THE AUTOMATIC FUEL ADJUSTMENT CLAUSE:

EFFICIENCY CONSIDERATIONS*

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I. Introduction

Fuel adjustment clauses permit regulated electric utilities to adjust their prices in reponse to changes in fuel prices. During inflationary periods, the use of fuel adjustment mechanisms permit the regulated firms to preserve their financial integrity without continual rate hearings. Thus, a well-designed fuel adjustment formula will permit rate increases that the regulatory agency would approve eventually while it conserves the considerable resources that would go into formal rate proceedings. In spite of these obvious advantages, two concerns have been expressed concerning the use of fuel adjustment mechanisms.

First, it is possible that the automatic fuel adjustment mechanism may lead to productive inefficiencies similar to those described by Averch and Johnson.[1] Since the electricity rate is linked directly to fuel costs, the electric utility may have an incentive to employ too much fuel relative to other inputs. Second, there is a concern that the electric utility may not be an efficient fuel purchaser. In the real world in which the utilities operate, competitive markets are often characterized by price dispersion rather than single price equilibria.[2] An efficient purchaser will engage in an optimal amount of search for favorable prices. There is some concern that automatic fuel adjustment clauses may dull the incentives for efficiency in this regard.

In this paper, we shall examine these issues analytically. The results will be discussed for their public policy relevance.

II. The Long-Run Case.

We shall examine the effect of a fuel adjustment clause on a firm subject to rate of return regulation. For such a firm, the profit function is given by

$$(1) \qquad \pi = PQ - rcK - fF - wL$$

where the demand function, $P = P(Q)$, is a negatively-sloped function of output Q; r is the risk-free interest rate and c and K are the cost and quantity of capital; f and F are the price and quantity of fuel; and w and L are the wage rate and quantity of labor. The firm produces its output with a neoclassical production function represented by

$$(2) \qquad Q = Q(K, F, L).$$

The rate of return constraint is a modified version of the one specified by Averch and Johnson [1]:

$$(3) \qquad \frac{PQ - fF - wL}{cK} \leq s.$$

The precise formulation of the automatic fuel adjustment clause varies across states. We shall adopt the formulation that follows: current output price minus current fuel cost per unit of output is kept equal to some base year difference which is now exogenous. Consequently, we may observe that

$$P - \frac{fF}{Q} = P_B - \frac{f_B F_B}{Q}$$

or

$$P - \frac{fF}{Q} = \delta ,$$

where δ is a positive constant exogenously determined, or

$$(4) \qquad PQ - fF = \delta Q.$$

The regulated firm is assumed to maximize profit (1) subject to the constraints in (3) and (4). The Lagrangean for this problem is

$$Z = PQ - rcK - fF - wL - \lambda_1 (PQ - fF - wL - scK) - \lambda_2 (PQ - fF - \delta Q). \tag{5}$$

The first order conditions for an interior optimum require that the first partial derivatives of Z vanish:

$$\frac{\partial Z}{\partial K} = \left(\frac{\partial P}{\partial Q} \cdot Q + P\right) \frac{\partial Q}{\partial K} - rc - \lambda_1 \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial K} + \lambda_1 sc - \lambda_2 \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial K} + \lambda_2 \delta \frac{\partial Q}{\partial K} = 0; \tag{6}$$

$$\frac{\partial Z}{\partial F} = \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial F} - f - \lambda_1 \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial F} + \lambda_1 F - \lambda_2 \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial F} + \lambda_2 F + \lambda_2 \delta \frac{\partial Q}{\partial F} = 0, \tag{7}$$

$$\frac{\partial Z}{\partial L} = \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial L} - w - \lambda_1 \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial L} + \lambda_1 w - \lambda_2 \left(\frac{\partial P}{\partial Q} Q + P\right) \frac{\partial Q}{\partial L} + \lambda_2 \delta \frac{\partial Q}{\partial L} = 0, \tag{8}$$

$$\frac{\partial Z}{\partial \lambda_1} = PQ - fF - wL - scK = 0, \text{ and} \tag{9}$$

$$\frac{\partial Z}{\partial \lambda_2} = PQ - fF - \delta Q = 0. \tag{10}$$

Conditions (6), (7), and (8) can be rearranged algebraically to provide the following expressions:

