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PART III

REGULATORY POLICY ISSUES

CHAPTER 7

REGULATORY INCENTIVES AND THE ECONOMICS OF ALLOWANCE TRADING

This chapter develops an economic model of allowance trading when the output market of affected firms is subject to public utility regulation. Rather than placing a firm's productive enterprise in the background to highlight the effects of environmental policy, the productive and environmental decisions of the firm are placed at the center of the model.

This work will not attempt to advance the treatment of rate-of-return regulation, and so it begins with the venerable formulation of Averch and Johnson.[1] In turn, the model is augmented with command-and-control (CAC) and market-based environmental constraints. In each instance we seek to deduce the effects of environmental and rate-of-return regulation, and in particular the *joint* effects of the regulatory treatment of allowances and the environmental constraint upon utility decisions.

The CAC case is analyzed for purposes of comparison between the current (pre-1995) environmental law governing utility behavior and the CAAA. A rate-of-return- regulated firm will respond in some predictable ways to the rate base treatment of scrubber capital. In particular, if scrubbers are placed in the rate base (as they are in forty-nine states) then revenue requirements rise and with them electricity prices. This suggests that current regulatory practice is probably not optimal from the viewpoint of consumers, though utilities certainly benefit. Whether the inclusion of scrubbers makes society better off or not is an open question, but early results from some related research suggests that society does indeed benefit.

In the presence of emission allowances, under the assumption that scrubbers are included in the rate base, the question of whether emission allowances themselves should be rate base assets is then taken up. It is found that from the viewpoint of consumers, allowances should not be included in the rate base. Including them unquestionably is good for utilities, and it may be

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[1] Harvey Averch and Leland L. Johnson, "Behavior of the Firm Under Regulatory Constraint," *American Economic Review* 52 (1962): 1052-69.

that their inclusion is good for society as a whole. Consumers, however, will benefit if allowances are not included in rate base. This is not a final answer, however, to the question of how compliance capital should be treated. If the two decisions--whether to include scrubbers and whether to include allowances in rate base--are made simultaneously, then the optimal regulatory treatment may look different. Two strong tensions that commissions feel are examined in the remainder of this chapter: (1) they must balance the interests of consumers against the interests of society as a whole (which benefits from a stable, healthy utility industry) and (2) they should, in the interest of minimizing the cost of environmental protection in the manner laid out in the CAAA, seek to foster the allowance market by encouraging its use.

The mathematical development that supports the arguments of the chapter appears in Appendix D. In some instances the prescriptions of the formal model are somewhat tentative. However, there are some recommendations that appear to follow from a reasonable set of assumptions.

Two themes unify the chapter. First, the theoretical results on the efficiency properties of allowance trading schemes in the absence of market imperfections are taken as given (as outlined in Chapter 3). If nothing went wrong, market-based environmental control would be a good form of public policy. In fact, of course, things do go wrong, and this constitutes the second theme: the way that the decisions of the two regulatory bodies--federal and state environmental regulators and economic regulators (commissions)--interact with one another and affect the compliance decisions of utilities.

A series of results is derived that points out the inherent paradox that commissions face in deciding how to treat allowances for ratemaking purposes. On the one hand, a smoothly functioning active allowance market is needed to minimize the cost of complying with the CAAA. The advantages of market-based environmental regulation may be lost if this allowance market does not develop. However, fostering the market by making allowances an attractive compliance strategy requires that allowances be treated in a manner similar to abatement capital, which can result in higher prices for ratepayers.

A brief overview of the regulatory literature is also provided. The next section develops the model and explores the joint effect upon an electric utility of a simple CAC environmental constraint in the presence of ROR regulation. The subsequent section investigates the firm's response to an allowance market without ROR regulation, then adds an ROR constraint, investigating how this sort of regulatory regime further affects a firm that faces environmental regulation. Some concluding comments and thoughts about further extensions of this work appear in the last section.

The central question of this chapter is what happens when the two themes of environmental and economic regulation are joined. As each has a separate and extensive literature, it is helpful to review them briefly. The development of tradable pollution rights research was described in Chapter 3, with an emphasis on those ideas that bear upon the clean air legislation. This chapter next summarizes the utility regulation literature, which once again focuses on those ideas of primary importance for this study.

The Economics of Public Utility Regulation

There exist many thorough accounts of the rationale for, and the objectives and methods of regulating, public utilities and other businesses.[2] A "natural monopoly"--that is, a firm whose marginal costs are everywhere lower than average costs--supplies its product at a lower cost than any two or more smaller firms could do. In this case, a single firm or a few firms may be allowed to exist, protected in some fashion from new entrants and other competitive forces, but required to submit to government control over some portion of their operations.

[2] Alfred Kahn's two-volume *The Economics of Regulation: Principles and Institutions* (Cambridge, MA: MIT Press, 1988), is a classic source. A more recent volume that addresses certain concerns that are of current interest is J. J. Hillman and R. R. Braeutigam, *Price Level Regulation for Diversified Public Utilities* (Norwell, MA: Kluwer Academic Press, 1989).

The theory of economic regulation supposes that the regulator's behavior is guided by the interests of the consuming public, and also, in some cases, the national security. Regulator might regulate the return that owners of a regulated firm are allowed to earn on their investment. Even when the principal driving regulatory policy is rate-of-return regulation, the regulation itself is likely to take the form of a price level or rate structure for electricity, natural gas, or telephone services.

