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INFORMATION, INCENTIVES, AND COMMITMENT IN REGULATORY MECHANISMS: REGULATORY INNOVATION IN TELECOMMUNICATIONS

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1. Introduction

The incentive theory of regulation has generally been developed in the context of monopoly regulation or of supply by a publicly owned firm and thus is most applicable to state regulation of local telephone companies.[1] Although this theory may not be directly applicable to those segments of the telecommunications industry that are, or soon will be, sufficiently competitive that regulation will not be needed, the principles identified may be applicable to the transition period from regulation to competition. The theory presented here thus is viewed as pertaining to the transition to competition and to the regulation of local telephone service which, in spite of the alternative of cellular and cable systems, is likely to remain regulated for the foreseeable future. The article thus focuses on cost-based pricing policies and the associated incentive problems with particular emphasis on long-term policies that respond to information that is generated through performance in earlier periods. The regulatory mechanisms considered are in the spirit of recent policy proposals to delegate to the firm the authority to make certain decisions subject only to caps on profits or prices. The mechanisms prescribe a set of implementable policies and delegate to the firm the choice of a particular policy based on the information it has about its costs. The policies cover extended periods of time, so they may include provisions that allow prices to adapt to information revealed by either exogenous events or performance in earlier periods.

An important factor affecting the efficiency of such a mechanism is the regulator's ability to commit credibly to long-term regulatory policies. Commitment refers to the ability of the regulator to specify credibly at the beginning of the regulatory horizon the policies for each future period. When the regulator is unable

M. A. Einhorn (ed.), *Price Caps and Incentive Regulation in Telecommunications*

to commit credibly to long-term policies, it may act opportunistically either to exploit information that becomes available or to take advantage of sunk investments.

Commitment is a practical problem because one government cannot bind a future government to a specific policy. More fundamentally, citizens cannot bind themselves to act politically in a particular manner; for example, as to how they will vote in the future. Consequently, regulatory commissions cannot be bound to long-term policies even if they want to bind themselves (and to bind future commissions). In addition, regulatory commissions have difficulty making credible commitments because all parties recognize that their membership can change as a consequence of a direct election or an appointment by an executive officer. Furthermore, regulatory commissions may choose to alter policies in response to political pressure or political opportunities.

Consequently, the incentive problems inherent in regulation take on added complexity in a multiperiod setting. As Joskow and Schmalensee (1986) argue,

> . . . the nature of the game played by the regulator and the firm changes dramatically when both make decisions over time. In principle, the commission can use repeated observations of firm performance to improve its information, and use that information to fine tune rewards and penalties. Knowing this, the firm has an incentive to try to fool the regulator, perhaps even raising costs and sacrificing profits today in order to make tomorrow's reward/penalty structure more favorable. Since public utility commissioners cannot sign contracts that prevent themselves or their successors - not to mention current and future legislatures - from changing policies, they cannot solve this problem by promising not to use what they learn. Such a head-in-the-sand policy would be plainly irresponsible even if it were credible. When incentives to deceive are taken into account, the problem of designing an optimal dynamic regulatory regime moves to a new level of complexity. (p. 24)

The relation between this commitment problem and politics has been addressed by Noll (1989) in a review of the politics of regulation.

> One key issue is whether political agents can credibly commit to durable, long-term arrangements with utilities which, even if optimal ex ante, could produce supracompetitive profits ex post. Such an outcome would leave the architects of a bidding or cost-revelation mechanism vulnerable to attack by political entrepreneurs seeking elective office. But even if this problem could be solved, interest group theory suggests that such mechanisms are extremely unlikely to be politically acceptable because they reduce to formula the politically relevant act of creating and distributing rents. Only upon the collapse of an economic regulatory process when too many interests are being cut in, combined with natural monopoly, would the political process be likely to consider such a mechanism. These circumstances have taken place in railroads, and may be under way in electricity and local telephone networks. (page 39)

The regulatory policies that are optimal when information is incomplete and commitment is limited are analogous to private long-term contracts but differ in their incompleteness. In private contracting, parties can conclude an agreement that takes into account all available information and any future events that are anticipated. As long as the variables on which the contracts are based are jointly observable and are verifiable to a court, the parties can be confident that the contract will be implemented as anticipated. Government agencies, however, may have more difficulty in making credible long-term commitments than do private parties because political forces can cause changes in policies and procedures.[2]

When credible commitments cannot be made, efficiency is reduced by the opportunism of the regulator and the regulated firm. As Baron and Besanko (1987c, 413) argue,[3]

> This opportunism may be more characteristic of the policies of public agencies than of private parties because although courts will prohibit inefficient breach by private parties they generally will not proscribe revisions of policies by regulatory or administrative agencies. Instead courts tend to restrict their review to procedure, process, and consistency. Perhaps the greatest impediment to establishing commitment in governmental and regulatory settings arises from electoral competition. Presidential candidates and parties can pledge to preserve or to rescind laws or to force regulatory agencies to alter policies either through the appointment process, executive orders, or the authorization and appropriations process. Similarly, Congress can alter policies as well as initiate new ones. The political incentive to respond to an ex post opportunity, even though that opportunity results from an event anticipated under an ex ante efficient policy, seems unavoidable in many settings.

The politics of regulation ultimately spelled the end of the cost-of-service indexing policy for the Public Service Company of New Mexico. As hearing examiner Helman (1984, 152-3) stated, "The political atmosphere is such that the consumer and public view with suspicion any automatic rate relief to a utility even when there is no question of 'the appearance of the eye'; therefore, how much more so when suspicions are strengthened."[4]

Even in the absence of political competition, a legislature is likely to prefer to leave open an option to review the policies of a regulator. As State Senator Robert C. Jubelirer of Pennsylvania stated regarding deregulation of intrastate telecommunications services, "It is not altogether clear whether or not deregulation could be achieved solely through state regulatory process. However, even if public utility commissioners have the authority, I do not think they want to take such a step without legislative sanction. And quite frankly, I do not believe most legislators would want them to do so." (1987, 4) Even when a legislature does establish policy, it may specifically choose to limit commitments to long-term policies. For example, Section 115 of the Public Utility Regulatory Policies Act limits the extent to which state regulatory commissions can commit to automatic adjustment clauses for electric utilities. The Act limits such clauses to four years and requires that they be reviewed at least every two years.[5]

There are a variety of obvious reasons why a regulatory policy may be altered when one political party succeeds another or when different constituencies prevail at different points in time. The concern here is with a more fundamental reason for an inability to make credible long-term commitments: the incentive to act opportunistically by taking advantage of ex post inefficiencies associated with ex ante efficient policies. That is, in a setting in which incomplete contracts are a fact of life, events may occur that provide an opportunity to revise policies in order to capture efficiency and/or distributive benefits. This opportunity may result from a desire to reduce "excess" profits, to capture quasi-rents associated with sunk investments, or to revise policies in light of information revealed about the capabilities and costs of the firm. In the setting considered here, the firm has private information about its costs and hence is able to earn rents on that information. Performance provides information about those costs, and the regulator has an ex post incentive to take advantage of that information by revising its policy. Since the firm recognizes that the regulator will have this incentive and cannot commit credibly not to take advantage of it, the firm will anticipate the regulator's behavior and will act strategically at the time the initial policy is formulated. This prevents the regulator from implementing ex ante efficient policies.

One reason a regulator might behave opportunistically stems from the objectives that political office holders and commission members have to seek short-run benefits when they recognize that they may not be around to bear the long-run costs. To the extent that regulators, or their reputations, do not bear the long-run consequences of their actions, they may have an incentive to act opportunistically to their own advantage. Particularly when the opportunistic behavior appears on the surface to be promoting ex post efficiency, resisting the temptation may be difficult. The inability to give credible assurances not to act opportunistically then generates the inefficiency.[6]

The incentive of a regulator to act opportunistically to confiscate rents or quasi-rents in order to serve political or constituent interests is constrained both by the law and by characteristics of the political system. For example, a firm with non-fungible assets is potentially subject to the risk of regulatory "confiscation" of the quasi-rents generated by those assets through prices or mandated service that are not compensatory. In *Smith v. Ames*, however, the Supreme Court concluded that the Constitution requires a fair return on assets employed in regulated service. What constitutes a fair return, however, is subject to a range of interpretation that allows considerable variation over time and across jurisdictions. That there remains considerable leeway for state regulators is evidenced by the change many states made during the 1970s from a "fair value" system of rate base measurement to an "original cost" method with the objective of holding down rates during a period of high inflation. The theory presented here respects the fair return requirement.

The structure of political institutions can also impede changes in regulatory policies. Legislative changes in regulatory mandates and procedures must command a majority in committee and on the floor of both chambers of the legislature and must be signed by the executive. Failure at any point in the process preserves the status quo and makes legislative modification of regulatory policies difficult.

The procedural due process requirements of administrative law also limit regulatory opportunism by requiring that changes in policies be supported by the record. This, however, is a procedural test and as such does not constrain substantive changes in policy for which a basis can be established in the record. That is, the courts will generally review regulatory decisions for procedural correctness and not for substantive content such as whether the policy change promotes efficiency.

