Natural Monopoly Regulation in the Presence of Cost Misreporting

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Abstract

This paper explores the implications of asymmetric cost information within the context of a regulated natural monopoly. The paper provides a unifying framework for the analysis of cost padding and exaggeration, both of which are referred to simply as misreporting of costs. The paper studies the incentives embedded in the regulatory regime itself and shows how simple comparative statics may be useful in detecting falsification of the cost report which the regulated firm must submit to the regulator. (JEL L43)

Introduction

This paper explores the implications of asymmetric information under both marginal cost pricing (MCP) and average cost pricing (ACP) regulation. Two related aspects of the asymmetric information problem are noteworthy. Tollison and Wagner [1991] have argued that due to lack of information on the part of the regulator, the regulated firm could be expected to allow observed expenses to increase in such a way as to yield the profit maximizing outcome. The only difference between the regulated and the unregulated outcome is that, in the absence of regulation, the monopoly rents are received directly by the firms' ownership, whereas, in the regulated setting, these rents are received indirectly by owners and managers as they are dissipated by incurring expenditures that generate something of a positive value. The firm is engaging in cost padding and thereby incurring costs that are not in the best interest of the consumers of its product.

Related to this is the notion that since the regulator must rely to some extent on the firm to report its costs, the monopolist has an incentive to exaggerate these costs in an attempt to approximate the unregulated profit maximum [Sappington, 1980; Baron, 1989; Joskow and Rose, 1989].

This paper provides a unifying framework for the analysis of cost padding and exaggeration, both of which are referred to simply as misreporting. The paper develops a model of regulation in which the regulator is imperfectly informed regarding the firm's cost function. Both the MCP solution and the ACP solution are analyzed within the context of this model and the model is applied to the case discussed by Tollison and Wagner [1991]. The paper then employs a linear-quadratic version of the model, based on Berg and Tschirhart [1988], to generate additional insights into the nature and consequences of the incentives created by the regulatory process. Among other things, the paper demonstrates how simple comparative statics may be useful in detecting falsification of the firm's cost report.

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It is now an accepted definition that a firm is a natural monopoly if and only if its cost function $C(q)$ is subadditive in the sense that:

$$C\left(\sum_{i=1}^{N} q^i\right) < \sum_{i=1}^{N} C\left(q^i\right)$$

for all quantities q^1,..., q^N for which:

$$\sum_{i=1}^{N} q^i = q$$

[Sharkey, 1982, p. 58]. A firm whose cost function is subadditive can produce any given output level at a lower cost than that incurred by two or more firms whose aggregate production equals the same given output level. Thus, subadditivity insures that the total cost will be the lowest when there is a single supplier serving the market. It should be noted that economies of scale (decreasing average cost (AC)) implies but is not implied by subadditivity.

Taking the sum of consumer surplus and profit as a welfare measure, the equality of price (p) and marginal cost (MC) is a necessary condition for welfare maximization. The profit maximizing monopolist will not set $p = MC$. Therefore, regulation is typically justified. If the regulator imposes the $p = MC$ solution and $MC < AC$ due to economies of scale, then the monopolist is not financially viable and therefore, must receive a subsidy that is sufficient to permit break-even operation. Subsidization is often politically controversial, however, so the regulator may, as an alternative, permit the firm to set $p = AC$. Although, there is thus a welfare loss (relative to the $p = MC$ ideal), the firm is financially viable and subsidization is unnecessary.

There are a number of ways in which asymmetric information may arise and affect the implementation of both the MCP and the ACP solution discussed above. One very significant way is that some aspects of the regulated firm's production technology may be unknown to the regulator. Baron and Myerson [1982] derive the optimal regulatory policy—when the regulator can set prices and provide subsidies but must rely on the firm to report a critical cost parameter. This model assumes that it is prohibitively costly for the regulator to observe the firm's costs, i.e, no auditing is permitted. Baron [1984] and Baron and Besanko [1984] derive the optimal regulatory policy in a similar context when, for a fixed fee, the regulator can audit the firm's realized costs. These models employ the Revelation Principle, which allows the policy maker to focus on policies that induce truthful reporting of costs [Myerson, 1979; Harris and Townsend, 1981].

Rate-of-return regulation is the formal mechanism by which ACP is typically enforced. A number of potential difficulties with rate-of-return regulation have been identified. For example, it has been shown that rate-of-return regulation creates incentives for the regulated firm to misreport its costs, choose inefficient technologies, undertake cost reducing innovation inefficiently, and view diversification issues inefficiently [Averch and Johnson, 1962; Braeutigam and Panzar, 1989; Tollison and Wagner, 1991; Blackmon, 1994]. In view of these problems, price caps and other forms of incentive regulation (revenue-sharing plans, earnings-sharing plans, etc.) have gradually supplanted rate-of-return regulation in many regulated industries, such as telecommunications. Indeed, the previously mentioned problems associated with rate-of-return regulation have mitigated or have been entirely eliminated under these incentive regulatory schemes [Braeutigam and Panzar, 1989, 1993].

