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Price Regulation, Quality and Asymmetric Information

by

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Direct economic regulation of prices at the firm or industry level involves rules that specify prices based on the costs or profits of those firms or on exogenous factors affecting their performance. These rules may be explicit functions, such as fuel adjustment clauses that automatically adjust electricity rates in response to changes in fuel costs,[1] or they may be implicit rules such as those that yield prices based on estimates of "test year" costs and "revenue requirements."[2] A common characteristic of these price-setting procedures is that prices are to some extent based on the costs actually incurred by the firms being regulated, and when those costs depend on the actions of the firms, an incentive problem arises that can affect performance. Usually, such an incentive problem is lamented and economists strive to create mechanisms to eliminate or at least lessen its consequences. This paper argues, however, that the incentive problem created by a cost-based pricing rule can be used constructively to achieve welfare gains when output has a quality dimension and the regulator lacks the statutory authority or the information to implement a first-best policy.

The model to be considered pertains to an individual firm or an industry that is subject to price regulation and is able to choose the quality of its output. Given a fixed price, the firm or industry will supply a level of product quality that is below the socially-optimal level. If the regulatory commission has the statutory authority and the information to enable it to control product quality, the socially-optimal quality can be achieved. The commission may not however be granted the authority to regulate quality, and even if it has the requisite authority, it may have difficulty measuring quality and determining the cost of producing outputs of different quality levels. In either case firms are likely to have better information regarding quality and costs than does a regulator, and a regulatory policy formulated to deal with the undersupply of quality must necessarily be based on limited and asymmetric information. One response to this problem is for the regulator to extend its authority over the quality dimension and to attempt to reduce or eliminate its informational disadvantage by hiring staff, forcing information disclosure, increasing required reporting, and monitoring the decisions taken by the firms it regulates. The alternative to this all too customary response is to delegate the quality supply decision to the firms and to attempt to induce them to make appropriate decisions through the relationship it sets between price and costs.[3] For example, by setting price as an increasing function of average cost, the supply of product quality can be stimulated at the expense of giving firms some degree of control over price. This paper is concerned with the design of such a regulatory policy under delegation to deal with the supply of product quality when the regulatory commission has an informational disadvantage relative to the firms it regulates.

In the special case of a constant price elasticity demand function a regulatory policy that sets price as a constant percentage markup above marginal cost can yield the socially-optimal price and quality levels that would be implemented if the regulator had the same information as the firm and had the authority to specify both price and quality. In general, however, the socially-optimal solution cannot be attained through cost-based price regulation when there is an informational asymmetry, and hence, only a second-best solution can be attained. If an additional regulatory instrument analogous to Weitzman's (1978) quantities or targets can be utilized, however, it will be shown that the socially-optimal solution can be achieved for the model considered here. Furthermore, optimality is achieved by using a target function that has the property that the expected target payment is zero.

An example of the type of situation to which the model considered here is relevant is the system of price regulation practiced in Belgium, which since 1950 has had a form of price regulation for virtually its entire economy. One instrument used in this regulation is a "price calculation contract" that allows "firms to calculate new prices in an agreed upon manner, with further regulatory interference presumably limited to checks on the proper administration of the agreements." (DeBondt 1978, p. 253) While the form of the price functions specified in these contracts is secret, the functions are believed to specify an allowed markup above specified cost items. A number of industries supplying such products as petroleum, bread, chocolate, electric home appliances, imported wood, composite animal foods, margarine, and nonferrous metals have operated under such a price function.[4] Firms in these industries have varying degrees of control over the quality of the products they provide, and thus have some opportunity to influence price. For example, the contract for the cattle feed industry specifies the mix of the feeds used in order to limit the ability of firms to manipulate the quality and hence the cost and thus the price.