Regulatory opportunism is also restrained by administrative rules that are difficult to change. For example, capital recovery rules limit opportunism by requiring that an asset's cost be recovered from consumer revenue. Unless the regulator determines that the asset is not "used or useful," its cost and return must be included in the revenue requirement. Consequently, regulatory opportunism associated with the confiscation of quasi-rents on long-term investments is restricted if the assets continue to be used. The analysis presented here is intended to be consistent with the requirements of administrative law and the protection of sunk assets. In particular, in the Appendix a capital recovery rule will be shown to be important in limiting the opportunism of the firm, which allows the regulator to implement an expanded class of policies when it is unable to commit credibly not to act opportunistically.

The implications of the incentive theory considered here for this class of regulatory issues are summarized by the following points.

1. In a setting with incomplete information, the regulator prefers to commit to a mechanism, or collection, of regulatory policies with a policy for each possible cost level that the firm might have. The regulator then delegates to the firm the choice of the policy to be implemented. That policy will be chosen as a function of the firm's knowledge of its costs, and the firm will earn rents on it information. It is generally impossible to hold the firm to a specific ex post rate of return, so a range of returns must be tolerated. The resulting pricing policies are prospectively cost-based and depend on the (prior) information of the regulator and on the observed performance. Prices will be fully responsive to costs when a regularity condition is satisfied.
2. In a setting with incomplete information, commitment to long-term policies by the regulator improves ex ante efficiency, but those policies will generally be ex post inefficient given the information learned by the regulator through performance.
3. In a multiperiod regulatory setting in which the costs of the firm are known to be perfectly correlated over time and in which credible commitments are possible, the regulator prefers not to exploit the information learned through performance; i.e., prices will be constant over time even though costs are learned perfectly at the end of the first period.
4. If costs are anticipated to change over time according to a known stochastic process and if credible commitments are possible, the optimal regulatory mechanism adjusts prices prospectively in every period in response to the changes in costs.

5. When the regulator cannot commit credibly to multiperiod policies, the set of policies the regulator is able to implement is restricted by its opportunism and by the consequent opportunism of the firm. That opportunism may be reduced by regulatory institutions, such as fairness (defined below), or by capital recovery rules that provide a means of deferred compensation.
6. With an inability to commit to multiperiod policies but with either fairness regulation or capital recovery rules that limit the opportunism of the firm, the regulator fully exploits the information obtained from the firm. This allows implementation of policies that are ex post efficient yet ex ante inefficient.
7. With fairness or capital recovery rules the regulator will choose a regulatory mechanism in which prices are only coarsely-responsive to costs. The purpose of such a policy is to limit the opportunism of the regulator.
8. With an inability to commit credibly to multiperiod policies but with either fairness or capital recovery rules that limit opportunism, the incentive to invest is diminished because the regulator will be expected to confiscate the rents the firm earns on its information.

The next section presents optimal multiperiod regulatory mechanisms for the cases in which commitment is and is not possible. The impact on investment decisions is addressed in Section 3, and an example of regulation with the monitoring of performance is presented in Section 4. Conclusions are offered in the final section.

2. Optimal Regulatory Policies

2.1 The Model

The model is intended to provide a basis for the development of the intuition underlying the design of regulatory mechanisms and for the presentation of results, most of which are developed in the source papers referenced herein.[7] The model incorporates private information about costs with that information evolving over time based on past costs and investments. The firm is assumed to produce a single service, and the cost C_t incurred in period t when the firm produces a quantity q_t is[8]

$$C_t = \theta_t q_t + k_t + B(x_t), \tag{1}$$

where θ_t is marginal cost, k_t is a fixed cost (e.g., overhead), x_t is the investment made in period t, and $B(x_t)$ is the cost of that investment with $B(0) = 0$, $B'(0) = 0$, $B'(x_t) > 0$ if $x_t > 0$, and $B''(x_t) \geq 0$.

The cost θ_t is observed by the firm at the beginning of period t but is unobservable to the regulator. The cost thus is the private information of the firm and represents its "type." The private information could correspond to information about the firm's technology or about costs common to regulated and unregulated segments of the firm's business, to opportunity costs of its assets, or to characteristics of technological change.

The marginal cost θ_t evolves according to a stochastic process with transition function

$$\theta_t = \theta_t(\theta_{t-1}, x_{t-1}, \xi_t), \tag{2}$$

where $\theta_t \in \Theta_t$ and ξ_t is a random variable representing uncertain components of costs that are observable only to the firm. Investment x_{t-1} in period $t-1$ thus directly affects marginal costs in period t and indirectly affects future costs through the relation between θ_t and $\theta_j, j = t+1,\ldots,\tau$. The marginal cost θ_t is specified as increasing in θ_{t-1}, so higher costs in one period imply (stochastically) higher costs in the next and every subsequent period. Investment reduces cost in the subsequent period. The assumptions on the transition functions thus are

$$\frac{\partial\theta_t}{\partial x_{t-1}} < 0; \quad \frac{\partial\theta_t}{\partial\theta_{t-1}} > 0.$$

The optimal regulatory mechanism in this setting depends importantly on whether the firm has private information prior to the regulator's choice of a mechanism or obtains private information after the mechanism has been chosen. The former seems more descriptive of the current state of the telecommunications industry, so attention will be restricted to it. The firm thus knows θ_1 at the beginning of the regulatory horizon, and the regulator's prior information is represented by the distribution function $F_1(\theta_1)$. A regularity assumption to be employed is that $[\theta_1 + F(\theta_1)/f(\theta_1)]$ is a nondecreasing function of θ_1, where $f(\theta_1)$ is the density function. The random variable ξ_t in the transition function (2) induces a distribution function $F_t(\theta_t \mid \theta_{t-1}, x_{t-1})$ on the marginal cost θ_t.

The regulator is assumed to have the authority to regulate prices and would like to base its pricing policy on the marginal cost of the firm, but it does not know which cost the firm actually has. The next best alternative is to design a mechanism that includes a collection of pricing policies and delegate to the firm the choice of one of those policies. That choice will be based on its true cost, so the pricing policy can be made responsive to the costs of the firm through its selection of a policy. The task of the regulator is thus to choose a mechanism such that the firm's choice of a pricing policy serves the mandate of the regulator. A two-part price structure will be employed where p_t denotes the price and T_t is a fixed (or monthly) charge.[9] For each period t, a policy specifies the price $p_t(\hat{\theta}_t, \hat{\theta}_{t-1}, \ldots, \hat{\theta}_1)$ and a transfer or fixed charge $T_t(\hat{\theta}_t, \hat{\theta}_{t-1}, \ldots, \hat{\theta}_1)$, where the arguments denote selection variables by which the firm chooses a policy. A strategy of the firm in period t is thus a function $\hat{\theta}_t(\theta_t)$: $\Theta_t \to \Theta_t$.

In this setting, the firm has a natural incentive to choose a pricing policy intended for a higher marginal cost. For example, if the regulator were to attempt to implement a marginal cost pricing policy $p_t(\hat{\theta}_t) = \hat{\theta}_t$ with $T_t(\hat{\theta}_t) = k_t$ when $x_t = 0$, the firm has an incentive to choose a policy intended for a firm with a higher marginal cost. To illustrate this, consider a one-period model. The profit $\pi(\hat{\theta}_1; \theta_1)$ for a firm with marginal cost θ_1 is

$$\Pi(\hat{\theta}_1; \theta_1) = (\hat{\theta}_1 - \theta_1)\, Q(\hat{\theta}_1),$$

which has a maximum at $\hat{\theta}_1 > \theta_1$. The regulator thus prefers to design the mechanism to counter this incentive to overstate costs. The revelation principle implies that an optimal regulatory mechanism can be found in the class of policies such that the firm prefers to choose the policy designed for its marginal cost, i.e., $\hat{\theta}_t(\theta_t) = \theta_t$ for all θ_t.

The sequence of moves by the regulator and the firm depends on whether the regulator can credibly commit to a policy for the entire length of the horizon.[10] If the regulator can make such commitments, it chooses a multiperiod mechanism M that specifies pricing policies for every period. The mechanism M thus is a collection

$$M = \left\{ (p_t(\hat{\theta}_t, \hat{\theta}_{t-1}, \ldots, \hat{\theta}_1), T_t(\hat{\theta}_t, \hat{\theta}_{t-1}, \ldots, \hat{\theta}_1)), t = 1, \ldots, \tau \right\}, \tag{3}$$

where τ is the number of periods in the horizon.[11] Then, at the beginning of each period, the firm chooses from the policies for that period by selecting $\hat{\theta}_t$. Thus, the regulator moves first and chooses a mechanism M. At the beginning of period one, the firm chooses a particular pricing policy $(p_1(\hat{\theta}_1), T_1(\hat{\theta}_1))$ by selecting $\hat{\theta}_1 = \hat{\theta}_1(\theta_1) \in \Theta_1$. At the beginning of period two, the firm observes θ_2 and chooses a pricing policy $(p_2(\hat{\theta}_2, \hat{\theta}_1), T_2(\hat{\theta}_2, \hat{\theta}_1))$ by selecting $\hat{\theta}_2 = \hat{\theta}_2(\theta_2) \in \Theta_2$. The subsequent periods are analogous. The equilibrium sought is a Bayesian Nash equilibrium.[12] Since θ_t is observed at the beginning of period t, prices are prospectively based on costs for the coming period.