In spite of the potential difficulties associated with the implementation of MCP and ACP regulation, they remain important topics for research. MCP remains important because it represents a first-best optimum and, as the theoretical ideal, economic theory should be able to contribute to one's understanding of why it is not feasible, even if nondistortionary subsidies can be provided [Sheshinski, 1986, p. 1251]. ACP remains important for several reasons. First, traditional rate-of-return regulation is still employed by governmental authorities in other countries to regulate public utilities and natural monopolies [Carlton and Perloff, 2000, p. 676; Kidokoro, 1998]. Second, it has been argued that rate-of-return regulation may perform well in situations where uncertainties are minimal and prospects for new and improved goods and services are limited [Sappington and Weisman, 1996]. Third, consumers as well as firms can often benefit if the regulated firm is given a choice between incentive regulation (price caps) and rate-of-return regulation, thus permitting the regulated firm to select the regulatory regime that it prefers [Sappington and Weisman, 1996; Donald and Sappington, 1997]. Finally, when making a transition from rate-of-return regulation to price caps, the price level under rate-of-return regulation has direct implications for the level of the subsequent price cap [Train, 1991, p. 327]. In view of these considerations, MCP and ACP and their attendant advantages and disadvantages merit continued study.

A Framework for the Analysis of Cost Misreporting

Consider now a natural monopoly that seeks to exploit the profit-making opportunities offered by the regulatory regime it faces. Suppose that the firm and the regulator know market demand $p(\alpha, q)$, where $\alpha = (\alpha_1, ..., \alpha_N)$ is a vector of parameters. The firm has the true cost function $C^T(\beta, q)$, where $\beta = (\beta_1, ..., \beta_m)$ is a vector of parameters. To capture the fact that the regulator is imperfectly informed regarding this cost function, this model assumes that the regulator knows the form of C^T,except for one parameter value.[1] This unknown parameter value must be reported to the regulator by the monopolist. As a notational convenience, let $\beta = (\beta_i, \overline{\beta_i})$, where $\overline{\beta_i}$ denotes all coordinates of β except β_i. Then, $C^T(\beta, q) \equiv C^T(\beta_i, \overline{\beta_i}, q)$. Suppose that $\overline{\beta_i}$ is known by the regulator and that the firm seeks to exploit the regulatory regime by misreporting β_i. To make this notion precise, suppose that the monopolist selects a real number $(k > 0)$ and reports parameter (i) to be $k\beta_i$. By implication, the monopolist's reported cost function is $C^R(k\beta_i, \overline{\beta_i}, q)$. Furthermore, the firm is reporting truthfully if and only if $k = 1$, in which case $C^R = C^T$. The firm is assumed to report the value of k that best allows the exploitation of the profit-making opportunities contained in the regulatory constraints under which it is operated. Thus, k represents a measure of the extent to which actual costs are padded or reported costs are exaggerated.

First, suppose all functions are appropriately differentiable and that the monopolist operates under a MCP regime with subsidization. The firm will then solve P1.

$$\underset{k,q}{Maximize}\ p(\alpha, q)q - C^T(\beta,\ q) + s \quad , \tag{P1}$$

subject to:

$$\begin{aligned} p(\alpha, q) &= MC^R(k\beta_i, \overline{\beta_i}, q) \\ s &= C^R(k\beta_i, \overline{\beta_i}, q) - p(\alpha, q)q \\ s &\geq 0 \end{aligned}$$

where $MC^R(k\beta_i, \overline{\beta_i}, q) = \partial C^R(k\beta_i, \overline{\beta_i}, q)/\partial q$. Here, the firm maximizes its true profit (including the subsidy) given that the regulator sets the price and subsidy on the basis of the reported information. (Ex-post auditing by the regulator to determine whether any misreporting has occurred is assumed to be impossible.)[2]

In general, one expects $s > 0$ at the solution. Therefore, to characterize the solution to $P1$, form the Lagrangian function

$$\begin{aligned} L(k,q,\lambda) &= p(\alpha,q)q - C^T(\beta,q) + C^R(k\beta_i,\overline{\beta_i},q) - \\ & \quad p(\alpha,q)q + \lambda\left[p(\alpha,q) - MC^R(k\beta_i,\overline{\beta_i},q)\right] \quad , \end{aligned}$$

where λ denotes the Lagrange multiplier and the constraint s $= C^R(k\beta_i,\overline{\beta_i},q) - p(\alpha,q)q$ has been substituted into the objective function. The first-order necessary conditions for an interior maximum, assuming that the relevant second-order sufficient condition holds are:

$$\begin{aligned} L_k &= \left(C^R_{k\beta_i}\right)\beta_i - \lambda\left(MC^R_{k\beta_i}\right)\beta_i = 0 \\ L_q &= p + qp_q - C^T_q + C^R_q - p - qp_q + \lambda\left[p_q - MC^R_q\right] = 0 \\ L_\lambda &= p(\alpha,q) - MC^R(k\beta_i,\overline{\beta_i},q) = 0 \quad , \end{aligned} \tag{1}$$

where the subscripts denote partial derivatives. Now $p + qp_q = MR =$ marginal revenue, so (1) may be written as:

$$MR - MC^T = (MR - MC^R) - \lambda(p_q - MC^R_q)$$

which, generally will not equal zero. Therefore, the conventional profit maximization condition will not be satisfied in the presence of cost misreporting under MCP.