In the United States prices appear to have been set as a function of costs both through the revenue requirements approach for public utility pricing as well as through less well-specified approaches. For example, a telephone company can determine the reliability and durability of the terminal equipment it supplies and can choose the probability of obtaining a dial tone within a particular time interval. An electric utility can determine its capacity and hence its ability to meet peak demands without voltage reductions. Prior to the deregulation movement the domestic airline industry was characterized by rivalrous activity directed towards increasing market share by attempting to increase the percentage of capacity provided on a route.[5] Similarly, the Federal Maritime Commission regulates ocean liner shipping through an "open conference" arrangement with rates approved by the Commission and capacity decisions made by the liners. The resulting performance is similar to that in the airline industry with overcapacity and prices higher than would otherwise result in the absence of price regulation (see Baesemann, Moses, and Roberts (1978)). The extent to which prices in a particular industry are set based on costs is a subject of continuing research, but it appears that firms have been able to obtain price increases to cover the costs resulting from their choices of "quality."[6]

In Section I a model of an industry in which firms compete on a quality dimension is considered and a symmetric industry equilibrium is characterized. The first-best regulatory pricing policy is characterized in Section II for the case in which the regulator has the same information as does the firm, and markup regulation is shown to lead to the first-best policy for a special case. In general, only a second-best solution can be attained through cost-based price regulation as considered in Section III. The use of target functions to attain the first-best solution is considered in Section IV, and conclusions are offered in the final section.

I. The Model

When price is regulated, firms may be able to compete through design and performance features, durability, convenience of use, reliability, etc., which will collectively be referred to as "quality." In order to simplify the analysis, each firm will be assumed to produce only one quality level although a more realistic formulation would allow firms to produce a number of models with different quality levels. One explanation of the supply of a single model by each firm is that there are fixed costs associated with the number of models produced, and hence a firm finds it optimal to produce only one.[7] Similarly, the regulatory authority will be assumed to set a single price for the product in question, and given that price, firms choose the level of quality they wish to supply. An air conditioner manufacturer may choose the amount of insulation in its product, a power tool manufacturer may choose the type of electric motor utilized and hence the length of time the tool may be continuously used, and airlines may choose their seating density, meal quality, service, and reliability. To facilitate the analysis and to obtain tractable results, however, the industry demand functions will be assumed to be symmetric in the quality dimension, and in equilibrium each firm will find it optimal to supply the same level of quality.

The total industry demand Q is assumed to be an increasing function of the average quality ($\sum_{j=1}^{n} r_j/n$) of the products supplied by the n firms and of the price or

$$Q(p,r_1,\ldots,r_n) = (\Sigma\ r_j/n)^{\alpha} G(p), \qquad 0 < \alpha \leq 1,$$

where $G(p)$ is a decreasing function of price. The parameter $\alpha \varepsilon (0,1)$ represents the responsiveness of industry demand to the average quality ($\sum_j r_j/n$) of the models produced by the firms in the industry. The share s_i of industry demand obtained by firm i is given by

$$s_i = \frac{1}{n} \frac{r_i^{\eta}}{(\sum_j r_j^{\eta}/n)}, \qquad \eta > 0,$$

which is (1/n) times the ratio of its quality (to the η power) to the average of the qualities (to the η power) supplied by all firms in the industry. The demand q_i for the i^{th} firm is thus[8]

$$q_i = \frac{r_i^{\eta}/n}{(\sum_j r_j^{\eta}/n)} (\sum_j r_j/n)^{\alpha} G(p) .$$

The quality elasticity γ of demand q_i evaluated at a symmetric point $(r_1 = r_2 = \dots = r_n)$ is

$$\gamma = \eta(n-1)/n + \alpha/n,$$

which is the sum of the quality elasticity $(\eta(n-1)/n)$ of market share and the quality elasticity (α/n) of total industry demand Q. If n=1, $\gamma = \alpha$, and $q_i = r_i^{\alpha} G(p)$.