Commitment means than the regulator can credibly pledge not to act opportunistically when it receives information relevant to the cost of the firm. If the regulator is capable of making such credible commitments, the firm need not take into account the future behavior of the regulator but can instead rely on the announced mechanism. The agreements reached between the NYPSC and the New York Telephone Company may be interpreted as attempts to establish credible commitments for the periods of the agreements. This is weaker than full commitment, however, because at the conclusion of the period covered by the agreement the regulator would presumably establish a new policy based on the information available at that time. The regulator's choice of the new policy thus will affect the firm's behavior which in turn affects the choice of the initial agreement. This is the source of the inefficiency addressed by Vickers and Yarrow in their analysis of the price-cap system used to regulate British Telecom.

If, as discussed in Section 1, the regulator is unable to make credible commitments to future policies, the regulator will act optimally in every period, conditional on the information available. The regulator thus will choose its policies for period t at the beginning of that period. The regulator still prefers to rely on self-selection by the firm and therefore will choose a menu

$$M_t = \{p_t(\hat{\theta}_t, \hat{\theta}_{t-1}, \ldots, \hat{\theta}_1), T_t(\hat{\theta}_t, \hat{\theta}_{t-1}, \ldots, \hat{\theta}_1)\} \tag{3a}$$

at the beginning of each period t. This choice will be made optimally given the information the regulator has about θ_t, so the equilibrium sought is a sequential (subgame perfect, Bayesian Nash) equilibrium. In the absence of commitment, the regulator is unable to avoid exploiting whatever opportunities are available in period t. In particular, the regulator is unable to commit not to exploit any information that becomes available regarding marginal cost. The regulator thus cannot avoid acting opportunistically, and recognizing this the firm will act strategically by anticipating the behavior of the regulator. As shown in Section 3.3, this opportunism results in ex ante inefficiency.

The profit π_t of the firm in period t is

$$\pi_t = p_t Q(p_t) + T_t - \theta_t Q(p_t) - k_t - B(x_t), \tag{4}$$

where $Q(p_t)$ is the demand function. The objective of the firm is to maximize the (expected) discounted sum of its profit over the τ-period horizon. The firm is assumed to be privately owned and is assured a fair return in each period. The regulatory policy is thus chosen subject to the constraints

$$\pi_t \geq 0, \quad t = 1, \ldots, \tau. \tag{5}$$

The regulator is assumed to maximize the ex ante (expected) discounted sum of consumer surplus where the expectation is taken with respect to the regulator's information about θ_t conditional on the history to that point.[13] Consumer surplus $S(Q(p_t))$ in period t is given by

$$S(Q(p_t)) = Y(Q(p_t)) - p_t Q(p_t) - T_t, \tag{6}$$

where Y is the aggregate willingness to pay of consumers.

3.2 Optimal Regulatory Mechanisms with Commitment

The basic tradeoff facing the regulator is between consumer surplus and the profit (or information rent) of the firm, since substituting (4) into (6) yields

$$S(Q(p_t)) = Y(Q(p_t)) - \theta_t Q(p_t) - k_t - B(x_t) - \pi_t. \tag{7}$$

If the regulator knew θ_t, it could choose a pricing policy that held profit π_t to zero. With incomplete information, however, the firm earns profit, or more correctly rents, on its private information. In a one-period model those rents $\pi_1(\theta_1)$ are[14]

$$\pi_1(\theta_1) = \int_{\theta_1}^{\theta^+} Q(p_1(\theta_1^0))d\theta_1^0, \tag{8}$$

as shown in Baron and Myerson (1982). Consequently, the lower are the costs of the firm the higher are the rents it earns. The natural incentive of the firm is to select ($\hat{\theta}_1 > \theta_1$) a pricing policy intended for a higher cost firm in order to obtain higher profits. The rents represent the incentive payment that must be made to the firm with cost θ_1 to offset the incentive to select a pricing policy intended for a firm with a higher cost.[15]

The objective of the regulator is to maximize ex ante consumer surplus W which from (7) is given by[16]

$$W = \int\Big[Y(Q(p_1(\theta_1))) - \theta_1 Q(p_1(\theta_1)) - k_1 - \pi_1(\theta_1)\Big] f_1(\theta_1) d\theta_1. \tag{7a}$$

In this setting, the regulator is able to implement a marginal-cost-pricing policy. From (8), however, the higher is the price the lower are the information rents, so the regulator has an incentive to distort price above marginal cost to reduce the rents even though that reduces the surplus $[Y(Q(p_1)) - \theta_1 Q(p_1) - k_1]$ in (7). The price $p_1(\theta_1)$ that optimally trades off rents and surplus is[17]

$$p_1(\theta_1) = \theta_1 + \frac{F_1(\theta_1)}{f_1(\theta_1)} = \theta_1\left(1 + \frac{F_1(\theta_1)}{\theta_1 f_1(\theta_1)}\right), \tag{9}$$

where $F_1(\theta_1)/f_1(\theta_1)$ has the interpretation as the marginal information costs to the regulator. Note that as long as $(\theta_1 + F(\theta_1)/f(\theta_1))$ is strictly increasing in θ_1, the price is "fully responsive" to costs.[18] The fixed charges $T_1(\theta_1)$ are then chosen to implement $p_1(\theta_1)$ by inducing the firm to select the policy $(\hat{\theta}_1(\theta_1) = \theta_1)$ corresponding to its marginal costs. These fixed charges are given by equating (4) and (8) which yields

$$T_1(\theta_1) = \theta_1 Q(p_1(\theta_1)) + k_1 - p_1(\theta_1)Q(p_1(\theta_1)) + \int_{\theta_1}^{\theta^+} Q(p_1(\theta_1^0))d\theta_1^0. \tag{10}$$

The incentive for political opportunism is evident from the price in (9). The ex ante efficient price is greater than marginal cost, and hence there is an ex post incentive to reduce the price in the next period to generate efficiency gains. For example, if $f_1(\theta_1)$ is uniform, then price $p_1(\theta_1)$ is twice the marginal cost. The difference between price and marginal cost increases with θ_1, so the incentive is greater for high costs than for low costs. It is this incentive that is at the heart of the commitment problem studied in Sections 2.3 and 3.2. The optimal multiperiod regulatory mechanism with commitment is characterized next to identify the properties of the ex ante efficient mechanism and to provide a benchmark for the evaluation of mechanisms when credible commitment is not possible.

To indicate the nature of efficient regulation in a multiperiod model, consider the case in which the costs of the firm are characterized by technological change that reduces marginal cost over time. This is intended to be representative of the long-term decline in the real costs of telecommunications services. Marginal cost θ_t will initially be assumed to be given by the deterministic transition function

$$\theta_t = \gamma\,\theta_{t-1} = \gamma^{t-1}\theta_1, \tag{11}$$

where the productivity parameter γ is less than or equal to one and is common knowledge. Marginal costs are thus perfectly correlated and decrease over time according to a known function. In this case, the regulator need only choose a mechanism M of the form $M=\{(p_1(\hat{\theta}_1), T_1(\hat{\theta}_1)), (p_2(\hat{\theta}_1), T_2(\hat{\theta}_1)), \ldots, (p_\tau(\hat{\theta}_1), T_\tau(\hat{\theta}_1))\}$, , since the information about costs does not change over time. In the context of the price cap systems discussed in Section 1, the cap in each period is represented by the pair $(p_t(\hat{\theta}_1), T_t(\hat{\theta}_1))$, which may be interpreted as caps on both the usage charge and the monthly charge. With these caps the firm, when delegated the choice of prices, will choose the usage charge and the monthly charge at their caps.[19]

The optimal prices, expressed here as a function of θ_1, can be derived from the characterization in Baron and Besanko (1984) as[20]

$$p_t(\theta_1) = \gamma^{t-1}\theta_1\left(1 + \frac{1}{\theta_1}\frac{F(\theta_1)}{f(\theta_1)}\right)$$

$$= \gamma^{t-1}p_1(\theta_1) \quad . \tag{12}$$

The price cap thus decreases over time at the same rate at which marginal costs decrease, but in all periods the price is above marginal cost and by the same percent.

As an example, suppose θ_1 has a triangular distribution with $f_1(\theta_1) = 2\theta_1$ for $\theta_1 \in [0,1]$, so that high costs are more likely than low costs. Then the prices are given by[21]

$$p_t(\theta_1) = \gamma^{t-1}\frac{3}{2}\theta_1 .$$

Price is thus 50 percent greater than marginal cost in every period but declines at the same rate as does marginal cost.

Viewed from time zero when the regulator designs the regulatory mechanism, the time path of prices is deterministic once the firm has selected the particular policy based on its true θ_1. Prices decline over time at the same rate as marginal costs, but in every period price incorporates a mark-up above marginal cost equal to the marginal information costs resulting from the firm's private information. An optimal regulatory mechanism thus specifies price caps that decrease over time if $\gamma < 1$ and are constant over time if $\gamma = 1$. Since the transition function in (11) is known to the regulator, the regulator is able to specify the caps in advance. In this respect, this mechanism corresponds to the price-cap system used for British Telecom. That system is not directly cost-based, however, but instead was based on the existing prices at the time the system was instituted.