It is not our purpose here to add to the extensive writings on the pure economic theory of regulation, nor even to provide anything like a comprehensive survey of that literature. However, the regulation of industries is informed by certain economic principles, which shall be summarized briefly. The rate-of-return approach to regulation has been a prominent feature of regulatory practice for several decades. In recent years, the disadvantages of ROR regulation have spurred scholars and practitioners to seek alternative regimes.

Rate-of-return regulation consists of placing a limit on the rate of return that a regulated firm may earn on its capital investment. This constraint, if effective, cannot be helpful to the firm, whose optimal operating decision would not be improved by a new restriction on what it can do. The purpose of such a policy is to ensure that the firm cannot exploit fully its monopoly power at the expense of consumers. In practice, the regulator most often sets a price or a set of prices that the firm must charge for its product. This rate structure is devised so that the resulting return on the firm's capital matches the regulated rate. At various intervals, the rate structure might be revised to maintain the rate of return at its proper level while input prices, demand levels, productive capacity, or a host of other conditions change over time. Typically, the regulator uses some measure of the actual book value of the utility's invested capital. The allowed rate of return is applied to this rate base. Naturally, the choice of rate base is critical for the firm's overall profitability, so the selection of a rate base measure also is extremely important.[3]

In a landmark article, Averch and Johnson[4] argued that if the firm is allowed to earn a rate

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[3] Bruce C. Greenwald, "Rate Base Selection and the Structure of Regulation," *Rand Journal of Economics* 15 (1984): 85-95.

[4] Averch and Johnson, "Behavior of the Firm Under Regulatory Constraint."

of return that exceeds its cost of capital, then the regulated firm will have an incentive to overinvest in capital. This rate base inflation leads to a corresponding increase in the total returns that the firm may earn while still satisfying the constraint. The overcapitalization result they described has become known as the "A-J effect." Whether the effect exists has been the subject of a good deal of empirical research.[5]

Spann[6] and Petersen[7] find a significant degree of overcapitalization, while Baron and Taggart[8] find the opposite. Whether the A-J effect is an empirical reality or not, indications are that ROR regulation provides a regulated firm with the incentive to behave inefficiently. For example, diversification into industries unrelated to the regulated industry might let the firm cross-subsidize and increase its profitability. This is true so long as the capital required for new ventures is counted as part of the rate base or the cost can be passed on to its regulated customers. Another example is the propensity of regulated firms, prior to the mid-1970s, to substitute capital for fuel.

The Averch and Johnson model is static in nature, meaning it cannot account for any dynamic rate adjustment mechanisms, prudence reviews, or other matters that unfold over time. This feature was criticized by Joskow,[9] who argued that in an inflationary period the rate of return on capital will tend to fall below capital costs, an outcome the A-J model cannot accommodate.

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[5] For a survey of this literature, see Paul L. Joskow and Nancy L. Rose, "The Effects of Economic Regulation," in R. Schmalensee and R. D. Willig, eds., *Handbook of Industrial Organization, Volume II* (Amsterdam: Elsevier Science Publishers, 1989).

[6] Robert M. Spann, "Rate of Return Regulation and Efficiency in Production: An Empirical Test of the Averch-Johnson Thesis," *Bell Journal of Economics and Management Science* 5 (1974): 38-52.

[7] H. C. Peterson, "An Empirical Test of Regulatory Effects," *Bell Journal of Economics and Management Science* 6 (1975): 111-26.

[8] David P. Baron and Robert A. Taggart, "A Model of Regulation Under Uncertainty and a Test of Regulatory Bias," *Bell Journal of Economics* 8 (1977): 151-67.

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

Baumol and Klevorick[10] present Averch and Johnson's results in a more rigorous manner, clarifying some of its assumptions and interpreting the answers more carefully. Baumol and Klevorick show, for example, that it cannot be concluded from Averch and Johnson that the capital-fuel ratio of the regulated firm will be larger than that of a corresponding unregulated firm. Rather, all that can be said is that the capital-fuel ratio will be larger for a regulated firm than if the firm were minimizing costs and producing the same level of output. This point is important, for it emphasizes one of the problems that ROR regulation presents for industry and regulatory agencies alike: firms may not have an incentive to select input levels efficiently. Baron provides a model in which the firm and the regulator satisfy an incentive compatibility requirement and in which an equilibrium outcome coincides with the Averch and Johnson overcapitalization result.[11] The important point from Baron's discussion is that in a situation such as the one under investigation here, the A-J outcome occurs.

Rate-of-return regulation has often been criticized for not responding well to dynamic changes in the regulatory environment. The incentive that this gives firms to produce in an inefficient manner[12] has prompted the search for alternative regulatory schemes that remove or at least alleviate such a problem. One leading alternative is price cap regulation.[13] This new

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[10] William J. Baumol and Alvin K. Klevorick, "Input Choices and Rate-of-Return Regulation: An Overview of the Discussion," *Bell Journal of Economics and Management Sciences* 1 (1970): 162-90.

[11] David P. Baron, "Design of Regulatory Mechanisms and Institutions," in R. Schmalensee and R. D. Willig, eds., *Handbook of Industrial Organization, Volume II* (Amsterdam: Elsevier Science Publishers, 1989). A regulatory regime is incentive compatible if the regulator and the firm gain nothing by withholding information from one another. The firm, for example, will not misrepresent its costs.

[12] For a discussion of these limitations of ROR see Chapter 8 of S. V. Berg and J. Tschirhart, *Natural Monopoly Regulation: Principles and Practice* (Cambridge, U.K.: Cambridge University Press, 1988). For an opposing view see Douglas N. Jones, "What's Right With Utility Regulation," *Public Utilities Fortnightly* (March 6, 1986).