The cost of producing a model of quality r_i is specified as the sum of both production costs and product quality costs. The production technology of the firm will be assumed to be characterized by constant returns to scale with marginal cost c for a "base" model ($r_i = 0$). The unit cost of producing a product of quality r_i is r_i^{β}, $\beta \geq 1$, so the marginal cost y_i of supplying a unit with quality level r_i is[9]

$$y_i = c + r_i^{\beta} .$$

The firm is also assumed to incur a fixed cost K associated with the supply of a model, so profit π^i is

$$\pi^i = (p - y_i)q_i - K = (p - c - r_i^\beta)q_i - K.$$

Firms in the industry are identical except for the quality levels they choose, but given a common price p, equilibrium in the industry will be symmetric so all firms in fact choose the same quality level.[10] The profit function π^i will be assumed to be concave in (p, r_i).

Firms are assumed to behave in a Nash manner and thus maximize profit for given values of the quality levels of the other n-1 firms. Since the demand function is symmetric and all firms have the same cost function, the industry equilibrium will be symmetric with $r_i = r$, $i = 1,\ldots,n$.[11] A firm's optimal response function r(c) at a symmetric equilibrium is

$$r(c) = \left[\frac{(p-c)\gamma}{\beta + \gamma}\right]^{1/\beta}, \tag{1}$$

and the profit π^i of an individual firm is then

$$\pi^i = \left(\frac{p-c}{\beta+\gamma}\right)^{(\alpha+\beta)/\beta} \beta\gamma^{\alpha/\beta}\, n^{-1} G(p) - K, \tag{2}$$

where the price p is assumed to be such that $\pi^i \geq 0$.

In practice, a regulatory authority does not have the same information as does the firm, and for the purposes of the analysis here the unit cost c will be considered uncertain and to represent characteristics of production or factor prices that firms will be able to take into account when making their quality decisions but which the regulator will not be able to observe. That is, c is known to a firm when it chooses its product quality, but _ex post_ the regulator is unable to determine which of the possible values of c actually resulted. This then represents the situation in which the regulator has less information regarding costs than do firms.[12] In addition, the regulator will in general have difficulty distinguishing between costs that are due to the value of c that was realized and costs that are due to the endogenous choice of product quality by a firm. The task of the regulatory authority is, prior to the realization of c, to design price and target functions to achieve regulatory objectives by creating incentives that can be used to affect the supply of quality under a delegation scheme. Before characterizing the optimal regulatory policy under delegation, the first-best regulatory solution will be considered.

II. The First-Best Solution

The model introduced in the previous section is intended to be illustrative of an industry composed of firms that compete on a quality dimension.[13] In a similar vein the regulatory objectives will be specified from a descriptive, rather than a normative, perspective. The regulator is assumed to have both consumer surplus and producer surplus objectives which will be formulated as the maximization of consumer surplus subject to a constrained level of producer surplus.[14] As Bailey (1976) argues, this is likely to be a better description of regulatory practice, at least in the United States, than the maximization of total surplus.[15] The results obtained with this formulation can be easily modified to yield the solution maximizing total surplus.

A firm is assumed to be committed to producing during the period if expected profit is at least as great as a reservation level π^* ($\pi^* \geq 0$), but the firm recognizes that _ex post_ profit may be either above or below that level.[16] Both the regulator and the firms are assumed to have the same *a priori* information regarding c, so both use the same density function $f(c)$, $c \varepsilon [0,\infty)$.[17] A first-best regulatory policy refers to the case in which the authority has the same information as does the firm and hence can observe c before making its regulatory decisions.[18] Since c is uncertain, the first-best policy requires the determination of functions $p(c)$ and $r_i(c)$, $i = 1,\ldots,n$. Given a single price $p(c)$ and the symmetry of the demand function, the optimal regulatory policy will be such that $r_i = r$, $i = 1,\ldots,n$, and hence, conditional consumer surplus $S(c)$ can be written as

$$S(c) = \sum_{i=1}^{n} \int_{p(c)}^{\infty} q_i dp^+ = \sum_{i=1}^{n} \frac{r_i^\eta}{\sum_j r_j^\eta} (\sum_j r_j/n)^\alpha \int_{p(c)}^{\infty} G(p^+)dp^+ .$$