To indicate the significance of commitment for the design of a price-cap mechanism, consider the case in which $\gamma = 1$. The optimal caps are then to commit to the repetition in each period of the optimal price in (9) for a one-period model with the fixed charges given in (10). Even though the regulator observes the selection of a policy in the first period which completely reveals the marginal cost

θ_1, the regulator prefers to commit not to use that information in subsequent periods. The regulator prefers to implement a policy in which there is no adaptation to the information because that provides the optimal tradeoff between consumer surplus and the rents the firm earns on its private information. Since the firm has at the beginning of the horizon the same private information about its costs in each future period, it earns rents on that information in each period. The tradeoff between rent reduction and consumer surplus is thus the same for each period.

Of course, after the selection of a regulatory policy in the first period, the regulator knows θ_1 and hence knows what costs will be in every subsequent period. The regulator thus could implement marginal cost pricing in every period other than the first. The regulator prefers not to exploit that information, however, because the firm would anticipate that its rents would be exploited and would act strategically in its initial selection of a policy. This would then reduce the efficiency of the regulatory mechanism.

In a multiperiod model, the rents $\Pi(\theta_1)$ earned by the firm with transition function in (11) as a consequence of its private information about θ_1 are analogous to (8)

$$\Pi(\theta_1) = \int_{\theta_1}^{\theta^+} \left[\sum_{t=1}^{\tau} \beta^{t-1} \gamma^{t-1} Q(p_t(\theta_1^0)) \right] d\theta_1^0, \tag{8a}$$

where β is the discount factor. The firm thus earns more than its cost of capital, but it does so because of its private information about costs. Because of that private information it is impossible for the regulator to eliminate these "excess" profits because eliminating profits for a firm with marginal cost θ would cause a firm with a higher cost not to recover its capital costs. This firm would then be unable to raise capital.

Next consider a stochastic transition function where γ is the realization of a random variable $\tilde{\gamma}$ that is uniformly distributed on the interval [0,1]. Costs are thus imperfectly correlated over time. Initially, consider a two-period horizon so that γ is realized once at the beginning of period two. The price cap for the first period is unaffected and is given in (9). Viewed from time zero when the regulator designs the mechanism of regulatory policies, the distribution $F_2(\theta_2 \mid \theta_1)$ is given by

$$F_2(\theta_2 \mid \theta_1) = \frac{\theta_2}{\theta_1} \quad \text{if } \theta_2 \in [0, \theta_1]. \tag{13}$$

At the beginning of period two the regulator does not know θ_2 and thus designs a price cap $p_2^*(\theta_2, \theta_1)$. That cap is[22]

$$p_2^*(\theta_2, \theta_1) = \theta_2 - \frac{\dfrac{\partial F_2(\theta_2 \mid \theta_1)}{\partial \theta_1}}{f_2(\theta_2 \mid \theta_1)} \frac{F_1(\theta_1)}{f_1(\theta_1)}$$

$$= \theta_2 \left(1 + \frac{1}{\theta_1} \frac{F_1(\theta_1)}{f_1(\theta_1)} \right)$$

$$= \frac{\theta_2}{\theta_1} p_1(\theta_1) \ . \tag{14}$$

The second term on the right side of (14) is the marginal information cost resulting from the firm's private information about θ_1. It is important to note that this regulatory mechanism is "nested" in that in each period the firm makes a selection of a pricing policy by reporting $\hat{\theta}_t$ but that policy is conditioned on the selections in earlier periods.

It is important to note that the price caps are set prospectively but are also based on costs in prior periods. That is, in (14), for example, the price cap for period two is proportional to the costs that the firm will have in period two. The margin above that marginal cost, however, depends on the costs in period one. That dependence is due to the information that period-one costs provide for period-two costs. That is, in the first line of (14) the term $\partial F_2(\theta_2 \mid \theta_1)/\partial\theta_1$ represents the impact of θ_1 on the information about θ_2. For the case of perfect correlation, $\theta_2 = \theta_1$ and this derivative equals -1. The expression in (14) then reduces to (9). If θ_1 provides no information about period-two marginal costs so that θ_1 and θ_2 are statistically independent, then $\partial F_2(\theta_2 \mid \theta_1)/\partial\theta_1 = 0$ and $p_2^*(\theta_2, \theta_1) = \theta_2$. Thus, it is the information that costs in earlier periods provides for costs in the future periods that determines how the price caps depend on past costs. In all cases, however, the cap for the next period is prospectively based on the costs anticipated for that period.

If θ_1 has a triangular density $f_1(\theta_1) = 2\theta_1$, then (14) becomes

$$p_2^*(\theta_2, \theta_1) = \frac{3}{2}\theta_2. \tag{15}$$

Again, price is marked up above marginal cost by 50 percent of the marginal information costs. Although the markup is present in every period, the path of the price caps is stochastic when viewed from the time at which the regulator chooses the mechanism. In general, the price $p_t^*(\theta_t, \theta_{t-1}, \ldots, \theta_1)$ in period t is given by

$$p_t^*(\theta_t, \theta_{t-1}, \ldots, \theta_1) = \theta_t \left(1 + \frac{F_1(\theta_1)}{\theta_1 f_1(\theta_1)} \right) = \frac{\theta_t}{\theta_1} p_1(\theta_1). \tag{16}$$

The cap on the fixed charges $T_t^*(\theta_t, \theta_{t-1}, \ldots, \theta_1)$ is then determined in the manner used to obtain (10).

The price patterns when costs evolve deterministically and stochastically can be compared by examining the case in which $\gamma = 1/2$ and $f_1(\theta_1)$ is triangular. The expected prices, where the expectation is taken at the beginning of period one, are then equal:

$$Ep_t = Ep_t^* = 1 \quad \text{if } t = 1$$
$$= \tfrac{3}{4}\gamma^{t-1} \quad \text{if } t > 1. \tag{17}$$

Although the expected time paths are the same, the path for the case of perfect correlation is deterministic once the firm selects the regulatory policy in the first period, whereas the path is stochastic in the case of imperfect correlation.

The mechanism in the case of $\tilde{\gamma}$ stochastic involves a price cap that is revised at the beginning of each period based on the costs that the firm realizes. Since the realized cost is exogenously determined, this is consistent with the FCC's policy that adjustments in the cap should be based on exogenous factors. Even though the price cap is established in each period and viewed from time zero the cap is a random variable, the formula governing the adjustment is specified in advance. Commitment means that the formula cannot be adjusted. The FCC proposal for price-cap regulation would, however, allow adjustments in the cap. The theory presented here indicates how the price cap should be adjusted if commitment to the mechanism can be made credible. The formula for the adjustment should not be subject to change. If the rate at which costs are anticipated to decline is known with certainty, the rate at which the cap will decrease can be specified in advance. In the more realistic case in which the rate of change is not known in advance, the mechanism should specify the formula by which information will be used to adjust the cap.

2.3. Optimal Regulation with No Commitment

If credible commitments to long-term policies cannot be made, as indicated in (3a) the regulator will at the end of the first period base the mechanism M_2 for the second period on whatever information was revealed by the firm's selection from the mechanism M_1 in the first period. The policies that the regulator is able to implement in this case depend importantly on the extent of the opportunism that is possible in the regulatory relationship. In the perfect correlation case specified in (11), Laffont and Tirole (1986a) demonstrate that if the regulator can fully exploit the cost information it obtains in the first period, and thus would implement a marginal-cost price cap in period two if it learned θ_1 in the first period, the firm has an incentive in the first period to select a pricing policy designed for a lower marginal cost and then not to produce in the second period. Thus in period one, the regulator cannot implement pricing policies that are fully responsive to costs and must resort to "coarse" policies that specify the same price for many different costs. This argument is presented in more detail in the Appendix.

Two forces serve to limit this opportunism. First, if the firm has substantial sunk investment costs that through regulatory rules are recoverable over several years, the incentive of the firm to act strategically is limited as demonstrated in the Appendix. This capital recovery rule, coupled with substantial sunk costs, allows the regulator to implement pricing policies that are continuously responsive to costs. Second, Baron and Besanko (1987c) consider a regulatory relationship, characterized by what they label as "fairness," under which the firm agrees not to quit the regulatory relationship as long as the regulator provides the firm with a fair return given the information it reveals through its selection of a pricing policy in the first period.[23] This limited form of commitment allows the regulator to implement pricing policies that are continuously responsive to costs.[24] In this section the regulatory relationship is assumed to be characterized either by fairness or by substantial sunk costs and a capital recovery rule.

The regulatory policies that would be implemented in the absence of commitment correspond to those that would be implemented at the conclusion of a regulatory mechanism such as that for British Telecom or that implemented in New York. Two aspects of this regulatory setting are of particular interest. First, what mechanism will be implemented at the conclusion of the duration of the first mechanism? Second, what is the impact of the choice of the second-period mechanism on the choice of the mechanism for the prior period? That is, since the firm will anticipate the regulator's choice of a second-period mechanism and will take that into account in making its selection from the mechanism in the first period, the regulators will find it optimal to anticipate the firm's strategic choice. This results in a reduction in ex ante efficiency.