[13] See R. R. Braeutigam and J. C. Panzar, "Diversification Incentives Under `Price-Based' and `Cost-Based' Regulation," *Rand Journal of Economics* 20 (1989): 373-91; Hillman and Braeutigam, *Price Level Regulation for Diversified Public Utilities*; Paul L. Joskow and Richard Schmalensee,
(continued...)

approach has a number of potential benefits over ROR regulation. In the pure form of price cap regulation, once the price cap is set the firm has no or little incentive to choose an inefficient input mix, to underproduce, to undercut its competitors in its unregulated markets, or to behave inefficiently when choosing its production technologies. In short, the firm is provided with more incentive to minimize its cost. Also, since the regulator is focused on the firm's prices rather than costs, there is no incentive to misreport costs. Baron[14] and Hillman and Braeutigam[15] offer thorough surveys of the literature on incentive-based regulation. Lawton and Rose[16] discuss some of the practical issues that arise in implementing price cap regulation.

This sketch of the theory of regulation provides a backdrop for the model developed in the following section. Once again, the objective of this chapter is to combine a model of regulatory constraint with an environmental constraint, and to use

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[13](...continued)
"Incentive Regulation for Electric Utilities," *Yale Journal on Regulation* 4 (1986): 1-49; T. R. Lewis and David E. M. Sappington, "Regulatory Options and Price-Cap Regulation," *Rand Journal of Economics* 20 (1989): 405-16; and David Besanko and David E. M. Sappington, *Designing Regulatory Policy with Limited Information* (New York: Harwood Academic Publishers, 1987) for a variety of views upon price cap and incentive-based regulatory regimes.

[14] Baron, "Design of Regulatory Mechanisms and Institutions."

[15] Hillman and Braeutigam, *Price Level Regulation for Diversified Public Utilities*.

[16] Raymond W. Lawton and Kenneth Rose, eds., *Regulatory Perspectives on Price Caps* (Columbus, OH: The National Regulatory Research Institute, 1992).

the model to examine the effect of different commission policies on utility decisionmaking.

A Model of ROR Regulation with a CAC Environmental Constraint

Much has been said about rate-of-return regulation and market-based environmental regulation when only one of these two regimes is present. How do firms respond when they simultaneously must satisfy both environmental and economic controls? The analysis conducted here provides a framework to examine how regulatory treatment of compliance strategies affects utility decisionmaking. Even the simplest version of a model with both economic and environmental regulation is fairly complicated. Before proceeding to a version with allowance trading, an intermediate case will be presented. Here, the utility still must satisfy an ROR constraint, but also faces a command-and-control environmental constraint. In the following two sections things become more complicated: an allowance market is added to the firm's choice of compliance strategies.

The starting point here is a variant of the model of firm behavior under rate-of-return regulation due to Averch and Johnson. This model supposes that a monopoly firm is producing some output, which will be called q, using a pair of inputs, x and k_1. This firm is not a natural monopolist but derives its monopoly power from its status as the only seller of q. Suppose that x denotes some variable input such as fuel, and that k_1 denotes capital input. The firm's profits are subject to a regulatory constraint that prevents the firm from earning a rate of return on its capital investment greater than some amount s, where the cost of capital equals r, and where $s > r$. The cost of x, the noncapital input, is recovered at exactly its acquisition cost.

The model's primary components are (1) the demand for electricity (denoted $p(q)$), (2) the prices of the inputs (denoted w and r for fuel and capital respectively), (3) the relationship between inputs and output (represented mathematically by a *production function* $q = f(x,k_1)$), and (4) the allowed rate of return s. By its choice of input levels, the firm automatically selects q (and thereby selects the price p) and the cost of purchasing inputs. Thus, the firm's only real decision is a pair of input levels. Its profits (revenues less costs) are completely determined once x and k_1 are chosen.

As is well known, if the A-J model governs firm behavior and if $s > r$, the firm will "overcapitalize": its choice of inputs will not necessarily minimize the cost of producing a given level of output. The same firm, in the absence of an ROR constraint, will always choose input levels so that the marginal rate of technical substitution between them equals the ratio of their prices. This is the usual cost-minimizing input choice. This result does not hold in the presence of an ROR constraint, however. Instead, the firm overinvests in capital. For any given level of electricity production, the theory says, the utility will use more capital and less fuel than if it were minimizing cost. Though not all utilities overuse capital, it is not difficult to find instances in utility industries where firms appear to have overinvested in capital.[17]

The Averch-Johnson story--and the debate surrounding it--shall be left here, and the effect of environmental regulation on the behavior of a firm in the presence of a ROR constraint taken up. Imagine now that the utility's emissions of some pollutant (say, sulfur dioxide) are constrained. For an electric utility, it is natural to think of the "pollutant of interest" as sulfur dioxide; that language will be used here. It will be assumed that the limit on emissions may be reached only by reducing output or by installing abatement capital (such as scrubbing equipment). Suppose that the firm may purchase this abatement capital, denoted k_2, at the price r per unit, and that its emissions depend upon output q and the amount of abatement capital the firm installs. The emission level e depends only upon the level of generation q and the level of k_2. Let emissions be represented by the mathematical expression $e = h(q,k_2)$. If everything else is held constant, sulfur emissions rise with increases in output q; they decrease with increases in abatement capital.