Now, let $\pi = pq - C^T$. Observe that the firm can always achieve $\pi + s = 0$ by reporting truthfully ($k = 1$). Thus, if $k \neq 1$, $\pi + s > 0$. But $\pi + s = C^R - C^T$, so $\pi + s > 0$ implies $C^R > C^T$ and one observes that, as expected, costs are inflated *via* misreporting.

Alternatively, suppose the firm is operated under an ACP regime. Furthermore, suppose that the firm's profit function $\pi(\alpha,\beta,q) = p(\alpha,q)q - C^T(\beta,q)$ is a strictly concave function of q and attains a unique global maximum at $\hat{q} > 0$ with $\pi(\alpha,\beta,\hat{q}) > 0$. The firm then solves problem P2.

$$\underset{k,q}{Max}\; p(\alpha,q)q - C^T(\beta,q) \quad , \tag{P2}$$

subject to:

$$p(\alpha,q) = AC^R(k\beta_i,\overline{\beta_i},q)$$

where $AC^R(k\beta_i,\overline{\beta}_i,q) = C^R(k\beta_i,\overline{\beta_i},q)/q$. In this case, the firm maximizes true profit, given that the regulator sets price equal to the reported average cost.
To characterize the solution to P2, form the Lagrangian function:

$$L(k,q,\lambda) = p(\alpha,q)q - C^T(\beta,q) + \lambda[p(\alpha,q) - AC^R\left(k\beta_i,\overline{\beta_i},q\right)]$$

The first-order necessary conditions for an interior maximum are:

$$\begin{aligned} L_k &= \lambda\left[-\left(AC^R_{k\beta_i}\right)\beta_i\right] = 0 \\ L_q &= p + qp_q - C^T_q + \lambda\left[p_q - AC^R_q\right] = 0 \\ L_\lambda &= p(\alpha,q) - AC^R\left(k\beta_i,\overline{\beta_i},q\right) = 0 \quad . \end{aligned} \tag{2}$$

Since $\beta_i \neq 0$ and $AC^R_{k\beta_i} \neq 0, \lambda = 0$. Therefore, (2) implies that $p+qp_q = C^T_q$ or $MR = MC^T$. Thus, the first-order necessary condition for profit maximization is satisfied. Further, owing to the concavity of π, $MR = MC^T$ is satisfied only at $\hat{q}$. Therefore, it can be concluded that under the ACP regime, with cost misreporting, the regulated firm produces precisely the same output level and earns the same profit that it would earn in the complete absence of regulation. For examples of other models where manipulation of the ACP regulatory scheme can result in the regulated firm achieving the unregulated profit maximum, see Averch and Johnson [1962]; Braeutigam and Panzar [1989].

Now, let $\hat{\pi} = \pi(\alpha, \beta, \hat{q})$. Since $\hat{\pi} > 0$, it follows that $p(\underline{\alpha}, \hat{q}) > AC^T(\beta, \hat{q})$. Since the regulator sets price equal to reported average cost, $AC^R(k\beta_i, \overline{\beta}_i, \hat{q}) > AC^T(\beta, \hat{q})$ and hence, $C^R > C^T$. Therefore, as in the case of MCP, costs are inflated *via* misreporting.

As a simple application of the model, consider the linear model discussed by Tollison and Wagner [1991]. Let demand and cost be given by:

$$\begin{aligned} p &= c - dq \quad c, d > 0 \\ C^T &= aq \qquad a > 0,\ a < c \end{aligned}$$

and let $C^R = kaq$. Owing to the linearity of the model, the ACP and MCP regimes are identical.

Suppose that the regulator and the firm knows the equation of the demand curve, but that the regulator is imperfectly informed regarding the firm's cost function. Specifically, assume that the regulator only knows that the firm's true cost function is linear with no fixed costs. The monopolist reports the parameter in the cost function to be ka, and thus the regulator sets $p = c - dq = ka$, which implies $q = (c - ka)/d$. The firm knows that the regulator will set price in this manner and therefore, selects k to solve:

$$\begin{array}{l} Maximize (c - dq)q - aq + s \\ k \end{array}$$

subject to:

$$\begin{aligned} q &= \frac{c - ka}{d} \\ s &= kaq - (c - dq)q \end{aligned}$$

Substituting the constraints into the objective function and simplifying yields $\pi(k) = a(k - 1)(c - ka)/d$ as the monopolist's objective function. Setting the derivative $\pi'(k) = 0$ yields $k^* = (c + a)/2a$. Therefore, the firm reports $C^R = \left(\frac{c+a}{2}\right) q$ to the regulator.