Since the cost c is uncertain at the time the regulatory policy is formulated, expected consumer surplus will be taken to be the measure of consumer welfare.[19] The regulator's program is thus

$$\max_{\substack{p(c),r_i(c)\\ i = 1,\ldots,n}} \int S(c)f(c)dc$$

$$\text{S.T.} \quad \int \pi^i f(c)dc \geq \pi^*, \quad i = 1,\ldots,n . \tag{3}$$

The optimal regulatory policy is determined by pointwise maximization on c which yields the necessary conditions

$$- (1 -\hat{\lambda})G(\hat{p}) + \hat{\lambda}(\hat{p} - c - \hat{r}^\beta)G'(\hat{p}) = 0 \tag{4}$$

$$\gamma\int_{\hat{p}}^{\infty} G(p^+)dp^+ + \hat{\lambda}(- \beta\hat{r}^\beta + (\hat{p} - c - \hat{r}^\beta)\gamma)G(\hat{p}) = 0 , \tag{5}$$

where $\hat{r} = \hat{r}(c)$ and $\hat{p} = \hat{p}(c)$ denote the first-best policy and $\hat{\lambda}$ is the common value of the multipliers associated with the constraints in (3). The second-order conditions will be assumed to be satisfied. From (4) if $\hat{\lambda} < 1$, $\hat{p} - c - \hat{r}^{\beta} < 0$ for all c, and hence the expected contribution to profit and fixed costs is negative. Consequently, if $\pi^* \geq 0$ $\hat{\lambda} \geq 1$ and price $\hat{p}(c)$ is at least as great as marginal cost y for all c. Similarly, if $\pi^* = K = 0$ $\hat{\lambda} = 1$ and price is equal to unit cost. The first-best price functions and the marginal cost $\hat{y}(c) \equiv c + \hat{r}(c)^{\beta}$ are shown in Appendix A to be strictly increasing functions of c, but $\hat{r}(c)$ may increase or decrease with c. An increase in the cost of a standard model thus may cause the firms to increase or decrease their supply of quality, but in either case the result is an increase in the marginal cost and the price of the model supplied.

The regulatory authority may not be able to achieve the first-best solution for either of two reasons: first, it may not have the statutory authority to do so, and second, even if it has the requisite authority, it may be unable to implement the first-best solution because of its inability to observe the quality supplied or to deduce that quality from cost information.[20] One of the problems faced by a regulatory authority that is not able to regulate product quality is that price may not be a sufficient regulatory instrument to achieve the first-best solution. Spence (1975) has shown that a monopolist that can choose its price may either over- or undersupply quality relative to the first-best solution, but for the model considered here the quality comparison is unambiguous. The following proposition demonstrates that if the regulator imposed the first-best price function $\hat{p}(c)$ the industry would undersupply quality for all c. That is, the response function $r(c)$ satisfying (1), with $\hat{p}(c)$ the price, is everywhere less than the first-best response function $\hat{r}(c)$.

Proposition 1: Given the first-best price $\hat{p}(c)$, the industry undersupplies quality relative to the first-best level; that is, $r(c) < \hat{r}(c)$.[21]

Proof: The constrained variation $(\partial L/\partial r_i)$ in welfare for a given c is

$$\frac{\partial L}{\partial r_i} = S(c)_{r_i} + \lambda_i \pi_{r_i} = \int_{\hat{p}(c)}^{\infty} q_{r_i}(p^+)dp^+ + \lambda_i \pi_{r_i} \ . \qquad (6)$$

At the optimal $r_i(c)$ chosen by the firm, $\pi_{r_i} = 0$, so evaluating (6) at $r_i(c)$ yields

$$\left.\frac{\partial L}{\partial r_i}\right|_{\substack{p = \hat{p}(c) \\ r_i = \hat{r}_i(c)}} = S(c)_{r_i} > 0 \qquad \text{for all } c.$$

Consequently, at a symmetric equilibrium $\hat{r}(c) > r(c)$. ∎

White (1972) has obtained a similar result in the context of a model representing the supply of transportation.