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[17] *Are the Electric Utilities Gold Plated? A Perspective on Electric Utility Reliability*, Congressional Research Service, Library of Congress (April 1979).

Finally, since this is command-and-control environmental regulation, we need a name for the upper limit on the firm's emissions. Let this quantity be called E_0; the environmental restriction says that $h(q,k_2) \leq E_0$. The utility still has a good deal of latitude in its production decisions. It may choose any combination of output and abatement capital that it wishes, so long as emissions stay below the cap and the utility fulfills its obligation to serve. The primary difference now is that any increase in electricity generation (which always means a higher level of sulfur emissions) must be accompanied by the purchase of a little bit more abatement equipment.

Once again, it is assumed that k_1 is in the rate base. At issue now is the decision of the regulator whether or not to allow k_2 in the rate base. The answer to this question in either a normative or a positive sense is not obvious. How do the firm's decisions about pricing, production levels, sulfur emissions, and so on depend upon the regulatory treatment of abatement equipment purchases? This question is the primary question of the chapter.

The symbol φ will be used to denote the *share* of k_2 placed in the rate base. If $\varphi = 1$, then the utility is allowed to claim all of its abatement capital. If $\varphi = 0$, none of k_2 is in the rate base. Of course, for values of φ between 0 and 1, some intermediate portion is in the rate base, which is now equal to $k_1 + \varphi k_2$.

Including the environmental constraint changes both the utility's profits and its ROR constraint. Costs formerly amounted to purchases of fuel and capital, equalling $wx + rk_1$. They now also include the cost of abatement capital, so that costs (assuming variable costs are unchanged) equal $wx + r(k_1 + k_2)$. The ROR constraint in the simple A-J model says that profits cannot exceed $(s - r)k_1$. Here, the utility is allowed to earn the rate s on at least a share of its abatement capital. If $\varphi = 1$, for instance, then the constraint becomes $(s - r)(k_1 + k_2)$.

In the absence of an environmental constraint, the utility facing ROR regulation balances the costs (due to purchase requirements) and benefits (due to increased rate base and the corresponding increase in profit opportunities) of owning capital. (In

Appendix D, the corresponding derivation for a utility facing both ROR and environmental constraints is presented.)

It is assumed here that the utility is free to choose the price at which it sells electricity and also the amount of electricity that it produces. How does this make sense when in practice ROR regulation amounts to a regulated price? Because the utility has some monopoly power. It faces a downward-sloping (and somewhat elastic) demand curve and the demand curve for electricity is well-defined. Therefore, it makes no difference whether the regulator dictates a price or a rate of return. In either case, the firm will use the demand curve to calculate the optimal amount of electricity to generate, and will satisfy the regulatory constraint while maximizing profits and meeting its obligation to serve.

Ultimately, the issue is in what direction would the firm's output move in response to a change in φ? To find the answer, think about the way a monopoly producer views additional output. Unlike a competitive firm (whose output is always valued at the prevailing price), an unregulated monopolist by *increasing* its output causes the price of its product to *fall*. To sell the additional product, it must now charge a lower price for all of its production. This fact makes life complicated (and profitable) for a monopolist. Of course, when the monopolist restricts production to achieve a higher price, consumers suffer because they buy less of the good and pay a higher unit price for it. This fact, and the perceived need to protect consumers from exploitation at the hands of a naturally monopolistic seller like an electric utility, underlie the logical justification for public utility regulation.

The fact that a utility usually wishes to reduce output has important consequences for the regulatory treatment of abatement capital. A regulated utility will usually respond to a decision by the regulator that permits profits to increase by reducing its output level. A monopolist's natural tendency is generally to reduce its output level. Now consider the case of the utility and suppose that φ is fixed at some level less than one. Take, for example, the case with $\varphi = 1/2$, in which case the rate base has value $k_1 + 0.5k_2$. Both the ROR constraint and the emissions constraint are binding. Now suppose that the commission decides to increase φ slightly. What will be the utility's response?

If the utility were to continue operating as before using the same input mix and producing the same level of output, the ROR constraint suddenly would be nonbinding. Profits would be lower than their allowed level. To take up the slack in this constraint and to increase profits to the maximum allowable level, the utility will *decrease* its output level.[18]

This sets in motion a series of events that leads to a situation in which electricity production has unequivocally fallen, the price of electricity has risen, the utility's emission level has remained unchanged, and the use of capital inputs--k_1, and k_2--has been reduced.

The intuition for this result relies on the fact that the firm can substitute k_1 for k_2 in its profit constraint.[19] These two inputs both appear in the constraint, and depending on the size of phi are more or less substitutable.

Figure 7-1 illustrates the logic of the argument that connects q and k_2. In the diagram, k_2 and q appear on the axes, and the curve labelled E_0 denotes the set of (k_2,q) pairs at which emissions equal exactly E_0. Given the CAC regime, the firm will always operate along this curve. Any time it reduces its output level q, say from q_0 to q_1, to stay on E_0-curve it must also use a bit less k_2, from k_2^0 to k_2^1g.

Cutting back on output to exploit the more liberal profit constraint, the utility will use less of k_1. When it reduces q, it also reduces emissions, so that the CAC emissions constraint E_0 is no longer binding. Though it will lead to a slight reduction in the size of the rate base, the firm's response is to reduce slightly its use of abatement capital k_2. At the new optimal plan, with φ now greater than 0.5, the firm's use of k_1 and k_2 will have

[18] There is a set of mathematical conditions that must be satisfied by the firm for this statement to be correct. These conditions are spelled out in Appendix D, and they are sufficiently mild that they will often be met.