The regulator sets $p = MC^R$, which implies that $q^* = (c - a)/2d$ and $p^* = (c + a)/2$. However, these are precisely the profit maximizing price and quantity for the monopolist. As argued by Tollison and Wagner [1991], the firm has succeeded in exploiting the regulatory process, yielding as the ultimate outcome the monopoly equilibrium.

In the present formulation of the problem, it is assumed that the regulator requires the firm to report the parameter in the cost function. However, assuming that the regulator can observe the firm's output level, this requirement is formally equivalent to requiring the firm to report total cost. Within the context of the above example, this follows directly from the fact that $C^R=\left(\frac{c+a}{2}\right)q$, if and only if $ka = \frac{(c+a)}{2}$. Thus, the process may be viewed as one in which the regulator asks the firm to report total cost, infers marginal cost on the basis of reported total cost, knowledge of the form of C^T, and the observed output level and then sets price equal to the inferred value of marginal cost.

In the following section, this paper employs a linear-quadratic model suggested by Berg and Tschirhart [1988] to gain additional insights into the implications of the incentives created by the regulatory process itself. In this more general model, the MCP and the ACP solution are distinct. Using simple comparative statics analysis, this paper demonstrates how the regulator's knowledge of the cost function's subadditivity can affect the firm's ability to implement the solutions to P1 and P2.

Optimal Misreporting Under Alternative Regulatory Regimes

In this section, the paper employs a linear-quadratic model of regulation to gain insights into the nature and consequences of the incentives created by the imposition of MCP or ACP on a natural monopoly. Begin by assuming the following structure.

$$\begin{aligned} C^T(a,b,q) &= aq - \frac{b}{2}q^2 & a,b > 0 \\ p(c,d,q) &= c - dq & c,d > 0, d > b, c > a \end{aligned}$$

The function C^T is the firm's true cost function where a and b are parameters known only to the firm. It is straightforward to demonstrate that C^T is subadditive. The function $p(c,d,q)$ is the market demand for the monopolist's output where c and d are parameters known both to the firm and the regulator. This paper shall refer to a situation in which c increases as a slope-preserving increase in demand.

Begin by noting the three solutions of the model presented in Table 1. An asterick (*) is used to denote the solution values of the variables in all models. The calculations necessary to obtain the information in Table 1 are routine and omitted for brevity.

TABLE 1
Solutions Under Truthful Reporting of Cost

	Unregulated (Profit Maximization) (p^*,q^*) determined by $MR = MC^T$	MCP, Truthful Reporting (p^*,q^*) determined by $p = MC^T$	ACP, Truthful Reporting (p^*,q^*) determined by $p = AC^T$
Output	$q^*=\frac{c-a}{2d-b}$	$q^*=\frac{c-a}{d-b}$	$q^*=\frac{2c-2a}{2d-b}$
Price	$p^*= c - d\left(\frac{c-a}{2d-b}\right)$	$p^*= c - d\left(\frac{c-a}{d-b}\right)$	$p^*= c - d\left(\frac{2c-2a}{2d-b}\right)$
Profit	$\pi^*=\frac{(c-a)^2}{2(2d-b)}$	$\pi^*+s^*= 0$	$\pi^* = 0$

The regulator's imperfect information regarding the firm's cost function may arise in different ways. To allow for this possibility, two scenarios are considered. The regulator may know the form of C^T and the value of parameter b, but requires the firm to report the value of parameter a. In this case, by implication, the reported cost function is $C^R(ka,b,q) = kaq - (b/2)q^2$. Alternatively, the regulator may know the form of C^T and the value of parameter a but requires the firm to report the value of parameter b. In this case, by implication, the reported cost function is:

$$C^R(a,kb,q) = kaq - (bk/2)q^2 \quad .$$

The paper considers both the possibilities within the context of both MCP and ACP. Again, it should be noted that the process may be viewed as one in which the regulator asks the firm to report total cost, infers marginal or average cost on the basis of reported total cost, knowledge of the form of C^T, and the observed output level, and then sets price equal to the inferred value of marginal or average cost.