To investigate these issues, consider a two-period ($\tau = 2$) horizon, and suppose that in the first period the regulator implements a mechanism M_1 that is continuously responsive to costs. At the end of the first period, the regulator would then be able to infer θ_1 from the policy selected by the firm in period one. Since the regulator cannot resist exploiting this information, it will base the price for the second period on the posterior distribution $F_2(\theta_2 \mid \theta_1)$. For the case in (11) of perfectly correlated costs, the posterior distribution places mass one on $\theta_2 = \gamma\,\theta_1$. The price in the second period, and in each subsequent period, is then equal to the marginal cost the regulator knows that the firm will have. The fixed charges T_2 then equal the fixed cost k_2 and the firm earns no rent after the first period. As demonstrated in Baron and Besanko (1987c), this results in a welfare loss compared to the mechansims characterized in the previous section because too large an incentive payment is required in the first period to implement those price caps.

For the case of imperfect correlation, the price $p_2^0(\theta_2, \theta_1)$ in period two is analogous to (9) but is based on the posterior distribution $F_2(\theta_2 \mid \theta_1)$ or

$$p_2^0(\theta_2, \theta_1) = \theta_2 + \frac{F_2(\theta_2 \mid \theta_1)}{f_2(\theta_2 \mid \theta_1)}. \tag{18}$$

For the example with θ_2 uniformly distributed on $[0, \theta_1]$ the price is

$$p_2^0(\theta_2, \theta_1) = 2\theta_2 \quad \text{if } \theta_2 \in [0, \theta_1]. \tag{18a}$$

In this case, the period-two price is higher when the regulator exploits the information obtained during the first period. A higher price is not necessarily an indication of inefficiency, but it is true that ex ante welfare is strictly lower in the absence of commitment because the regulator prefers to implement the price p_2* in (15).[25] The ex ante welfare loss when long-term commitments cannot be made and the regulatory relationship is governed by fairness is characterized in Baron and Besanko (1987c).

The answer to the first question posed above is thus that the regulator will act opportunistically by ratcheting price down as low as possible given the information revealed in earlier periods. In addition, profit is ratcheted down to the level of the rents on the remaining private information of the firm. In the case in which marginal costs evolve at a known rate, price ratchets down to the marginal cost and profit ratchets down to zero. To the extent that the renegotiation of a price cap system is similar to the case in which long-term commitment is not credible, renegotiation exploits the information that becomes available through performance. Price cap regulation thus evolves into revenue requirements regulation. Anticipation of this, however, results in inefficiency because a greater incentive payment has to be made in the first period in order to offset the greater incentive of the firm to act strategically when it knows that its profits will be ratcheted down through renegotiation.

Because an ex ante welfare loss results when the regulator cannot credibly commit to long-term policies and thus cannot avoid acting opportunistically when it observes the policy selection in the first period, the regulator would be expected to seek means of restricting its own opportunism. One means of doing so is not to learn θ_1 in the first period. The regulator can accomplish this by choosing a menu M_1 that contains a single pricing policy; i.e., a single price cap rather than a cap as a function of $\hat{\theta}_1$. In the case of perfectly correlated marginal costs this allows the optimal price cap with commitment to be implemented in the second period, but such a mechanism may not be optimal. For an example, Baron and Besanko (1987b) characterize the optimal mechanism and show that the first-period mechanism contains a countable number of policies that are coarsely responsive to costs. Those policies are more responsive for low costs than for high costs. There is thus a trade-off between coarse pricing in the first period as a means of limiting opportunism in the second period and the welfare loss in the first period that results when prices are not continuously responsive to costs. This suggests that regulatory mechanisms that are coarse and prescribe the same prices for sets of different possible costs may not be inefficient when long-term commitments cannot be made. Coarse price cap mechanisms thus may contribute to informational efficiency when the regulator is able to make only limited commitments to long-term policies.[26]

3. Investment

3.1 Investment with Commitment

The purpose of this section is to examine the importance of commitment for investment by the regulated firm. As a benchmark, the optimal investment with commitment is characterized, and the investment resulting in the absence of commitment is then examined.

If the regulator were able to make credible commitments, the incentives for investment would be second-best efficient given the prices set in response to the informational asymmetry. The resulting investment depends on whether the regulator can observe investment and force the investment it prefers. The first case considered is that in which the regulator can dictate investment, and the second case considered is that in which investment is unobservable to the regulator in which case the investment decision is necessarily delegated to the firm.

To illustrate these cases, the perfect correlation case in a two-period model will be used with $\theta_2 = \theta_1/(1 + x_1)$. The welfare W maximized by the regulator can be written as

$$W = \int_{\theta^-}^{\theta^+} \Bigg[Y(Q(p_1)) - \theta_1 Q(p_1) - k_1 + \beta\left(Y(Q(p_2)) - \frac{\theta_1}{1 + x_1} Q(p_2) - k_2 \right) - B(x_1) - \left(Q(p_1) + \frac{\beta Q(p_2)}{1 + x_1} \right) \cdot \frac{F_1(\theta_1)}{f_1(\theta_1)} \Bigg] f_1(\theta_1) d\theta_1. \tag{19}$$

The optimal (second-best) investment $x_1(\theta_1)$ that the regulator can implement when investment is observable satisfies

$$\beta \frac{\left(\theta_1 + \dfrac{F_1(\theta_1)}{f_1(\theta_1)}\right)}{(1 + x_1(\theta_1))^2} Q(p_2(\theta_1)) - B'(x_1(\theta_1)) = 0. \tag{20}$$

Substituting $\theta_2 = \theta_1/(1 + x_1)$ yields

$$\frac{\beta\theta_2}{1 + x_1(\theta_1)} \left(1 + \frac{F_1(\theta_1)}{\theta_1 f_1(\theta_1)} \right) Q(p_2(\theta_1)) - B'(x_1(\theta_1)) = 0, \tag{20a}$$

so the second-best investment equates the marginal investment cost and the marginal reduction in the variable production and information cost of producing $Q(p_2(\theta_1))$.[27] The regulator thus takes into account the marginal information cost in specifying the investment.

Compared to the complete information case, the marginal product of investment given the quantity is greater with incomplete information than with complete information because, with this specification investment decreases the information rents earned by the firm.[28] The investment decision under incomplete information thus involves a rent-reduction externality, which the regulator takes into account.

With the specifications $B(x_1) = x_1$ and $F_1(\theta_1) = \theta_1$, the optimal investment is given by

$$x_1(\theta_1) = \begin{cases} 0 & \text{if } 2\beta\theta_1 Q(p_2(\theta_1)) \leq 1 \\ (2\beta\theta_1 Q(p_2(\theta_1)))^{1/2} - 1 & \text{if } 2\beta\theta_1 Q(p_2(\theta_1)) \geq 1. \end{cases} \tag{21}$$

Given the quantity, the investment with incomplete information is greater than the efficient investment for the same quantity by a factor of 2.5. The price cap then satisfies, for $f_1(\theta_1)$ triangular,

$$p_2(\theta_1) = \frac{\theta_1}{1 + x_1(\theta_1)}\left(1 + \frac{F_1(\theta_1)}{\theta_1 f_1(\theta_1)}\right) = \frac{\frac{3}{2}\theta_1}{1 + x_1(\theta_1)} = \frac{\frac{3}{2}\theta_1}{(2\beta\theta_1 Q(p_2(\theta_1)))^{1/2}}.$$

If the investment were unobservable, then the firm would choose its investment to maximize its profit $\pi(\theta, \hat{x}_1; \theta)$ which is given by, using the $T_1(\theta_1)$ and $T_2(\theta_1)$ that implement $p_1(\theta_1)$ and $p_2(\theta_1)$,

$$\pi(\hat{\theta}_1, x_1; \theta_1) = (\hat{\theta}_1 - \theta_1)\, Q(p_1(\hat{\theta}_1)) + \beta\left(\frac{\hat{\theta}_1}{1 + x_1^0(\hat{\theta}_1)} - \frac{\theta_1}{1 + x_1}\right) Q(p_2(\hat{\theta}_1))$$
$$+ B(x_1^0(\hat{\theta}_1)) - B(x_1) + \int_{\hat{\theta}_1}^{\theta^+}\left(Q(p_1(\theta_1^0)) + \frac{\beta Q(p_2(\theta_1^0))}{1 + x_1^0(\theta_1^0)}\right) d\theta_1^0, \tag{22}$$

where $x_1^0(\cdot)$ is the equilibrium investment. The firm will choose its investment $x_1(\theta_1)$, which in the optimal policy equals $x_1^0(\theta_1)$, to satisfy, given $\hat{\theta}_1 = \theta_1$,

$$\beta \frac{1}{1 + x_1(\theta_1)}\, \theta_2 Q(p_2(\theta_1)) - B'(x_1(\theta_1)) = 0. \tag{23}$$

For the same quantity, the firm thus invests less than the regulator prefers as given in (20).[29] This results because the firm does not take into account the rent-reduction externality. The regulator will, however, take into account the firm's choice and alter the quantity produced accordingly. The price cap in this case is

$$p_2(\theta_1) = \frac{\theta_1}{1 + x_1^0(\theta_1)}\left(1 + \frac{F_1(\theta_1)}{\theta_1 f_1(\theta_1)} - \lambda(\theta_1)\beta \frac{\theta_1}{1 + x_1^0(\theta_1)}\right)$$

where $\lambda(\theta_1)$ is the multiplier associated with the constraint in (23). Since the regulator prefers a greater investment than does the firm, the multiplier $\lambda(\theta_1)$ is positive. The regulator then will choose a lower price, and hence higher quantity, in the second period so as to increase the marginal product of investment.