$$\left[\left(\frac{\partial P}{\partial Q} Q + P\right)(1 - \lambda_1 - \lambda_2) + \lambda_2 \delta\right] \frac{\partial Q}{\partial K} = rc - \lambda_1 sc \tag{11}$$

$$\left[\left(\frac{\partial P}{\partial Q} Q + P\right)(1 - \lambda_1 - \lambda_2) + \lambda_2 \delta\right] \frac{\partial Q}{\partial F} = (1 - \lambda_1 - \lambda_2) f \tag{12}$$

$$\left[\left(\frac{\partial P}{\partial Q} Q + P\right)(1 - \lambda_1 - \lambda_2) + \lambda_2 \delta\right] \frac{\partial Q}{\partial L} = (1 - \lambda_1) w. \tag{13}$$

Dividing (11) by (13), we have

$$(14) \qquad \frac{\partial Q/\partial K}{\partial Q/\partial L} = \frac{rc - \lambda_1 sc}{(1 - \lambda_1) w} .$$

Letting $v = s - r > 0$ be the amount by which the allowable rate of return exceeds the market rate of interest, equation (14) can be written as

$$(15) \qquad \frac{\partial Q/\partial K}{\partial Q/\partial L} = \frac{rc - \lambda_1 rc - \lambda_1 vc}{(1 - \lambda_1) w}$$

$$= \frac{rc}{w} - \frac{\lambda_1}{1 - \lambda_1} \cdot \frac{vc}{w} .$$

For $0 < \lambda_1 < 1$, the second term on the right-hand side of (15) will be positive and, therefore,

$$\frac{\partial Q/\partial K}{\partial Q/\partial L} < \frac{rc}{w} .$$

This, of course, is the standard Averch-Johnson result: capital will be employed beyond the efficient amount.

Now, let us divide (11) by (12):

$$(16) \qquad \frac{\partial Q/\partial F}{\partial Q/\partial L} = \frac{(1 - \lambda_1 - \lambda_2) f}{(1 - \lambda_1) w} .$$

For $0 < \lambda_1 < 1$ and $0 < \lambda_2 < 1$, we find that

$$\frac{\partial Q/\partial F}{\partial Q/\partial L} = \frac{f}{w} \left(1 - \frac{\lambda_2}{1 - \lambda_1}\right) < \frac{f}{w} .$$

In other words, fuel will be employed beyond the efficient amount relative to labor. Consequently, the fuel adjustment clause leads to overutilization of fuel.

Finally, dividing (11) by (13) we obtain

$$\frac{\partial Q/\partial K}{\partial Q/\partial F} = \frac{rc - \lambda_1 sc}{(1 - \lambda_1 - \lambda_2) f}$$

$$= \frac{rc - \lambda_1 vc - \lambda_1 rc}{(1 - \lambda_1 - \lambda_2) f}$$

since $s = v + r$. Consequently, we find that

$$\frac{\partial Q/\partial K}{\partial Q/\partial F} \gtreqless \frac{rc}{f} \text{ as } \lambda_1 vc \gtreqless \lambda_2 rc.$$

Thus, whether capital is overemployed or underemployed relative to fuel depends upon the value of λ_1 vc relative to λ_2 rc.

III. The Short-Run Case.

In the short run, we can argue that the firm is unable to adjust its capital input but can adjust the quantities of labor and fuel. It should also be recognized that regulators are unable to enforce the rate of return constraint.[3] Consequently, the firm adjusts its fuel and labor inputs to maximize profits subject to the fuel adjustment clause constraint. The Lagrangean for this problem is

$$V = PQ - r\overline{K} - fF - wL - \mu\ [PQ - fF - \delta Q] \tag{17}$$

where μ is a Lagrange multiplier and $\overline{K}$ is the fixed quantity of capital. The first-order conditions for a maximum require that the first partial derivatives of (17) vanish:

$$\frac{\partial V}{\partial F} = R\,\frac{\partial Q}{\partial F} - f - \mu R\frac{\partial Q}{\partial F} + \mu f + \mu\delta\,\frac{\partial Q}{\partial F} = 0, \tag{18}$$

$$\frac{\partial V}{\partial L} = R\,\frac{\partial Q}{\partial L} - w - \mu R\,\frac{\partial Q}{\partial L} + \mu\delta\,\frac{\partial Q}{\partial L} = 0, \tag{19}$$

$$\frac{\partial V}{\partial \mu} = PQ - fF - \delta Q = 0 \tag{20}$$

where R is marginal revenue: $\frac{\partial P}{\partial Q}\,Q + P$.