[19] It is only in the profit constraint that k_1 and k_2 can be substituted for each other. They are distinct as inputs to abatement and production.

Fig. 7-1. Change in k_2 in response to a change in q.

fallen, as will its output level q. But if q falls then the price that consumers must pay for electricity will rise as we move upward along the demand curve. These two changes--reduced electricity use and increased price--both work against consumers. As the share of abatement capital allowed in the rate base increases, consumers are made worse off.

What must be noted is the fact that with the exception of Tennessee (which regulates no electric generating units), pollution abatement equipment is allowed to be placed in the rate base by every state commission and the FERC.[20] Plausible arguments justifying this policy are not difficult to come by. If society wishes to have clean air, one argument goes, it should expect to pay for it. The result of placing abatement capital in the rate base must be faced, however. This policy by commissions has significant equity consequences, and the financial losers are electricity users.

Though the consumers of electricity prefer to see scrubbers left out of the rate base, utilities and their shareholders prefer to have them included. Whether the inclusion observed in forty-nine states is optimal from society's viewpoint--that is, whether the gain felt by shareholders exceeds the cost to ratepayer--is an unanswered question. Still, the single most important finding from this model with CAC environmental regulation is that electricity prices always rise when abatement capital is included in the rate base. If $\varphi > 0$ (so that at least a part of abatement capital is included), then reducing φ always increases the amount of electricity produced and leads to lower electricity prices. Both of these add to consumer welfare.

As we will see, things become a good deal more complicated when environmental regulation includes market-based allowance trading. This investigation is the focus of the next section. There, the competing interests of reducing the cost of complying with the CAAA (by encouraging allowance trading) and increasing consumer surplus (by leaving things out of the rate base) must be dealt with. Given that in practice $\varphi = 1$, a decision to rate base allowances may help in the former (by encouraging the trading of allowances) but hurt in the latter (by further increasing profit opportunities for utilities, which then reduce output further). Commissions should seek to equalize the incentive structure across compliance strategies, but that this may worsen the unpalatable features of the status quo regulatory policy.

Emission Allowance Trading without ROR Regulation

[20] National Association of Regulatory Utility Commissioners, *1989 Annual Report on Utility and Carrier Regulation* (Washington, D.C.: National Association of Regulatory Utility Commissioners, 1990).

When a utility faces a command-and-control environmental constraint, its problem is both more difficult and simpler than if it were able to trade emission allowances. It is made more difficult because the constraint on pollution is more firm--there is less flexibility permitted in compliance planning when allowance trading is not an option. But the decisionmaking process itself is simpler because one complicating factor may be safely ignored since the firm is simply told how much it can pollute. If the allowance price is known, the utility makes its decision about how much to pollute based only upon its own situation. This freedom to choose any amount of emissions makes the decision more complicated. To reduce the degree of complexity somewhat, the firm's decision first will be explored without the complication added by an ROR constraint. The next section presents the results of putting the two regulatory constraints together.

Suppose, as before, that the firm uses x and k_1 in producing electricity, and that it emits pollution in an amount depending on q and the level of k_2. There is no ROR constraint so there is no concern over whether abatement capital is in the rate base. Gone as well is the pollution limit E_0 that appeared in the previous section. It is replaced with an allowance requirement that works as follows.

An *emission allowance* is a license to emit one unit of SO_2. The firm may choose to emit any level of pollution it wishes, so long as it holds allowances in at least that amount. Let ℓ denote allowances or licenses held by the firm, and suppose that the firm is given an endowment of licenses L_0. These licenses may be bought and sold in any amount at the price p_ℓ. What does this firm's profit function include? The firm still earns revenue from the sale of electricity (and potentially from the sale of allowances), and its costs are incurred through the purchase of fuel, the two kinds of capital (k_1 and k_2), and the purchase of allowances. Because we are not considering the dynamic nature of the problem, there is no incentive for the firm to store allowances for future use. This means the firm will always use exactly as many allowances as it holds; all extras will be sold at the prevailing allowance price.[21] Profits are described by $p(q)q - wx - r(k_1 + k_2) - p_\ell(h(q,k_2) - L_0)$. Note that if the firm chooses to use less than its endowment of allowances, $p_\ell(h(q,k_2) - L_0)$--which then would be negative--is an addition to profits.

[21] This means that $\ell = h(q,k_2)$ will always hold. See Appendix D for a discussion of the technical consequences.

Keep in mind how the decisions that the utility makes are implemented and how they affect profits. The choice of how much of the productive inputs x and k_1 to use determines the level of electricity production, q. Together k_2 and q determine the level of sulfur emissions the utility puts out, which in turn determines how many licenses it must hold. Of course, all these things must be selected simultaneously, but it is important to keep in mind just how the various choices feed upon one another. When rates of return are also regulated, things get more complicated.

The reader may consult Appendix D for an account of the mathematical problem that a firm seeks to solve. Of primary interest here is the expression that describes the incentives the firm responds to when choosing compliance strategies and emission levels in the absence of ROR regulation. Keep in mind how this fits into the larger picture. Economists have advocated allowance trading based upon the recommendations of their theoretical models, which have almost always been free of utility regulation. Here, the simple allowance trading model without ROR regulation gives us the clearest idea that this model can give about the firm's decisions when offered the chance to enter an allowance market for environmental regulation. In other words, this version is the benchmark against which things will be compared in the following section.

