EA will be positive. These results are summarized in the following proposition.

3 : With nondecreasing returns to scale and a price p_2 at least as great as marginal cost there is no incentive to purchase the fuel for any $\tau \in [0, \infty]$. With decreasing returns to scale and a price p_2 greater than marginal cost, the inefficient fuel supply will be $\tau \in [0, \tau^*]$ and the efficient choice will result for $\tau \in (\tau^*, \infty)$ such that

$$\tau^* = 0 \text{ for } \psi = 0.^{24}$$

the result pertaining to τ^* remains to be demonstrated. For decreasing returns to scale and $p_2 \leq \varphi'_M$, EA is a strictly increasing function of τ for all $\psi \in [0, 1]$. Defining τ^* as in (7) implies that for $\tau < \tau^*$, EA is negative and hence that $\psi = 0$ is not optimal. Thus choose $\psi = 1$.

The firm's technology is characterized by increasing returns to scale. The regulated price in effect after $t + \tau$ will in all likelihood be greater than marginal cost, and the firm will have no incentive to purchase fuel that is anticipated to have the greater price increase.

The regulator then can reduce the collection lag as much as possible without inducing inefficiency. This conclusion would support a policy of making the fuel adjustment on a "current month estimated" basis ($\tau = 0$). With constant returns to scale a zero collection lag could be utilized with $r_1 = M_1$, and the firm would be indifferent between the two fuel supplies, since $\partial V / \partial \psi = 0$. To insure that the efficient choice will be made, the regulator can set τ so that it is slightly positive.

With decreasing returns to scale the collection lag must be used to overcome the incentive for the choice of the higher cost fuel. Proposition 3 however indicates that the collection lag is a sufficient regulatory instrument to achieve this objective. Modifying the fuel adjustment formula to allow only some fraction of the average cost increase to be passed on, as has been suggested, is not necessary. Furthermore, the use of the collection lag has an important advantage over the use of a pass-through fraction. The use of the collection lag as a regulatory instrument does not affect the adjusted price p_2 , for a given p_1 , while the pass-through does. It is thus more difficult to predict the effect of the pass-through on the fuel choice.²⁵

Proposition 3 pertains to the case in which the regulated output prices are "appropriate" in the sense that with, for example, nondecreasing returns to scale the price is at least as great as marginal cost. In practice, the regulator may not know if the firm is operating in a region of increasing, constant, or decreasing returns and may have only imprecise information regarding marginal cost. For example, the cost functions estimated by

Christensen and Greane indicate a U-shaped cost function, and although they conclude that only one of the 114 firms in their sample had "significant scale diseconomies", a substantial number of large firms operated in a region of decreasing, but statistically insignificant, returns in 1970. A regulator thus may prefer to use a positive collection lag in order to be more confident that the firm will select the efficient fuel supply source. In addition, if there are costs associated with the ex post conversion from one fuel to another, a positive collection lag provides a greater incentive for conversion.²⁶ As indicated in Proposition 2, an increase in the collection lag results in the choice of a technology with a lower fuel-capital ratio when fuel factor prices are anticipated to increase. The collection lag can thus be used to induce fuel efficiency and to reduce the amount of fuel consumed although the latter may not be technically efficient. A lengthening of the collection lag, however, reduces the profit of the firm during the $[t, t + \tau)$ period, and hence to provide the firm with a fair-rate of return, a price p_1 higher than average cost may be required. An analysis of the optimal pricing decision by the regulator will not be presented here but can be found in [4] for the case in which c_2 is certain.

V. Conclusions

Fuel adjustment mechanisms can lead to inefficiency both with respect to a utility's choice of a technology and its selection of fuel supply sources. The fuel supply decision poses an efficiency problem primarily in conjunction with decreasing returns to scale, since a firm with non-decreasing returns to scale and an output price at least as great as

marginal cost will choose the fuel supply source that is anticipated to have the smallest factor price increase. When there is an incentive to purchase the inefficient fuel, the collection lag can be extended to induce efficiency. This extension, however, affects the choice of technology by reducing both the technically efficient fuel-capital ratio and the ratio preferred by the firm. The latter ratio will differ from the efficient ratio, but in general the direction of bias cannot be predicted. An anticipated factor price increase will result in a bias toward a technology utilizing a fuel-capital ratio that is greater than the efficient ratio, but an anticipated factor price level with a mean equal to the current factor price can lead to a fuel-capital ratio that is less than the efficient ratio. This results because of the covariation between the factor price level and the marginal profit with respect to the adjusted price. Fuel adjustment clauses thus pose a complex efficiency problem, which can be compensated for but not eliminated by the design of the adjustment formula as indicated in [5]. Whether the use of fuel adjustment mechanisms leads to greater efficiency problems than alternative regulatory processes, such as administrative rate review, remains an open issue.

Footnotes

- + The authors would like to thank Bengt Holmstrom and John Hiller for their helpful comments. The first author's work has been supported in part by a grant from the National Science Foundation, Grant No. SOC 77-07251.

1. A NERA survey indicated that

"In 13 jurisdictions (see Table A) the fuel clause format and/or formula is prescribed by the commission and in 27 others must be approved by the commission. In 33 jurisdictions each change in the adjustment itself is subject to commission review, ... (NERA, "The Fuel Adjustment Clause : A Survey of Criticisms, Justifications and Its Application in the Various Jurisdictions," reprinted as Appendix 1 of [19, p. 51]).