The undersupply of quality results because there is no market price that measures the marginal consumer surplus with respect to quality and hence no means to equate marginal private and social returns. To illustrate this result, solve (5) to obtain the first-best response function $\hat{r}(c)$

$$\hat{r}(c) = \left[\frac{\gamma(\hat{p}(c) - c + (\int_{\hat{p}(c)}^{\infty} G(p^+)dp^+)/(\hat{\lambda}G(\hat{p}(c))))}{\beta + \gamma}\right]^{1/\beta} \ . \qquad (7)$$

Comparing the first-best response function $\hat{r}(c)$ and the response function $r(c)$ given in (1) indicates that

$$\hat{r}(c)^{\beta} - r(c)^{\beta} = \left(\frac{1}{\beta+\gamma}\right)\frac{\int_{\hat{p}(c)}^{\infty} G(p^{+})dp^{+}}{\hat{\lambda}G(\hat{p}(c))} > 0.$$

Consequently, if a regulator were to implement a price function $\hat{p}(c)$ and did not have the authority to regulate quality, the industry will undersupply product quality.[22]

As an example consider the case of a constant price elasticity function $G(p) = p^{\varepsilon}$, $\varepsilon < -1 - \gamma/\beta$. Solving (4) yields

$$\hat{p}(c) = \frac{\hat{\lambda}\varepsilon(c + \hat{r}(c)^{\beta})}{\hat{\lambda}(\varepsilon+1) - 1} = \frac{\hat{\lambda}\varepsilon\hat{y}(c)}{\hat{\lambda}(\varepsilon + 1)-1}, \tag{8}$$

so marginal cost pricing is thus optimal only when $\hat{\lambda} = 1$ which requires $\pi^{*} = K = 0$. For the case of a constant elasticity demand function,

$$\int_{\hat{p}(c)}^{\infty} G(p^{+})dp^{+}/(\hat{\lambda}G(\hat{p}(c))) = - \hat{p}(c)/(\hat{\lambda}(\varepsilon + 1)),$$

so (7) is

$$\hat{r}(c) = \left[\frac{\gamma}{\beta+\gamma}\left(\hat{p}(c)\left(\frac{\hat{\lambda}(\varepsilon+1) - 1}{\hat{\lambda}(\varepsilon+1)}\right) - c\right)\right]^{1/\beta} \tag{9}$$

Substituting p(c) from (8) into (9) yields

$$\hat{r}(c) = \left[\frac{-\gamma c}{\beta(\varepsilon+1) + \gamma}\right]^{1/\beta},$$

The first-best price $\hat{p}(c)$ is an increasing function of $\hat{\lambda}$ (and hence of π^{*}), so a greater allowed profit requires a higher price while the quality level remains unchanged.[23]

One approach to alleviating the market failure when product quality cannot be regulated is to use price as a means of inducing a greater supply of quality. As is evident from (1), the response function r(c) of the firm is an increasing function of the price, so the supply of product quality can be stimulated through the use of a cost-based price function but only at the cost of a higher price. In a second-best setting the regulator thus may wish to base price on marginal cost y, so that a firm will have an incentive to increase its supply of quality in order to attain a higher price that otherwise could be attained under a second-best policy.