The solutions to the models are obtained in the manner described in the previous section. The models are referred to as MCP:a, MCP:b, ACP:a, and ACP:b, indicating both the type of regulatory policy and the parameter that is misreported. To demonstrate, consider model ACP:b. Here, the regulator asks the firm to report parameter b and then uses this information to set price equal to average cost. Knowing that the regulator will do this, the monopolist will select $k > 0$, report the parameter to be kb and by implication, the reported cost is:

$$C^R(a, kb, q) = aq - \left(\frac{bk}{2}\right) q^2 \quad .$$

To select the value of k optimally, the firm solves:

$$\underset{k,q}{Maximize}\ \pi = (c - dq)q - \left(aq - \frac{b}{2}q^2\right),$$

subject to:

$$c - dq = a - \frac{bk}{2}q$$

where $a - \left(\frac{bk}{2}\right) q = AC^R =$ reported average cost.
Solving the constraint for the output level yields:

$$q = \frac{2c - 2a}{2d - bk} \quad .$$

Simplifying the objective function yields:

$$\pi = (c - a)q + \left(\frac{b}{2} - d\right) q^2 \quad .$$

Substituting the above value of q into π and maximizing with respect to k yields:

$$k^* = \frac{(2b - 2d)}{b} \quad .$$

Thus, the reported cost function is:

$$C^R = aq - \left(\frac{bk^*}{2}\right) q^2 = aq - (b - d)q^2 \quad ,$$

and it is upon this information that the regulator bases all calculations. It should be noted that the second-order sufficient condition for a profit maximum requires $2d > b$, which implies that $C^R > C^T$ and that the monopolist is indeed over-reporting (exaggerating cost). The complete solutions to the models are presented in Table 2.

TABLE 2
Solutions Under Strategic Misreporting of Cost

	MCP:a	ACP:a	MCP:b	ACP:b
Output	$q^*=\frac{c-a}{2(d-b)}$	$q^*=\frac{c-a}{b-2d}$	$q^*=\frac{c-a}{2(d-b)}$	$q^*=\frac{c-a}{2d-b}$
Price	$p^*=c-\frac{d}{2}\left(\frac{c-a}{d-b}\right)$	$p^*=c-d\left(\frac{a-c}{b-2d}\right)$	$p^*=c-\frac{d}{2}\left(\frac{c-a}{d-b}\right)$	$p^*=c-d\left(\frac{c-a}{2d-b}\right)$
Profit	$\pi^*+s^*=\frac{(c-a)^2}{4(d-b)}$	$\pi^*=\frac{(a-c)^2}{2(2d-b)}$	$\pi^*+s^*=\frac{(c-a)^2}{8(d-b)}$	$\pi^*=\frac{(c-a)^2}{2(2d-b)}$
Reported Parameter Value	$k^*a=\frac{c+a}{2}$ $\left(k^*=\frac{c+a}{2a}\right)$	$k^*a=\frac{c+a}{2}$ $\left(k^*=\frac{c+a}{2a}\right)$	$k^*b=2b-d$ $\left(k^*=\frac{2b-d}{b}\right)$	$k^*b=2b-2d$ $\left(k^*=\frac{2b-2d}{b}\right)$
Reported Cost	$MC^R=\left(\frac{c+a}{2}\right)-bq$	$AC^R=\left(\frac{c+a}{2}\right)-\frac{bq}{2}$	$MC^R=a-(2b-d)q$	$AC^R=a-(b-d)q$

Discussion

A series of observations regarding the solutions to the models is presented.

Observation 1

Note that in models *MCP:a* and *ACP:a*, $k^* > 1$. Conversely, in models *MCP:b* and *ACP:b*, it was shown that $k^* < 1$. Hence, in the former case, the monopolist inflates the reported value of parameter a. In the latter case, the monopolist deflates the reported value of b. However, as demonstrated in the general model in the previous section, in all cases $C^R > C^T$and thus, reported cost is overstated. One observes therefore that, depending on the manner in which a parameter unknown to the regulator enters the cost function, its reported value may be overstated or understated, but that in all cases, overall cost is exaggerated. In general, if:

$$\frac{\partial C^T}{\partial \beta_i} < 0(> 0) \quad ,$$

β_i will be deflated (inflated).

Observation 2

Note the somewhat counter-intuitive result that if $b > 2d/3$, the profit earned under *MCP:b* exceeds the unregulated profit maximum. Moreover, this result always holds for *MCP:a* since $b > 0$. The monopolist is able to earn profit in excess of the unregulated profit maximum due to the fact that the reported parameter value determines the value of the subsidy as well as the regulated price. While the notion of providing a subsidy to a privately owned firm is not politically realistic, the notion of providing a subsidy to a firm with informational advantages that permit manipulation of the size of the subsidy are even less so. Moreover, this example illustrates that even if non-distortionary lump-sum taxes may be levied to finance the (overstated) deficit, with $p^* > MC^T(a, b, q^*)$, a welfare loss (relative to the full information *MCP* solution) will occur.