Equation (D-10) in Appendix D shows how the firm will balance the costs of two compliance strategies available to it: buying abatement capital and buying allowances. It shows that in the absence of ROR regulation, the firm behaves to equalize the marginal cost of purchasing allowances and buying abatement capital. The equation tells us that the firm should equate the marginal costs of using allowances and of purchasing abatement capital. Thus, we see that this mathematical result is in accord with the usual economic recommendation: a firm that is free of regulatory intervention will set the marginal cost of the various compliance inputs equal to one another and equal to their marginal benefits.

In the next section a more complicated treatment of the allowance market behavior of a utility is presented. There, the firm must worry both about the purchase of allowances and abatement capital and about the effect upon these purchases of the rate-of-return constraint. We will see that when the joint influences of environmental and economic regulation are allowed full play even in a simple model such as this one, things get very complicated. However, there are also some intuitively appealing recommendations that result from the mathematical work. These seem to agree with conventional wisdom about the role of market forces in the regulation of the environment.

Emission Allowance Trading with ROR Regulation

In an earlier section, the utility faced both environmental and ROR regulation, but was limited in the ways it could satisfy the environmental constraint. In the previous section, the decision of how to meet the environmental constraint was more complicated, but the utility was not further confined by economic regulation. Here all of the complications are in place: the utility faces a limit on the rate of return it may earn on its capital stock, it must decide how much sulfur dioxide to emit, and at the same time it must decide how much abatement capital to purchase.

Earlier we saw that whether or not abatement capital was allowed in the rate base helped to determine the firm's production and emissions decisions. The conclusion was that consumer welfare would be maximized by *excluding* abatement capital from the rate base. In fact, however, we see that abatement capital is almost always in the rate base, and it is assumed here that this practice will not change in response to the CAAA. Thus, it is assumed in what follows that abatement capital is placed entirely in the rate base (that is, $\varphi = 1$). The central question now concerns how emission allowances should be treated for ratemaking purposes.

Generally, this question has to do with the set of incentives that utilities should face when making compliance decisions. The CAAA envisions an economic setting in which utilities will be free to participate in the allowance market minimizing their cost of compliance. The spirit of the allowance trading scheme depends upon low-cost firms finding it in their interest to overcomply and to sell allowances at the same time that high-cost firms are purchasing allowances rather than scrubbing or switching. Utilities are being asked to respond to purely economic incentives when making these decisions, absent any regulatory distortions that may be present.

Of course, as noted earlier the CAAA deliberately sidesteps the issue of utility regulation. Specifically, then, the question of incentives for compliance planning has everything to do with how commissions alter the relative attractiveness of compliance strategies. This issue has often been described as the need to provide a "level playing field" for utilities. In short, if a firm that is high cost (and therefore should purchase allowances) in the absence of regulatory treatment finds that due solely to the way its compliance decisions are treated by the commission it should scrub, then the commission has provided the utility with a perverse incentive. This question is extremely complicated, and as utilities put together their compliance plans they will be considering myriad factors that are not addressed directly by this model. For example, systemwide least-cost planning (as noted in Chapter 4) will seek the lowest cost solution for the utility's entire system. The lesson that does translate to more complicated settings, though, is the need for appropriate incentives in compliance decisionmaking.

The utility regulator in this model must choose whether to place allowances in the rate base. Given the assumption that abatement capital is in the rate base, how will a utility respond if it learns that allowances (either originally allocated or purchased) are discriminated against in the sense that they are not in the rate base, or that they carry penalties of some other kind? This question is central to the incentive structure of compliance treatment, and to the compliance planning process utilities must soon complete.

The utility's profits are exactly the same as in the above section. Revenues come from the sale of electricity and allowances, and costs are incurred through the purchase of fuel, capital (both productive capital and abatement capital), and allowances. The firm is once again required to hold enough allowances to cover its emissions.[22] The difference between this section and the previous one is the ROR constraint the firm now faces. Economic profits are not allowed to exceed (s - r) times the rate base, where the precise makeup of the rate base is under the control of the commission. Let θ, a number between zero and one, represent the proportion of allowances that belong in the rate base. If $\theta = 1$, allowances are counted entirely in the rate base, while $\theta = 0$ means that no portion of the utility's allowances are in the rate base. Note that the rate base is equal to $(k_1 + k_2 + \theta\ell(p_\ell/r))$.[23]

In the mathematical derivation presented in Appendix D, the reader will notice a higher degree of complexity than was encountered in earlier sections. It is no longer sufficient for the firm simply to select an input combination. Now seemingly each decision, from the level of k_1 to use to the optimal emission level, feeds into the problem and helps determine how other choices should be made.

Equation (D-10) was the primary result of the mathematical work of the section, "Emission Allowance Trading Without ROR Regulation." In the absence of ROR regulation, the optimal decision was to set the marginal productivity of abatement capital in reducing emissions equal to the ratio of the cost of capital and the price of allowances (that is, $-\partial h/\partial k_2 = r/p_\ell$). The counterpart to that equation, when ROR regulation is

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[22] And, as before, the environmental constraint is assumed to be effective, so that in this static version of the problem the utility will not want to own more allowances than it plans to use.

[23] As with the capital variables, care must be taken to value allowances properly in the (single-period) profit function and in the rate base. It is assumed that an allowance has an infinite life, generating in each period a coupon that may be redeemed (in that period or in any subsequent period) in exchange for the right to emit one ton of SO_2. The price of the one-period coupon is p_ℓ (which appears in the profit function), while the asset is valued at p_ℓ/r (which appears in the rate base). The capitalized value of the allowance, then, appears in the rate base calculation, while the yearly rental price appears in the profit function.

present, is equation (D-4) in Appendix D, which once again shows how the utility will strike a balance between compliance strategies.