As an example of this approach suppose that the price is set at a percentage markup m above marginal cost or

$$p = y(1 + m) = (c + r_i^{\beta})(1 + m). \tag{12}$$

The equilibrium quality level for a constant elasticity demand function is

$$r_m(c) = \left[\frac{-\gamma c}{\beta(1+\varepsilon) + \gamma}\right]^{1/\beta} \quad \text{if} \quad \varepsilon < -1 - \alpha/\beta, \tag{13}$$

which is independent of m. Comparing the quality level in (13) with the first-best quality level in (10) indicates that markup regulation (for any markup m) leads to the first-best quality response function. The incentive created by markup regulation thus leads the industry in this case to supply the first-best level of product quality. The resulting price $p_m(c)$ for the constant price elasticity case satisfies

$$p_m(c) = (1+m)\,\frac{\beta c(\varepsilon+1)}{\beta(\varepsilon+1)+\gamma}, \tag{14}$$

which is equal to the first-best price in (11) if

$$m = \frac{1 - \hat{\lambda}}{\hat{\lambda}(\varepsilon + 1) - 1}. \tag{15}$$

Consequently, if the demand function has constant price elasticity, markup regulation can be used to attain the first-best solution corresponding to any level of $K + \pi^* \geq 0$.[24] This result is stated as:

Proposition 2: For the case of a constant price elasticity demand function with $\varepsilon < -1 - \gamma/\beta$, markup regulation of the form in (12) with markup given in (15) yields the first-best price function $\hat{p}(c)$ and the first-best quality response function $\hat{r}(c)$.

This result indicates that the incentive problem created by the dependence of price on a firm's quality decision can be used to induce the firm to supply more quality than it otherwise would, and if the markup is chosen correctly, both the first-best quality and the first-best price can be attained. Unfortunately, this result does not hold in general, and only a second-best solution can be attained when the regulatory authority is unable to regulate product quality or does not have the information to do so.

III. The Second-Best Price Function

The first-best solution will not be attainable in either of two circumstances. First, the regulator may not have the requisite authority to regulate product quality and may only be able to set prices based on the costs incurred by the firms it regulates. Second, there may be an informational asymmetry arising because the regulator may not be able to observe the components, c and r_i^β, of cost and to assess the quality supplied. In either case, the supply of product quality can be enhanced by basing the price function on the observable marginal cost y and in effect delegating the pricing decision to the firms. In this section the choice of a price function $p(y)$ is considered, while in the next section the use of targets in conjunction with a price function is considered. In order to simplify the notation, the firm is viewed as choosing its marginal cost $y_i = c + r_i^{\beta}$. Profit is then

$$\pi^i = (p(y_i) - y_i)(y_i - c)^{\eta/\beta}(\sum_j (y_j - c)^{\eta/\beta})^{-1}(\sum_j (y_j - c)^{1/\beta})^{\alpha} n^{-\alpha} G(p),$$

and maximizing with respect to y_i for $y_i \geq c$ yields the following first-order condition at a symmetric equilibrium

$$(G(p) + (p - \bar{y})G'(p))(\bar{y} - c)^{\alpha/\beta} n^{-1} p'(\bar{y}) \tag{16}$$

$$+ [-\beta(\bar{y}-c) + (p-\bar{y})\gamma](\bar{y}-c)^{\alpha/\beta - 1} G(p) n^{-1} \beta^{-1} = 0,$$

where $\bar{y} = \bar{y}(c)$ denotes the optimal response function. To simplify the notation in the following analysis, the condition in (16) will be written as

$$\pi_p p' + \pi_y = 0 \ , \tag{17}$$

where $\pi_p = \frac{\partial \pi}{\partial p}$ and $\pi_y = \frac{\partial \pi}{\partial y_i}$ are both evaluated at a symmetry equilibrium.