It may also be observed that under either *ACP* regime, the unregulated profit maximum may be obtained, as demonstrated in the previous section. Therefore, one concludes that the regulated firm (1) may have a basis for a preference between *MCP* and *ACP* regulation, (2) could prefer *MCP* to an unregulated environment, and (3) will be indifferent between no regulation and *ACP* if its informational advantages and ability to misreport costs without detection are sufficiently great. Moreover, since $d > b$, profits under *MCP:a* exceed those of *MCP:b*. From the firm's point of view, *MCP:a* is the preferred *MCP* regime. Thus, the firm has an incentive to attempt to create uncertainty regarding the parameter a so as to prompt the regulator to require the firm to report its value.

Observation 3

Consider now $ACP{:}b$. In general, this paper has shown that the regulated firm can achieve the unregulated profit maximum under ACP, assuming it can misreport with impunity. In the case of $ACP{:}b$, the monopolist's reported cost function is $C^R = aq-(b-d)q^2$. However, it is easy to demonstrate that since $b < d$, C^R is not subadditive. Since the firm is known to be a natural monopoly (C^T is subadditive), such a cost report would provide *prima facie* evidence of falsification. Since the firm is presumably constrained to report in a manner consistent with its natural monopoly status, this constraint may mitigate against achievement of the unregulated profit maximum. Therefore, the conclusion that under ACP, the unregulated profit maximum may always be achieved must be viewed as conditional.

Observation 4

This paper now provides a discussion of some important comparative statics properties of the models. The analysis begins by examining the comparative static implications of a slope-preserving increase in demand. First, suppose that under any regulatory regime, the monopolist reports truthfully. Then it is clear from Table 1 that a slope-preserving increase in demand will increase q^* and decrease p^*, since in each case $\partial q * /\partial c > 0$ and $\partial p * /\partial c < 0$. In general, these results are true under economies of scale and thus, represent testable propositions. Consider now models $MCP{:}a$ and $ACP{:}a$. In these models,

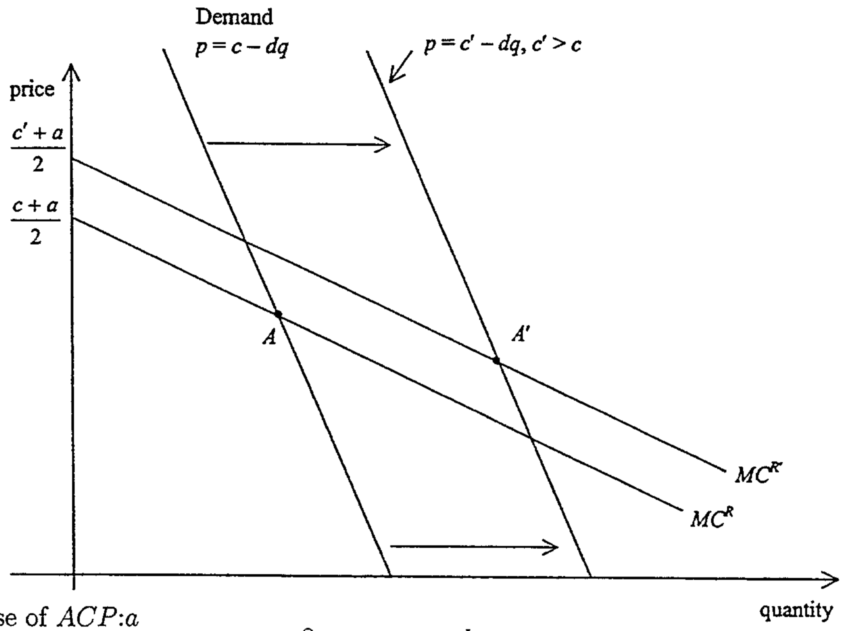
$$C^R = \left(\frac{c+a}{2}\right) q - \frac{b}{2}q^2,\ MC^R = \left(\frac{c+a}{2}\right) - bq,\ \text{and}\ AC^R = \left(\frac{c+a}{2}\right) - \frac{bq}{2} \quad .$$

Therefore, one observes that the reported cost structure depends on the demand parameter c. This implies therefore that the solution values of price and quantity also depend functionally on the value of parameter c, as can be seen in Table 2. Suppose first that the monopolist is operating under $MCP{:}a$ and experiences a slope-preserving increase in demand. The effect on the (regulated) price is given by:

$$\frac{\partial p^*}{\partial c} = 1 - \frac{d}{2}\left(\frac{1}{d-b}\right) \quad .$$