We can rearrange (18) and (19) as

$$(R\ (1 - \mu) + \mu\delta)\ \partial Q/\partial F = (1 - \mu)\ f \tag{21}$$

$$(R\ (1 - \mu) + \mu\delta)\ \partial Q/\partial L = w. \tag{22}$$

Thus, we can divide (21) by (22) to obtain

$$\frac{\partial Q/\partial F}{\partial Q/\partial L} = \frac{(1 - \mu)\ f}{w} < \frac{f}{w} \tag{23}$$

and fuel is overemployed relative to labor if $0 < \mu < 1$.

Solving (18) for μ provides

$$\mu = \frac{f - R\ \partial Q/\partial F}{f - R\ \partial Q/\partial F + \delta\ \partial Q/\partial F} \quad (24)$$

This implies that $0 < \mu < 1$ if $f > R\ \partial Q/\partial F$.

Solve (19) for w:

$$w = \left[R - \frac{f - R\ \partial Q/\partial F}{f - R\ \partial Q/\partial F + \delta\ \partial Q/\partial F}\ (R - \delta) \right] \frac{\partial Q}{\partial L}\ . \quad (25)$$

Finally, solving (20) for f yields

$$f = \frac{PQ - \delta Q}{F}\ . \quad (26)$$

The firm's profits are

$$\pi = PQ - r c \overline{K} - fF - wL. \quad (27)$$

Substituting the results in (24) - (26) into (27), we obtain an expression for constrained maximized profits:

$$\begin{aligned} \pi^* = {} & PQ - rc\overline{K} - \left(\frac{PQ - \delta Q}{F} \right) F \\ & - \left[R - \frac{f - R\ \partial Q/\partial F}{f - R\ \partial Q/\partial F + \delta\ \partial Q/\partial F}\ (R - \delta) \right] \frac{\partial Q}{\partial L}\ L\ , \end{aligned} \quad (28)$$

which reduces slightly to

$$\begin{aligned} \pi^* = {} & \delta Q - rc\overline{K} - RL\ \partial Q/\partial L \\ & + \frac{f - R\ \partial Q/\partial F}{f - R\ \partial Q/\partial F + \delta\ \partial Q/\partial F}\ (R - \delta)\ \frac{\partial Q}{\partial L}\ L. \end{aligned} \quad (29)$$

In order to examine the influence of fuel price changes on maximum profits, we differentiate π^* with respect to f:

(30) $$\frac{\partial\pi^*}{\partial f} = (R - \delta)\frac{\partial Q}{\partial L} L \left[\frac{\delta \ \partial Q/\partial F}{(f - R\ \partial Q/\partial F + \delta\ \partial Q/\partial F)^2}\right].$$

Consequently,

(31) $$\frac{\partial\pi^*}{\partial f} \gtreqless 0 \text{ as } R \gtreqless \delta.$$

Recalling the definitions of R and δ, this condition becomes

$$\frac{\partial\pi^*}{\partial f} \gtreqless 0 \text{ as } \quad \frac{\partial P}{\partial Q} Q + P \gtreqless P - \frac{fF}{Q}$$

$$\frac{\partial P}{\partial Q} Q \gtreqless - \frac{fF}{Q}$$

$$\frac{1}{\eta} \lesseqgtr \frac{fF}{PQ}.$$

Thus, the sign of $\partial\pi^*/\partial f$ depends upon the elasticity of demand, the expenditure on fuel, and total revenue. We know that $fF/PQ < 1$, therefore, is $\eta < 1$, $1/\eta > fF/PQ$, which means that $\partial\pi^*/\partial f < 0$. In other words, if demand is inelastic, then an increase in fuel price will decrease profits. Most empirical evidence indicates that the demand for electricity is price inelastic. We can feel quite confident, therefore, that $\partial\pi^*/\partial f < 0$ is likely to hold.