2. After this paper was completed, a report [16] by the Price Commission in the United Kingdom was obtained that discusses a number of similar issues in the U.K. context.

3. Trigg [17] has provided a study of the origin of these mechanisms.

4. The use of automatic adjustment mechanisms may have other benefits.

The New Mexico Public Service Commission has stated that :

"In short, this commission and its staff are subject to the tyranny of continuous rate cases, and our other regulatory responsibilities are neglected." [14, p. 120]

"Lastly, this commission and its staff are also benefited by the new method in that it enables us to concentrate on those neglected areas of regulation and supervision where we may effectively influence events before they develop and, thus, better serve the consumer and public interests." [14, p. 138]

5. The term "processing lag" is used by Joskow to refer to the time period between the initiation of a request for a rate change and its final implementation.
6. The data source is [9].

7. The House Subcommittee on Oversight and Investigations concluded

"With adequate staffing and resources there is no reason why utility commissions cannot significantly reduce the present 10.5 months needed to complete the average electric utility rate case. Should a commission, however, prove incapable of keeping up with its workload, utilities can be granted interim rate relief subject to final commission review and refund.

... The interim rate procedure can be designed, moreover, to provide consumers with safeguards to mitigate against the issuance of arbitrary interim rate increases without detracting from the ability of such proceedings to grant utilities the means to cope with fast rising fuel costs. Such safeguards to include, for example, a public notice and the right to challenge industry subcommissions on the need for interim rate relief and a requirement that commissions grant interim rate relief on the basis of a written decision. [18, p. 29]."

The primary weakness of this policy alternative is the difficulty in setting an interim rate before hearings and staff investigation can take place. W.W. Lindsay of the Federal Power Commission states

"... interim rate relief is not an acceptable substitute for automatic adjustment. It takes time and money to prepare an application for interim rate relief, and it takes time and effort for a regulatory agency to reach a considered judgment on the extent to which such relief should be granted.

... the interim rate technique during a period of rapidly rising costs means that the utility will be collecting a large amount of its revenue subject to refund with the attendant uncertainty and adverse impact on capital costs that this entails. ... if fuel costs move downward rapidly ... a proceeding to initiate a rate reduction, unless initiated by the utility itself, could only be brought under Section 206 of the Federal Power Act. This means that no rate reduction could be effected by the Commission except after notice and opportunity for hearing and the issuance of a final Commission order all of which could require years. [12, p. 12]"

8. Another criticism made by the Congressional Research Service [20]

is that the fuel price adjustments are being "rolled into" basic rates which may retard rate reductions when fuel costs are falling.

If the automatic adjustment clause operates symmetrically to pass on fuel cost decreases as well as increases, this argument appears to be an issue of labeling rather than of regulatory efficacy.

9. Some of this inclusion is consistent with standard regulatory practice.

"The Uniform System of Accounts expressly permits all costs which are related to the total fossil fuel expenses of utility to be treated as fuel expense. This necessarily includes all items of cost incurred by a company in securing fuel, having it delivered, unloaded, stored and ultimately transferred to the burners to generate electricity. Florida Public Service Commission, Order No. 6557, November 26, 1974." Cited in [19, p. 6.]

0. A putty-clay technology will be used to represent the distinction between the ex ante choice of technology and the ex post operation of that technology.
1. Barlow and Proschan [3] provide a treatment of hazard rates.
2. The assumption of a constant hazard rate is made to simplify the exposition and is not necessary for the results obtained.
3. Models with a lag resulting from delivery of capital equipment have been investigated by Nickell [15].
4. Output prices are assumed to be constant in time during each of the intervals, since prices established in a tariff remain in effect until a new tariff is posted. An alternative assumption would be to let the prices be functions of time, but with a constant hazard rate and no technological change or demand growth, it can be shown that the optimal prices are constant in t except at t and $t + \tau$.
5. This model of technology has also been used in [5] to investigate the optimal design of adjustment mechanisms.

16. As an example, for a CES function

$$Q_i = A (\alpha K_i^{-\eta} + \beta f_i^{-\eta})^{-1/\eta}$$

the functions φ and g are given by

$$\varphi(Q_i) = Q_i^{1/\eta}$$

$$g(\gamma_i) = A^{-1/\eta} (\alpha + \beta \gamma^{-\eta})^{1/\eta}$$

17. Issues associated with the effect of demand growth and technological change will not be considered here in order to focus on the fuel adjustment mechanism itself.
18. These results also hold if demand changes over time.
19. The converse of this result cannot be established in general for the case of an anticipated factor price decrease, although $d\gamma^*/d\tau > 0$ is likely to result.
20. The model assumes that the initial price p_1 is not affected by the firm's choice of technology, so the case in which p_1 equals average cost is used here as an illustration. The regulator's optimal choice of p_1 can be made so that p_1 is independent of γ as indicated in the model considered by Leland [11]. The optimal p_1 is considered in [4], when the regulator maximizes consumer surplus subject to the restriction that the firm earn its allowed return.

21. Christensen and Greene find substantial increasing returns to scale for smaller electric utilities.
22. The source of these data is [9].
23. Ex post conversion is considered in [5].
24. The same results obtain if the firm can make its fuel supply decision at time t .
25. An analysis of this point is provided in [4].
26. The conclusion of Proposition 3 also may not generalize to other informational contexts. For example, if the firm does not have complete information on the alternative sources of fuel supply and must search for that information, costs associated with search may lead to an incentive problem when the firm has nondecreasing returns to scale. The collection lag could then be used to combat this incentive problem.

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