Suppose now that $d > 2b$. Note, the second-order condition for $MCP{:}a$ is satisfied but $\partial p^*/\partial c > 0$. Therefore, one observes that in the presence of a slope-preserving increase in demand, the regulated firm would desire to petition the regulator for a price increase, contrary to the case in which the firm reports truthfully. Presumably, the regulator knows that with truthful reporting $\partial p^*/\partial c < 0$. Thus, petitioning for a price increase would be *prima facie* evidence of falsification. In this case, the need to report in a manner that appears consistent with truth telling may again mitigate against attainment of the solution to problem P1. However, for the case of $b < d < 2b$, $\partial p^*/\partial c < 0$ and the firm's observed behavior is consistent with truthful reporting. In this case, detection of the misreporting will be difficult because in the presence of the slope-preserving increase in demand, the firm increases output and requests a price reduction, which is precisely what would occur if it were reporting costs truthfully. The case of $b < d < 2b$ is illustrated in Figure 1. The parameter c is assumed to increase to $c' > c$, causing the demand curve to shift to the right. Since the firm is behaving strategically, reported costs depend on the value of parameter c. At the original value of c, reported marginal cost is denoted by MC^R. The MCP equilibrium is at point A. When c increases to $c' > c$, MC^R shifts rightward to $MC^{R'}$ and the new MCP equilibrium is at A'.

Figure 1
Comparative Statics Effect of an Increase in Demand



In the case of $ACP{:}a$

$$\frac{\partial p*}{\partial c} = 1 + \frac{d}{b-2d} \quad .$$

Since $b < d$, $\partial p^*/\partial c > 0$. Again, since the regulator knows that under truthful reporting $\partial p^*/\partial c < 0$, the need to report in a manner that appears consistent with truth telling may preclude attainment of the solution to P2, the unregulated profit maximum.

Consider now $MCP{:}b$. Furthermore, suppose $d > 2b$. Since

$$C^R = aq - \left(\frac{2b-d}{2}\right) q^2 \quad ,$$

$d > 2b$ implies that C^R is not subadditive. As discussed under Observation 3, such a report is *prima facie* evidence of misreporting since the firm is constrained to report consistent with subadditivity. However, if $2b > d$, C^R is subadditive and

$$\frac{\partial p*}{\partial c} = 1 - \frac{d}{2}\left(\frac{1}{d-b}\right) < 0 \quad .$$

Therefore, the firm's cost report is consistent with its natural monopoly status, and its observed behavior is consistent with truthful reporting. Thus, detection of misreporting will be difficult.

One may reasonably inquire as to whether the regulator would permit the firm to change reported parameter values in the cost function based on a change in demand alone. One case where this may be plausible is when the regulated firm possesses monopsony power in one or more input markets.[3] In this situation, an increase in demand will increase output, which by increasing input usage will increase input prices. If the reported parameter involves these input prices, an increase in its reported value may not be unreasonable.

In general, however, the regulator will have an incentive to disallow changes in the reported parameter values that are based only on a change in demand. To see this, consider the case of $b = 0$ in which the MCP solution and the ACP solution are identical. Suppose that under the current regulatory policy, $p = c - dq$ and the firm is strategically misreporting with $MC^R = AC^R = (c+a)/2$. Now, suppose c increases to $c' > c$, the demand curve shifts to $p = c' - dq$, and the regulator accepts the new cost report with $MC^{R'} = (c'+a)/2 = AC^{R'}$. This situation is illustrated in Figure 2 with the solution at point M'. At M', consumer surplus is indicated by area A, producer surplus by area $B + D$, with total surplus equal to $A + B + D$.