IV. Fixed Proportions Case.

We have been assuming that the production function permits substitution among factors. This is often the case in an ex ante sense. Before the firm purchases any inputs, there may be many different input combinations that can be employed. After some capital equipment is purchased, however, there may be no substitution possibilities. We may have a so-called putty-clay model of production where there is full ex ante substitution and zero ex post substitution. Fuss [3] has examined the various substitution possibilities for steam electric generation and found relatively few ex post input substitution opportunities.

In the short run, the issue of inefficient input combination does not arise due to fixed proportions. But the question of utility company incentives regarding fuel price increases still remains. The following propositions address this issue.

Proposition 1: If production occurs under fixed proportions, company profits will decline with increasing fuel prices despite the presence of an automatic fuel adjustment clause.

Proof: The automatic fuel adjustment mechanism adjusts the output price so as to maintain a constant margin between the current price P_t and the firm's per unit expenditure on fuel, f_tF_t/Q_t. That is, output price is adjusted such that

$$P_t - \frac{f_tF_t}{Q_t} = P_B - \frac{f_BF_B}{Q_B}$$

where the subscript B denotes base year prices and quantities. Thus, current output price is

$$P_t = P_B - \frac{f_BF_B}{Q_B} + \frac{f_tF_t}{Q_t}. \tag{32}$$

From (32), we note that

$$(33) \qquad \frac{\partial P_t}{\partial f_t} = \frac{F_t}{Q_t} ,$$

which is a constant due to the fixed proportions production function.

Since profit in period t is

$$(34) \qquad \pi_t = P_t \, Q_t - f_t \, F_t - w_t \, L_t - r_t \, K_t ,$$

we see that

$$(35) \qquad \frac{\partial \pi_t}{\partial f_t} = Q_t \frac{\partial P_t}{\partial f_t} + P_t \frac{\partial Q_t}{\partial P_t} \frac{\partial P_t}{\partial f_t} - F_t .$$

Substituting from (33) and using the definition of demand elasticity, $\eta = - (\partial Q/\partial P) \, (P/Q)$, we have

$$(36) \qquad \frac{\partial \pi_t}{\partial f_t} = P_t \frac{\partial Q_t}{\partial P_t} \frac{F_t}{Q_t}$$

$$= - F_t \, \eta < 0$$

and the proof is complete.

Proposition 2: The presence of an automatic fuel adjustment clause will moderate (exacerbate) the impact on profits of fuel price increases if demand is inelastic (elastic).

Proof: In the absence of an automatic fuel adjustment clause, output price remains constant at the level set in prior rate hearings. Therefore, in the absence of an adjustment clause, we have from (34) that

$$(37) \qquad \frac{\partial \pi_t}{\partial f_t} = - F_t < 0 .$$

Comparing (36) and (37), we see that

$$(38) \qquad |-F_t| \gtrless |-F_t\,\eta| \text{ as } |\eta| \lessgtr 1$$

which completes the proof.

Proposition 3: If production occurs under fixed proportions, the automatic fuel adjustment clause will hold per unit profit constant with increasing fuel prices.

Proof: With fixed proportions, per unit profit is

$$(39) \qquad \frac{\pi_t}{Q_t} = P_t - f_t\,\alpha_F - w_t\,\alpha_L - r_t\,\alpha_K \,,$$

where $\alpha_F = F_t/Q_t$, $\alpha_L = L_t/Q_t$, and $\alpha_K = K_t/Q_t$ are positive constants. Then

$$(40) \qquad \frac{\partial(\pi_t/Q_t)}{\partial f_t} = \frac{\partial P_t}{\partial f_t} - \alpha_F \,.$$

From (33), however, we see that the right-hand side of (40) is zero.

This means that if capital is free to exit the industry, a constant rate of return (equal to the allowable rate) can be maintained. To the extent that capital is fixed and is not free to exit, however, a constant per unit profit combined with a decline in the total number of units sold implies that the rate of return will fall below the allowable rate and a rate hearing will be requested. As indicated by Proposition 2, however, the presence of the fuel adjustment clause may delay the time between hearings. This will depend upon the elasticity of demand.

Footnotes

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1. See Averch and Johnson [1] and the amplified results provided by Baumol and Klevorick [2].
2. The seminal paper in this regard is Stigler [5].
3. For an interesting analysis of this, see Joskow [4].

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