For the condition in (17) to characterize a firm's optimal response function $\bar{y}(c)$, the second-order condition must be satisfied. To investigate that condition, differentiate (17) with respect to c to obtain

$$\frac{\partial}{\partial y} (\pi_p p' + \pi_y)\bar{y}'(c) + \frac{\partial}{\partial c} (\pi_p p' + \pi_y) = 0. \tag{18}$$

The last term may be written as[25]

$$\frac{\partial}{\partial c} (\pi_p p' + \pi_y) = \pi_p \frac{\partial}{\partial c} (\frac{\pi_y}{\pi_p}) \ ,$$

and evaluating yields

$$\pi_p \frac{\partial}{\partial c}\left(\frac{\pi_y}{\pi_p}\right) = \pi_y(\bar{y} - c)^{-1} + (\bar{y} - c)^{\alpha/\beta - 1}G(p)n^{-1} .$$

Evaluating π_y and substituting yields

$$\pi_p \frac{\partial}{\partial c}\left(\frac{\pi_y}{\pi_p}\right) = (p - \bar{y})\gamma(\bar{y} - c)^{\alpha/\beta - 2}G(p)n^{-1}\beta^{-1} > 0. \tag{19}$$

The following proposition then obtains.

Proposition 3: If $\bar{y}'(c) > 0$ for all c, the response function $\bar{y}(c)$ satisfying (17) yields a local maximum.

Given the result in Proposition 3, a theorem due to Holmström (1977) may be used to show that any increasing response function y(c) satisfying (17) is attainable through a price function p(y) and is furthermore a global solution to the firm's problem. Also, any response function satisfying (17) that can be generated by the use of a price p(y) is strictly increasing. This result will not be proven here, since the essence of the proof is used in the next section to establish Proposition 4.

Instead, here the response function is assumed to be such that $y'(c) > 0$, and attention will be focused on characterizing the solution to the regulator's program. The first-order condition in (17) involves a control p(y) that is an implicit function of c, so to put the regulator's problem in a more convenient form, let $\rho(c) \equiv p(y(c))$, so that $\rho'(c) = p'(y(c))y'(c)$. Then, (17) may be rewritten as

$$\pi_p\rho'(c) + \pi_y y'(c) = 0, \tag{20}$$

since $y'(c) > 0$. The regulator is then viewed as choosing functions $\rho(c)$ and $y(c)$, with the function $p(y)$ recoverable from $\rho(c)$ and $y(c)$. The Hamiltonian for the regulator's program is

$$H(c) = [S + \lambda\pi + \psi(c)(\pi_p\rho' + \pi_y y')]f(c), \tag{21}$$

where $\psi(c)f(c)$ is the multiplier associated with the constraint in (20).

The Euler conditions for $\rho(c)$ and $y(c)$ are, respectively,

$$-q + \lambda\pi_p - \psi\pi_{pc} - (\psi' - \psi f'/f)\pi_p = 0 \tag{22}$$

$$\int_\rho^\infty q_y dp + \lambda\pi_y - \psi\pi_{yc} - (\psi' + \psi f'/f)\pi_y = 0, \tag{23}$$

where $q_y = \frac{\partial q}{\partial y}$ which is positive. If π_p and π_y are nonzero, these conditions can be combined to obtain

$$\frac{q + \psi\pi_{pc}}{\pi_p} = \frac{-\int_\rho^\infty q_y dp^+ + \psi\pi_{yc}}{\pi_y} \quad . \tag{24}$$

Since

$$\pi_{yc} = \pi_y q_c/q + (p-y)q(y-c)^{-2}\alpha\beta^{-1} \tag{25}$$

and

$$\pi_{pc} = \pi_p q_c/q \ , \tag{26}$$

(24) may be rewritten after simplification as

$$\frac{q}{\pi_p} = \frac{-\int_\rho^\infty q_y dp^+}{\pi_y} + \psi\frac{(p-y)q(y-c)^{-2}\alpha\beta^{-1}}{\pi_y} \quad . \tag{27}$$

Comparing (27) with (4) and (5) for the first-best solution indicates that it differs from the first-best solution by the second term on the right side of (27). That term is ψ multiplied by the ratio of marginal profit resulting from an increase q_y in demand to the marginal profit π_y resulting from the supply of a product of higher marginal cost y given a fixed price.