3.2 Investment in the Absence of Commitment

If the regulator is unable to make credible commitments to future policies but a fairness relationship is in place, at the end of the first period it would choose a mechanism M_2 that is optimal given its information. That information includes what can be inferred from the policy selected in the first period and from what is known about equilibrium strategies. If, for example, the mechanism M_1 implemented in the first period were continuously responsive to costs (completely separating), the regulator would know θ_1 from the firm's choice of policy in the first period. From the equilibrium strategies, the regulator then could infer the investment chosen by the firm, so in the case of perfectly correlated marginal costs the regulator would know the marginal cost θ_2 the firm would have in the second period. The regulator could then fully exploit that information by instituting a marginal cost price cap.

For the case in which investment is observable and the regulator has the authority to control it, the regulatory mechanism M_1 would specify an investment $x_1(\theta_1)$ that satisfies (20) with $p_1(\theta_1) = \theta_1/(1 + x_1(\theta_1))$. The investment is thus greater than when commitment is possible because the cost reduction pertains to a greater output. If investment were unobservable, the firm would recognize that its profits in the second period will be zero. In the first period, the firm would then only recover its initial investment, so it would have no incentive to invest.[30] To provide some incentive to invest, the regulator would choose a coarse mechanism for period one that would prevent it from learning θ_1.

If costs were not perfectly correlated, the firm would earn rents in the second period on the information it privately observes at the beginning of period 2, and this could provide an incentive to invest. For the case in which M_1 is completely separating, the expected rents $E\pi_2(\theta_1, x_1)$ in period two as viewed from period one are, after integrating by parts,

$$E\pi_2(\theta_1, x_1) = \int_{\theta^-}^{\theta^+} Q(p_2(\theta_2^0))\, F_2(\theta_2^0 \mid \theta_1, x_1)\, d\theta_2^0. \tag{24}$$

Then, when investment is not observable, the firm will choose its investment to maximize $E\pi_2(\theta_1, x_1) - B(x_1)$, and the marginal (value) product of investment is thus

$$\frac{dE\pi_2(\theta_1, x_1)}{dx_1} = \int_{\theta^-}^{\theta^+} Q(p_2(\theta_2^0))\, \frac{\partial F_2(\theta_2^0 \mid \theta_1, x_1)}{\partial x_1}\, d\theta_2^0. \tag{25}$$

If the investment reduces marginal costs as in the specification considered here, the derivative in (25) is negative, so the firm will not invest when it recognizes that the regulator will fully exploit any information it has at the end of the first period.[31] If the investment were to increase the range of marginal costs, then the firm might have an incentive to invest. One would expect, however, that that incentive would be weak and that the investment would be considerably lower than that preferred by the regulator.

As suggested by this example, when the regulator cannot make credible commitments to multiperiod policies, and thus can be expected to act opportunistically in response to information obtained, the incentive for investment is nonexistent or weak at best. Since public utilities make considerable capital investments, the question is what generates the incentive to invest. Several explanations seem plausible. First, partial commitments of the type agreed to by the NYPSC and the New York Telephone Company provide the firm an opportunity to capture returns on investments with rapid recovery rates or which are fungible and can be used to provide unregulated services. This explanation is analogous to regulatory lag and allows some profits to be earned before rates are adjusted. Second, the capital recovery rule may be sufficiently protective that regulated firms are confident that the return on non-fungible assets will be forthcoming. This would be characteristic of revenue requirements regulation that provides revenue as a function of original investment. Third, the prospect of deregulation and the returns that potentially can be earned under competition can provide an incentive to invest.

Fourth, an equilibrium may result in which the regulator and the firm give and honor trust. The regulator has an incentive not to act opportunistically because it wants the firm to continue to invest to provide the capacity needed to serve a growing demand and to replace inefficient equipment and facilities. The firm has an incentive to invest because of the expectation that the regulator will forego the opportunity to take advantage of the information to confiscate profits. When the regulator does act opportunistically, the firm can punish the regulator by not investing and threatening that there will be inadequate capacity to meet demand. The regulator may then find it desirable to return to the strategy of honoring trust by not taking advantage of the firm and its non-fungible assets. This equilibrium, however, is susceptible to the short-run interests of politically ambitious regulators and legislators, particularly if they do not have to bear the long-run consequences of their opportunism. The possibility of such opportunism reduces the likelihood that such an equilibrium would be supportable. Even if such an equilibrium were attainable, the investment would likely be lower than that preferred by the regulator.

4. Monitoring: An Example

The theory presented in the previous sections is based on the assumption that the regulator is only able to observe the policy chosen or, equivalently, the price, quantity, and the fixed charges. All regulators, of course, closely monitor the accounting profits of the firms they regulate. Accounting profits are not, however, the same as the economic profits that motivate the firm, and thus accounting profits are at best a noisy monitor of true profits. When commitment is possible, the availability of a monitor may not affect the prices specified in the regulatory mechanism, but in general the fixed charges will depend on the monitor. In the absence of commitment, the monitor will also be used to update the regulator's information about the costs of the firm.

The example presented here is intended to illustrate the regulatory role of an observable monitor of performance. The example is "non-optimal" in the sense that the pricing policy in the first period is assumed to be constant over Θ, so the optimal mechanism is not characterized as in Baron and Besanko (1987b). The example focuses solely on the second period and hence does not address how the ability to observe performance might affect the first-period policy.

The example has two periods and perfectly correlated marginal costs $\theta_1 = \theta_2 = \theta$, which are uniformly distributed on the interval [0,1]. The cost C_1 incurred in the first period is assumed to be a function of θ and of a random variable that is not observed until the end of the period. The regulator is able to observe C_1, and hence it can use that observation to update its information in period two. Regulation is assumed to be governed by fairness, so the regulator is able to utilize fully this information in formulating the policy for the second period. The regulator must, however, offer a mechanism of price caps for the second period that allows the type of the firm revealed in the first period to earn nonnegative profits. The price cap p_1 in the first period is set at the beginning of the period and thus cannot be based on C_1, which is not observed until the end of the period.[32]

The first-period cost C_1 is assumed to have the form

$$C_1 = (\theta + \varepsilon_1)\, q_1 + k_1, \tag{26}$$

where q_1 is the quantity and ε_1 is the realization of a randon variable $\tilde{\varepsilon}_1$ that is uniformly distributed on the interval [0,1].[33] The marginal cost thus depends on a random component and on the private information of the firm. Conditional on θ, the density $g(C_1 \mid \theta)$ is

$$g(C_1 \mid \theta) = \frac{1}{q_1} \quad \text{if } C_1 \in [\theta q_1 + k, (\theta + 1)q_1 + k]. \tag{27}$$

The unconditional density function $g(C_1)$ is

$$\begin{aligned} g(C_1) &= \frac{C_1 - k}{q_1^2} \quad \text{if } C_1 \in [k, q_1 + k] \\ &= \frac{2q_1 + k - C_1}{q_1^2} \quad \text{if } C_1 \in [q_1 + k, 2q_1 + k]\,. \end{aligned} \tag{28}$$

If the regulatory policy in the first period pools over the interval $[\theta^-, \theta^+]$, the posterior density $f_2(\theta \mid C_1)$ at the beginning of the second period is uniform and given by

$$\begin{aligned} f_2(\theta \mid C_1) &= \frac{q_1}{C_1 - k} \quad \text{if } C_1 \in [k, q_1 + k] \\ &= \frac{q_1}{2q_1 + k - C_1} \quad \text{if } C_1 \in [q_1 + k, 2q_1 + k]\,. \end{aligned} \tag{29}$$

The support of θ, however, depends on C_1, since if $C_1 \leq q_1 + k$ then $\theta \leq \theta^*(C_1) \equiv (C_1 - k)/q_1$, and if $C_1 > q_1 + k$ then $\theta > \theta^{**}(C_1) \equiv (C_1 - q_1 - k)/q_1$.