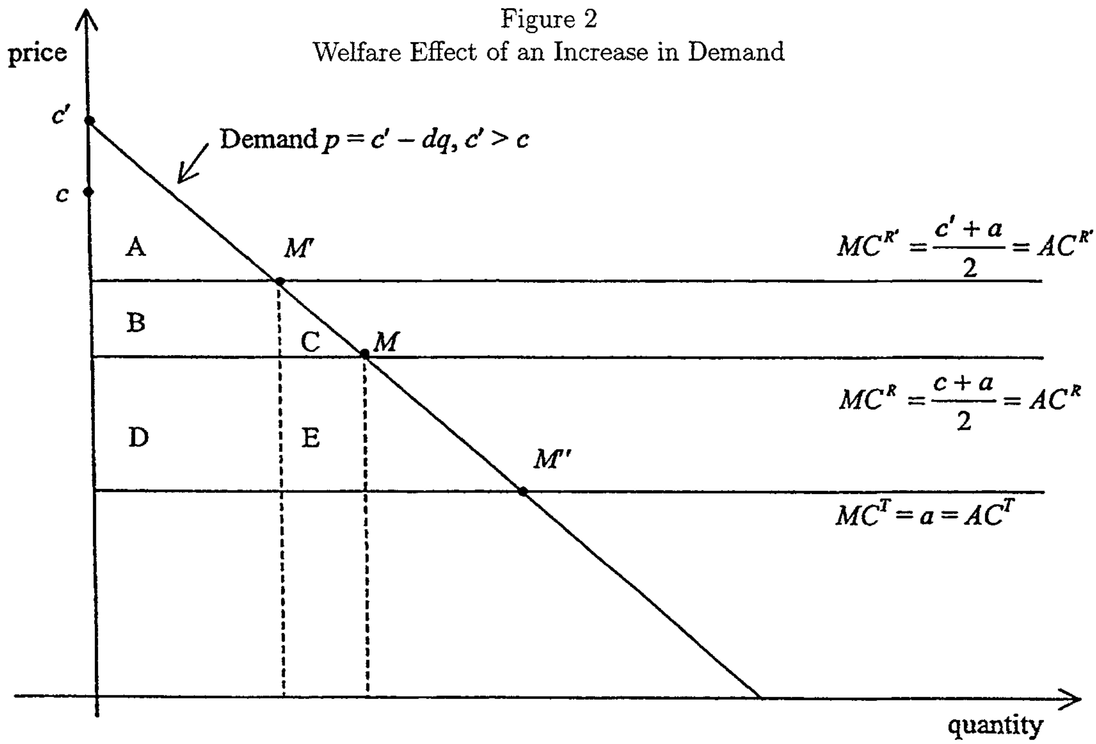


Figure 2
Welfare Effect of an Increase in Demand

Suppose that, with demand still given by $p = c' - dq$, the regulator disallows the new cost report and thus, requires the solution to be computed on the basis of the new demand $p = c' - dq$ and the original cost report $MC^R = (c+a)/2 = AC^R$. In this case, the solution is at point M with consumer surplus of $A + B + C$, producer surplus equal to $D + E$, and total surplus equal to $A + B + C + D + E$. Note that since point M' is the point where the firm is optimizing, $B + D > D + E$, implying that $B > E$. Hence, by disallowing the new cost report (which was based solely on the increase in c), the regulator increases total surplus by $C + E$, with consumer surplus increasing by more than producer surplus falls. (Of course, there still exists a welfare loss relative to the truthful-reporting solution M'').

Conclusions

This paper has provided a formal framework for the analysis of cost misreporting within the context of regulated single-product natural monopoly. While the use of price caps and other forms of incentive regulation has become relatively common, both ideal marginal cost pricing and traditional rate-of-return (average cost pricing) regulation remain important for a variety of reasons. The paper has explored both marginal and average cost regulatory schemes when the regulator must rely on the firm to report a cost parameter.

The paper first presented a general model of cost misreporting, assuming that the regulator knows demand, the functional form of the cost function, and the value of all but one parameter in the cost function. It was shown that for marginal cost pricing, the $MR = MC$ condition will not be satisfied but that inflation of the cost report will always be optimal. Within the context of average cost pricing, inflation of the cost report will always be optimal. However, in this case the firm can achieve the unregulated profit maximum if it can misreport with impunity.

Passing to a linear-quadratic model, additional insights were obtained. It was demonstrated that under marginal cost pricing, profit may exceed the level attainable in the absence of regulation. This is so because strategic misreporting affects both the value of the price and the subsidy set by the regulator. In addition, even if non-distortionary lump-sum taxes are feasible, there will be a welfare loss due to misreporting, unlike the full information marginal cost pricing solution. With average cost pricing, the unregulated profit maximum is, in principle, attainable. Thus, preferences for one form of regulation over the other may arise within the firm.

One very important issue is what may dampen the firm's incentives for misreporting. One possibility is emerging competition. For example, misreporting of costs that leads to higher prices today may provide enhanced incentives for entry in the future. A second possibility is that a regulator's ability to compare costs across regulated firms can provide a deterrent to falsification if prices and subsidies are determined on the basis of the costs of the most efficient firm [Schleifer, 1985].[4] The results suggest that the regulator's knowledge of the basic comparative statics of a change in demand and the fact that costs are subadditive may be an impediment to full exploitation of the regulatory regime. For example, to fully exploit the process, the firm may have to submit a cost report that is inconsistent with the fact that its cost function is known to be subadditive. Thus, this known subadditivity is a deterrent to misreporting to some degree. In the present model, for some parameter values, the firm can implement the solution to P1. However, any attempt to implement P2 will involve either contradicting subadditivity or asking for a rate increase when demand increases, both of which provide direct evidence of misreporting.

Finally, the paper has shown that even if the firm has been successfully misreporting, an increase in demand may induce the firm to attempt to alter its cost report. Permitting the firm to do so will generate an additional welfare loss and therefore, the regulator has an incentive to disallow alterations of the cost report based solely on a change in demand.

Footnotes

[1]See Lewis and Sappington [1988] for an example of a model in which the regulator is imperfectly informed regarding both cost and demand,

[2]If the regulator can audit, it is important to distinguish between a determination that costs were reported inaccurately (exaggerated) and a determination that costs were excessively high (padded). If actual costs are determined to be less than reported costs, the regulator may levy a penalty on the firm. If it is determined that unwarranted expenses were incurred, the regulator may not allow consideration of such expenses.

[3]For a discussion of how monopsony power complicates the determination of a firm's natural monopoly status, see Tschirhart [1995].

[4]The author is indebted to an anonymous referee for these two observations.

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