As long as $\theta < 1$ the utility will face a distorted set of incentives *for compliance purposes*. In the absence of ROR regulation, optimal behavior required setting the left hand term equal to r/p_ℓ. Now, with regulation the optimal decision will usually not be the same.

In other words, the economic regulator may end up introducing a bias into the way the firm satisfies the environmental constraint simply because of how it treats allowances and abatement capital for ratemaking purposes. There is one situation in which this bias is not introduced. If allowances (both originally allocated and purchased) are included in the rate base at their full value (that is, if $\theta = 1$), then the utility will make its pollution abatement decisions in precisely the same way as in the absence of ROR regulation. A method for doing this is discussed in Chapter 9.

A last set of conclusions has to do with the way that emission levels and the level of electricity generation change in response to changes in θ. Two important facts may be stated with some confidence. First, based upon the results of this model, *for a given level of q*, whenever θ gets closer to one the utility will use less abatement capital. This makes intuitive sense because the firm is more willing to use allowances when they are placed in the rate base than when they are not. The more attractive allowances are, the more they are used to replace abatement capital as a compliance strategy.

Second, *for a given level of k_2*, whenever θ increases the utility will produce more electricity. As before, when q goes up the monopoly firm charges a lower price so consumers are able to purchase more electricity for a lower price, both of which add to consumer welfare. Of course, the utility once again must use more allowances to cover the increased emissions that accompany an increase in production. These additional allowances are made more attractive because they are included in the rate base.

The real question of interest, however, is not the way that one variable changes when one or more of the others are held constant. Instead, we wish especially to know how output, emissions, and allowance usage change in response to a change in θ. The result is anticipated by what was discovered in an earlier section. There, a favorable ruling for utilities (in which abatement capital was placed in the rate base) led to a reduction in q and an increase in the electricity price. Utilities were given an opportunity to earn higher profits when φ was increased, and in response they cut back their production levels.

The same outcome seems to result here when θ increases, and the same argument applies. The conclusion is more tentative, however. If θ is currently set at some level less than one and if the commission chooses to increase θ, then the rate base is increased and the utility may now earn higher profits. If it makes no changes in its operation, profits will not increase. To increase profits the firm would have to scale back production because of less demand for electricity with the welfare consequences described earlier. From a consumer surplus maximization standpoint, the commission should set $\theta = 0$ and should not include the value of allowances in the rate base.

At this point the competing interests of allowance market effectiveness on the one hand and ratepayer protection on the other become important. If a single utility were located on an island, and if its behavior had no effect on the allowance market, there would be no *economic* reason for setting $\theta > 0$. However, the allowance market will not function as well (if by functioning well we mean that traded volumes are high), given that abatement capital is almost sure to be included in the rate base, if allowances are not placed in the rate base. Setting $\theta < 1$ creates an automatic bias in favor of abatement capital (again assuming $s > r$). The entire analysis used the assumption that allowances are available in a perfectly competitive market. This assumption stretches credulity in any case, but would be significantly less likely if commissions were systematically to discriminate against allowance use in this way.

To sum up, given the fact that abatement capital is and probably will continue to be in the rate base, it is in society's interest for allowances to be *included in* the rate base. Otherwise the allowance market will be thinly traded and the large cost savings accruing to the market-based nature of clean air compliance will be squandered. However, regardless of how abatement capital is treated by commissions, it is in consumers' interest for allowances to be *excluded from* the rate base. Placing allowances in the rate base at some nonzero value will lead to increases in electricity prices and reduced electricity generation. These two outcomes both reduce consumer surplus and erode the welfare of ratepayers. Society may be better off as θ increases, since it causes an increase in profits. Whether this increase exceeds the loss in consumer surplus is not known.

The mathematical support for this conclusion is the most difficult encountered in this study. Though it is as yet imperfectly completed in Appendix D, the economic insight is identical to the case that appears in the section, "A Model of ROR Regulation with a CAC Environmental Constraint." It must be acknowledged that the decisions that utility regulators face are not purely economic. Rather, political constraints abound and must be satisfied. The conclusions of this chapter are to be taken in a positive sense. If the welfare positions of various groups are measured in the customary way, then the ratemaking treatment outlined above leads to the conclusions described. Even from an economic standpoint, the fact that $\varphi = 1$ means that the entire analysis of allowance trading is necessarily a second-best analysis. The starting point, because of economic regulation, is not perfectly competitive in the economic sense of this phrase.

Even with that much granted, the economic insights of this chapter still appear to have some value. Very little has been said in the past about the way that environmental and utility regulation affect each other, and this chapter has attempted to contribute materially to that difficult problem. In the following section a few important features of the problem that this chapter has not addressed will be mentioned. Some of these points appear elsewhere in the report, but it is well to provide an account of the important considerations and to suggest how extensions of this model could be used to study these as well.

Summary and Conclusions

It appears that the insight about the need for a "balanced" regulatory incentive system is of crucial import for the analysis of compliance decisionmaking specifically and allowance trading generally. Nevertheless, from this conclusion it is a short distance to a number of further suggestions and recommendations that may be stated with some confidence. The remainder of the section consists of discussing these points and offering some thoughts about further extensions of the research.