The marginal cost in the second period is assumed to be $\theta + \varepsilon_2$, where ε_2 is the realization of a random variable $\tilde{\varepsilon}_2$ that is uniformly distributed on [0, 1]. Since the posterior density is uniform for any realization C_1, the price $p_2(\theta \mid C_1)$ set in the second period is[34]

$$p_2(\theta \mid C_1) = \theta + \frac{1}{2} + \frac{F_2(\theta \mid C_1)}{f_2(\theta \mid C_1)} = 2\theta + \frac{1}{2}$$

$$\text{if } \theta \geq \theta^*(C_1) \text{ and } C_1 \in [k, q_1 + k], \text{ and} \tag{30}$$

$$p_2(\theta \mid C_1) = 2\theta + \frac{1}{2} - \frac{C_1 - q_1 - k}{q_1}$$

$$\text{for } \theta \geq \theta^{**}(C_1) \text{ and } C_1 \in [q_1 + k, 2q_1 + k]. \tag{31}$$

Comparing (30) with (12) evaluated at $\gamma = 1$ indicates that the price in period two is higher than in the absence of a monitor if $\theta + \varepsilon_1 \leq 1$. If $\theta + \varepsilon_1 > 1$, the price from (31) can be lower than that in (12). For high realizations of cost C_1, lower prices thus result because the support of the posterior distribution is $[\theta^{**}(C_1), \theta^+]$. This reduces the marginal information costs to the regulator, and the regulator responds by reducing the price.

The rents $\pi_2(\theta \mid C_1)$ earned by the firm in period two then are given by

$$\pi_2(\theta \mid C_1) = \int_\theta^{\theta^*(C_1)} Q(2\theta^0 + \frac{1}{2})\, d\theta^0 \quad \text{if } C_1 \in [k, q_1 + k], \text{ and}$$

$$\pi_2(\theta \mid C_1) = \int_\theta^1 Q\left(2\theta^0 + \frac{1}{2} - \frac{C_1 - q_1 - k}{q_1}\right) d\theta^0$$

$$\text{for } \theta \geq \theta^{**}(C_1) \text{ and } C_1 \in [q_1 + k, 2q_1 + k].$$

The rents $\pi_2(\theta)$ in the absence of the observable performance are given by

$$\pi_2(\theta) = \int_\theta^1 Q(2\theta^0)\, d\theta^0 \quad \forall\, \theta \in [0,1].$$

The monitor of performance thus reduces the rents for low realizations of cost but may increase them for high realizations. The expected second-period rents may be greater or less than in the absence of the monitor, depending on the value of θ. Taking the expectation over θ indicates that the ex ante rents are reduced by the monitor.

Since the rents are affected, the period-one policy will be affected, but the effect is difficult to evaluate. Since the reason for pooling in the first period is that pooling reduces the information rents, intuition suggests that the availability of a monitor may reduce the incentive to pool in the first period. This would result in prices in the first period that are more responsive to first-period costs than is pricing in the absence of a monitor of performance.

The model analyzed here pertains to one regulatory jurisdiction and one regulated firm, but a commission may have authority over several firms in the same industry. In this case, monitors can be based on performance of all the firms. Since the private information of the firms is likely to be correlated, such monitors should sharpen the regulator's posterior distribution. Similarly, monitors based on firms in other jurisdictions should be employed.

Monitors of performance can improve the efficiency of regulatory mechanisms in several ways. First, a monitor can reduce the rents of the firm by "tightening" the posterior distribution of marginal cost.[35] Second, a monitor can affect pricing by altering the marginal information costs. Third, if the firm were risk-averse, a monitor could be used to relieve the firm of some risk.

These benefits suggest that monitoring can be an important function of a regulator when a price cap or delegation mechanism is employed. From a positive perspective, more active monitoring by a regulator would be expected to be correlated with an inability to make credible commitments. That is, monitoring is likely to be more valuable the more likely the regulator is to act opportunistically in response to information obtained through the observation of performance.

5. Conclusions

A variety of factors complicate the application of the principles addressed here. The major complicating factor is incompleteness of the policies due to unanticipated events and the costs of writing complex contingent policies. The theory presented above is based on the assumption that all possible events are known to the regulator and to the firm and their likelihood of occurrence is representable by a probability distribution. In addition, if complexity and its associated costs preclude writing policies that are conditioned on each possible event or possible value of a cost parameter, the regulatory policies will be incomplete. In either the case of incompleteness or when there are unanticipated events, ex ante efficiency may be enhanced by allowing revisions in policies. What is needed are practical means to permit changes in regulatory policies when those changes promote ex ante efficiency and to preclude changes in policies when that would reduce ex ante efficiency.

In terms of the evaluation of regulatory performance, the analysis presented here implies that it is the regulatory mechanism that should be the subject of the evaluation. The optimality of a regulatory mechanism is a function of 1) the information available to the regulator, 2) the transition function that governs how the costs of the firm are anticipated to evolve over time, 3) and the extent to which commitments can be made credible. If credible commitments can be made, the framework presented in Sections 2.2 and 3.1 provides the basis for the evaluation. An important conclusion from this theory is that a search for ex post efficiency is likely to be misleading. A second conclusion is that even under delegation, administrative rules that provide a degree of commitment can improve efficiency. A capital recovery rule, for example, can reduce strategic behavior in addition to providing a fair return.

If credible commitments cannot be made, the cause of that inability must be assessed. If it is due to the policies of the regulator, then the consequences are attributable to the efficiency of regulation. If, however, the source of the inability to make credible commitments is due to other factors, such as opportunism by a legislature, then its consequences should be evaluated separately.

Appendix

Sunk Costs, the Inability To Commit, and Implementable Policies

For the case in which the marginal costs of the firm are perfectly correlated ($\theta_1 = \theta_2 = \theta$), Laffont and Tirole (1988) have demonstrated that the regulator is unable to implement any regulatory policy that is continuously responsive to costs over any interval of possible costs that has positive probability. This results because of a conjunction of the conditions required for responsive pricing and the expanded strategy set of the regulated firm when it can make a participation decision in each period. Since the firm has a natural incentive to overstate its costs in an attempt to obtain a more profitable regulatory policy (i.e., to choose a policy intended for a higher cost type), the regulator must specify the fixed charges to offset that incentive. To do so in a multiperiod model in which the regulator cannot commit credibly to future policies, the policy in the first period must include a payment that offsets for both periods the incentive to select a policy designed for a higher cost type. The rent $\Pi(\theta)$ required to implement any prices $(p_1(\theta), p_2(\theta))$ is thus

$$\Pi(\theta) = \int_{\theta}^{\theta^+} [Q(p_1(\theta^0)) + \beta Q(p_2(\theta^0))]\, d\theta^0.$$

If the firm were to select the policy defined for its marginal cost, the regulator in the second period would, knowing the marginal cost θ, choose a policy of marginal cost pricing (i.e., $(p_2(\theta) = \theta, T_2(\theta) = k_2)$), which yields the firm a zero profit. If the firm selected $\hat{\theta} \neq \theta$ and produced in the second period, the rent $\pi_2(\hat{\theta}; \theta)$ in the second period would thus be

$$\pi_2(\hat{\theta}; \theta) = (\hat{\theta} - \theta)\, Q(\hat{\theta}),$$

which is negative if in the first period the firm selected a pricing policy intended for a $\hat{\theta}$ less than θ.

Because the firm can always limit its period-two profit to zero by refusing to participate in the second period, its two-period profit $\Pi(\hat{\theta};\theta)$ is

$$\Pi(\hat{\theta};\theta) = (\hat{\theta} - \theta)Q(p_1(\theta)) + \int_{\hat{\theta}}^{\theta^+} [Q(p_1(\theta^0)) + \beta Q(p_2(\theta^0))]d\theta^0$$
$$+ \beta \max\{0,(\hat{\theta} - \theta)Q(p_1(\hat{\theta}))\}.$$

Given this profit function, the firm finds it optimal to underreport ($\hat{\theta} < \theta$) its costs in the first period and then not to participate in the second period in order to avoid having to produce at a loss.[36] This conclusion holds for all intervals of marginal cost, so no policy that is continuously responsive to costs on any interval can be implemented.

In the case of a regulated firm with long-lived assets that are sunk and non-fungible, the capital recovery rules used by regulatory commissions may eliminate the problem identified by Laffont and Tirole. A capital recovery rule is taken here to be a rule enforceable under administrative law that entitles the firm to recover an asset's cost according to a prescribed schedule as long as the firm continues to produce the quantity specified in the regulatory policy. Suppose that the firm has a sunk investment $B(x_0)$ prior to period one, and suppose that an enforceable recovery rule allows the firm to recover that cost at a constant rate over the n-period life of the asset. In a two-period model, the cash flow in the second period is now $\frac{1}{2}B(x_0)$ if the firm continues to participate under a marginal cost pricing policy. The firm's two-period profit $\Pi^*(\hat{\theta};\theta)$ is thus

$$\Pi^*(\hat{\theta};\theta) = (\hat{\theta} - \theta)\, Q(p_1(\hat{\theta})) + \int_{\hat{\theta}}^{\theta^+} [Q(p_1(\theta^0)) + \beta Q(p_2(\theta^0))]\, d\theta^0$$
$$+ \beta \max\{0, \tfrac{1}{2} B(x_0) + (\hat{\theta} - \theta)\, Q(p_1(\hat{\theta}))\}.$$

If the sunk assets are sufficiently great, the incentive to underreport costs in the first period and not participate in the second period may be outweighed, allowing the regulator to implement a policy even if it cannot commit to its pricing policy in the second period. This results because a capital recovery rule provides a limited form of commitment that allows compensation to be deferred.[37,38]

The significance of sunk, non-fungible assets and a capital recovery rule is that in the absence of commitment the regulator may be able to implement a regulatory policy that is continuously responsive to costs. In particular, it may allow the regulator to implement a policy that fully exploits the information revealed in the first period. Such a policy is not generally optimal, however, as indicated above.

Notes

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1. This theory has been surveyed by Baron (1989), Besanko and Sappington (1988), Caillaud, Guesnerie, Rey, and Tirole (1988), and Sappington and Stiglitz (1986). Recent work by Demski, Sappington, and Spiller (1986) has extended the theory to include a market alternative to regulation.

2. The experience with incentive regulatory systems is reviewed by Schmidt (1984) and Joskow and Schmalensee (1986).

3. Even apparently conclusive legislation establishing regulatory policy may not survive subsequent electoral politics. As Kahn (1987, 18) states, "What of the possibility, finally, of total deregulation of local service? Nebraska has in fact passed a law—which is, incidently, the subject of strenuous Constitutional challenge—imposing a ceiling of ten percent per year on rate increases for local telephone service, subject to regulatory review if specified percentages of subscribers complain—and providing for total deregulation at the end of five years. I find it unsurprising that the bill's sponsor was just defeated in his bid for reelection, obtaining only 38 percent of the vote."

4. Helman refers to three incidents that, although their "overall revenue effects were small," attracted public, staff, and commission attention. One was an incentive compensation system for management, and another was the purchase of a Lear jet that management claimed would reduce transportation expenses. The third was the decision by management not to file a product liability suit to recover a $250,000 insurance deductible.

5. See Schmidt (1984).

6. In practice, regulatory behavior responds to unanticipated events, but the theory addressed here cannot accommodate such events.

7. The static theory is presented in Baron and Myerson (1982), Guesnerie and Laffont (1984), Laffont and Tirole (1986), and Sappington (1982). The dynamic theory is presented in Baron and Besanko (1984, 1987) and Laffont and Tirole (1986).

8. Sappington (1983) presents a single-period, multiproduct theory in a related model.

9. The fixed charge is assumed not to affect demand.

10. The model involves no unanticipated events, so the regulator can in principle choose a policy at time zero and have it govern subsequent decisions for the entire horizon.

11. The policy selected is the only variable observable to the regulator.

12. The optimal regulatory mechanism in the case of commitment is characterized in Baron and Besanko (1984).

13. The model can be extended directly to the case in which the regulator maximizes a weighted average of consumer and producer surplus. The optimal mechanism has the same qualitative properties as that considered here.

14. An important issue is whether in a regulatory context a firm has a property right to its information about its costs. If so, the firm may be viewed as having a right to reveal its information only in exchange for adequate compensation. The information rents thus may be viewed as the return extracted by the firm for its information. In a regulatory setting, the regulator has the authority to minimize those rents by making a take-it-or-leave-it offer, but the regulator has to trade-off rent reduction against the efficiency of the regulatory policy.

15. If the firm had an unobservable effort decision a_t to make where marginal cost was $c(\theta_t, a_t)$, the firm will choose its effort $a_1(\theta_1)$ to satisfy

$$-c_a(\theta_1, a_1(\theta_1))Q(p_1(\theta_1)) - V'(a_1(\theta_1))=0,$$

where $V'(a_1(\theta_1))$ is the marginal disutility of effort. This is the same effort level the regulator prefers, so with commitment the effort decision can be delegated to the firm. The same is true for the second period. See Baron (1987), Section IV.F, for an analysis of this case. This result would differ if the model were formulated with an ex post monitor z, so that the fixed charges could be based on both $\hat{\theta}$ and z. Laffont and Tirole (1986) consider such a case and show that the regulator will base prices on the monitor as a means of reducing the information rents. Baron and Besanko (1987a, 1988) consider a similar model with a risk-averse manager.

16. The investment x_1 is assumed to be zero here.

17. This is derived by substituting (8) into (7a), integrating by parts, and maximizing pointwise with respect to $p_1(\theta_1)$.

18. See Baron and Myerson (1982) or Baron (1989) for a demonstration of the optimality of this mechanism.

19. This conclusion is based on the condition that prices $p_t(\hat{\theta})$ are below the monopoly price for all θ_1. This condition seems reasonable, but it is possible from (9) that the regulator would prefer a price above the monopoly price as a means of economizing on the information rents.

20. If the costs were independent across periods, the optimal price cap would be the price in (9) for the first period and in each subsequent period a cap equal to marginal cost. The optimal one-period price is implemented in the first period because the firm has the same informational advantage in the first period as in the single-period model. At the beginning of the regulatory horizon, however, the firm has no informational advantage relative to the regulator about the cost in any future period. The firm thus can earn no information rents associated with its operations in future periods, so the regulator need not trade off efficiency against rent control. The regulator thus implements a marginal cost price cap in every period after the first. Since the firm observes its cost at the beginning of each period and the regulator does not observe it, the regulator still must implement marginal cost pricing by employing in every period a self-selection mechanism. The firm earns rents in that period, but the regulator can costlessly eliminate those rents by charging in the previous period a "franchise fee" equal to the discounted expectation of the future rents. Thus, other than for the first period the rents do not affect the pricing policy.

21. The optimality of the mechanisms characterized here requires verification of global incentive compatibility conditions. See Baron (1987) and Guesnerie and Laffont (1984) for an analysis of these conditions. With commitment and perfectly correlated marginal costs, the condition that $\theta + F(\theta)/f(\theta)$ be nondecreasing in θ is sufficient for global incentive compatibility. In other cases, the specification of sufficient conditions is more complicated.

22. This follows from Baron and Besanko (1984).

23. Fairness is directed to the incentive the parties have to revise regulatory policies once information has been revealed either by self-selection or by performance. An inability to ignore this incentive prevents the implementation of efficient policies in prior periods. For an example, Baron and Besanko demonstrate that both the firm and the regulator may prefer to abide by a regulatory relationship characterized by fairness than to participate in one in which commitment is not possible. Administrative rules and the courts, however, are required to make the fairness agreement credible.

24. Even though continuously responsive prices can be implemented, the regulator may not find them to be optimal but instead may prefer a coarse pricing policy in which different price caps are specified for different sets of possible costs.

25. The price with commitment may be higher than the price with fairness. Consider a triangular distribution $f_1(\theta_1) = 2(1 - \theta_1)$ if $\theta_1 \in [0,1]$. Then, the period-two price cap with commitment is $p_2^*(\theta_2, \theta_1) = [\theta_2/(1 - \theta_1)]\,[2 - \tfrac{3}{2}\theta_1]$, which is greater than the price with fairness for all θ_1 and θ_2 such that $\theta_1\theta_2 > 0$.

26. With an inability to commit, the effort chosen by the firm will again be second-best efficient. That is, in each period the firm simultaneously chooses the pricing policy and effort a_t given the mechanism M_t. The effort choice is efficient given the pricing policy p_t^0.

27. Equation (20a) can also be written as

$$\beta \frac{\theta_2}{\theta_1} p_2(\theta_1)\, Q(p_2(\theta_1)) - B'(x_1(\theta_1)) = 0.$$

The marginal benefit from investment is thus the proportionate reduction in the variable cost.

28. The information rents are decreasing in the investment because investment reduces the range of costs to which the regulator must respond. The rents $\Pi(\theta_1)$ are

$$\Pi(\theta_1) = \int_{\theta_1}^{\theta^+} [Q(p_1(\theta_1^0)) + \frac{\beta Q(p_2(\theta_1^0))}{1 + x_1(\theta_1^0)}]\, d\theta_1^0.$$

29. The investment level is given by the expression in (21) with the 2 replaced by 1.

30. The opportunism of the regulator here pertains only to information and because of the fair return requirement does not involve confiscation of second-period quasi-rents on the (sunk) investment made in the first period.

31. It is important to note that the firm would still be provided a fair return in this case through the amortization of $B(x_1)$. If a capital recovery rule were in effect, then $B(x_1)$ would be recovered over some set of periods.

32. The fixed charges T_1 can be based on the monitor.

33. The mechanism M_1 is the pair ($q_1 = Q(p_1)$, $T_1 = T_1^*$), where T_1^* is a constant, so there is no self-selection in the first period.

34. The term $\theta_1+½$ is the expectation of marginal cost.

35. If commitment were possible, the regulator would implement prices $p_t(\theta) = 2\theta + ½$, $t = 1, 2$.

36. Technically, the incentive compatibility constraints bind both upwards and downwards.

37. If the asset were fungible so that the firm could earn $½B(x_0)$ on the asset employed elsewhere, the capital recovery rule would be ineffective in limiting the incentive to underreport costs.

38. This effect is offset if the firm has financed the asset with debt on which the firm could default. For example, suppose that an η share of $B(x_0)$ is financed with debt with a repayment schedule with half repaid in each period. The cash flow of the owners of the firm is then only $½(1 - \eta)\, B(x_0)$, which provides a diminished incentive to participate in the second period.

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