Numerous difficulties having to do with the accounting treatment of allowances must be addressed. For example, it appears likely that for accounting and tax purposes the initial allotment of allowances will be valued at a price of zero (as discussed in Chapters 5 and 9). It could also turn out that state utility commissioners will choose to value these allowances, for ratemaking purposes, in the same way. If they do, then the treatment presented here, in which the L_0 allowances that the firm was given at the beginning of the planning period were valued at p_ℓ, is not appropriate. Instead, the question of including the initial allowances in the rate base would be moot. Whether this occurs will have nothing to do with the use of allowances.

Taxation policy itself is a knotty issue that has been ignored here for simplicity's sake, but it cannot be ignored either by utilities or commissions. Just how tax treatment of allowances will alter the decisionmaking process is very difficult to predict. It is safe to assume, however, that a zero tax basis will reduce trading volume since the proceeds from an allowance sale would be subject to the 34 percent capital gains tax (which could only be offset by a capital loss). It is also difficult in the confines of the Averch-Johnson model this analysis has used to account properly for the details of revenue treatment and ratepayer ownership of certain assets. A more detailed model of managerial decisionmaking would permit these questions to be explored. Such an exercise is beyond the scope of this model.

Yet another important omission of this analysis is the fuel switching option for CAAA compliance. A utility compliance planner instinctively thinks about the decision between "scrubbing or switching" when attempting to form a compliance strategy or plan. This choice has not been treated in this model. While it would be no trivial matter, the present model could be extended to permit a careful analysis of the fuel switching strategy. When should a firm choose scrubbing over switching, and how do the conditions in the allowance market affect this decision? The primary required alteration would be to add more than just one variable input. This extension has been achieved for the ROR-regulated firm in the absence of environmental regulation,[24] and no new analytical techniques would be needed to make that extension here. Further complicating the switching option are fuel adjustment clauses that many utilities have available to them. This can also cause a bias in the utility's decisionmaking process, particularly if the utility is reluctant to

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[24] See, for example, W. Erwin Diewert, "The Theory of Total Factor Productivity Measurement in Regulated Industries," in T. G. Cowing and R. E. Stevenson, eds., *Productivity Measurement in Regulated Industries* (New York: Academic Press, 1981).

invest in capital because of previous disallowances. This is discussed more fully in the context of ratemaking in Chapter 9.

Utilities and utility regulators alike exist in a world that is dynamic in essential ways. How much can one depend upon the insights of an expressly static model when studying this dynamic problem? Many authors have criticized the Averch and Johnson model by noting its inability to account for certain observed regularities in the utility industries, but it was not designed to explain events and decisions played out over time. The model used here, likewise, cannot speak to issues dynamic in nature. Still, its simplicity can be its chief advantage, for it yields insights obscured by the act of devising complex and elaborate substitute models.

The primary complaint against Averch-Johnson, of course, is that we do not always see $s > r$. Electric utilities no longer expect to earn an economic profit (price above average cost) on their capital expenditures. To be sure, realized rates of return has often fallen below the cost of capital, but to what extent is this due to a systematic violation of the A-J assumptions, and to what extent is it due to an incorrect forecast by utility managers about whether a given project will be placed in rate base? If a prudence review results in only a fraction of k_1 being recoverable, data will be generated that look like $s < r$. To a large extent, this has been the result of large scale (mostly nuclear) projects (see the discussion in Chapter 6). Over time this may seem to be an anomaly due to high interest rates and inflation and not as a permanent feature of regulation. If these factors are accounted for, the $s > r$ assumption may be reasonable.

In any case, even granted that the $s > r$ assumption is not always satisfied, the insights linking ratemaking policy to environmental compliance appear to be fairly robust to model specification. In future work, especially regarding compliance planning in a more general context, a dynamic model that takes into account the timing of utility investment and profits should prove to be an interesting extension.

Finally, as noted previously, decisions about CAAA compliance are made in an uncertain setting. Utility compliance planners do not know the price that allowances will be traded at, nor the future cost of coal and other inputs. Especially important is the effect that the allowance market itself will have upon demand for low-sulfur coal and its price. Everyone involved has reasons to make choices that are conservative in the sense that they do not put a utility or a group of ratepayers in jeopardy in the event that certain important uncertainties are resolved unfavorably.

It is worth noting once more in this regard the extreme importance of the uncertainty regarding property rights. Understandably, utilities can be expected to treat allowances with caution simply because they could disappear one day. It may be that commissions will seek above all to provide incentive systems that do not artificially favor one compliance strategy over another.[25] It is not so easy in the face of extreme uncertainty to specify what an incentive system like this actually will look like. Even if one could be sure that aside from considerations having to do with property rights, such a system of incentives was in place, a single act of Congress repealing or altering Title IV of the CAAA would obliterate the incentives' desirable properties. It may be appropriate and in the interest of ratepayers, however, to assume and plan that for the foreseeable future this will not occur.

The task of merging results on environmental regulation and utility regulation is formidable, and this chapter constitutes only an early first step. Concerns over protecting the environment are not going to go away soon, and utility industries will need to respond to other environmental controls in the future. Within a very short time, greenhouse gas legislation requiring a plethora of new restrictions may be passed into law. The groundwork laid here, then, promises to be helpful for some time to come and in widely diverse settings. The one lesson of this study is that new contours on the regulatory landscape make it necessary to reevaluate the regulatory treatment and its effect on utility decisions. In particular, decisions such as whether to include allowances in utility rate base and at what value (which can never simultaneously help both groups) are always going to be difficult.

Go to Chapter 2

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[25] Such an incentive system is proposed in Chapter 9.