The second-best solution is difficult to characterize in general, so only one possible solution, which seems plausible, will be suggested. An optimal solution must be such that $\pi_p > 0$, since otherwise a marginal price reduction would increase consumer surplus and improve or leave unchanged profit. Since the price function p(y) is used to stimulate the supply of product quality, π_y will be negative in an optimal solution.[26] Then, (27) implies that $\psi(c)$ is positive (zero) (negative) as

$$\frac{q}{\pi_p} + \frac{\int_{\rho}^{\infty} q_y dp^+}{\pi_y} < (=)(>)\ 0.$$

The multiplier $\psi(c)$ represents the marginal welfare resulting from the firm's choice of y(c) and the regulator's inability to impose the first-best solution. The next section considers the use of a target function to eliminate that welfare loss.

IV. Target Functions and Welfare Improvements

The first-best price function satisfying (4) can be expressed as a function $\hat{p}(y)$ of marginal cost y, which suggests that one strategy that might be adopted by the regulator is to announce the first-best price function $\hat{p}(y)$ and to attempt to combat the incentive problem resulting from the dependence of price on a firm's quality decision by using a target function. A target function represents a payment to (or from) the firm, and since the regulator is unable to observe c or r_i, the target must be based on the marginal cost y.[27] This section demonstrates that a target cost function T(y) exists that induces the firm to choose the first-best response function $\hat{y}(c)$ when the first-best price $\hat{p}(y)$ is used.

Given $\hat{p}(y)$ and a differentiable target cost function T(y), a firm's response function y(c) satisfies for all c

$$\pi_p \hat{p}'(y) + \pi_y + T'(y) = 0. \tag{28}$$

Defining a function $\hat{\pi}_y(y,c)$ by

$$\hat{\pi}_y(y,c) = \pi_p \hat{p}'(y) + \pi_y,$$

differentiation of the first-order condition with respect to c yields

$$\frac{\partial}{\partial y}(\hat{\pi}_y + T'(y))y'(c) + \hat{\pi}_{yc} = 0 . \tag{29}$$

The first-best response function $\hat{y}(c)$ is strictly increasing in c, so if $\hat{\pi}_{yc} \geq 0$ and T(y) can be chosen such that $\hat{y}(c)$ satisfies (28), $\hat{y}(c)$ will be a local maximum of the firm's problem. Using (25) and (26), $\hat{\pi}_{yc}$ may be written as

$$\hat{\pi}_{yc} = \pi_{pc}\hat{p}'(y) + \pi_{yc} = \hat{\pi}_y q_c/q + (\hat{p}(y) - y)q(y-c)^{-2}\gamma\beta^{-1}$$
$$= (-\hat{\pi}_y + (\hat{p}(y)-y)q(y-c)^{-1})(y-c)^{-1}\gamma\beta^{-1}.$$

The term q_c is negative, so if $\hat{\pi}_y < 0$, $\hat{\pi}_{yc} > 0$. From (28) $\hat{\pi}_y$ will be negative if $T'(y) > 0$. Since the industry undersupplies product quality for all c when facing an exogenous price, it seems likely that $\hat{\pi}_y < 0$. The sign of $\hat{\pi}_{yc}$ is investigated in more detail in Appendix B, and will be assumed to be nonnegative in the subsequent analysis.

The above analysis demonstrates that if a function $\hat{T}(y)$ exists such that $\hat{y}(c)$ satisfies the first-order condition in (28), then $\hat{y}(c)$ yields at least a local maximum of the firm's problem. The following proposition indicates that such a function $\hat{T}(y)$ exists and that $\hat{y}(c)$ is in fact a global optimum to the firm's problem. The proof follows that given by Holmström (1977) and is presented in Appendix C.

Proposition 4: There exists a target function $\hat{T}(y)$ such that the first-best solution can be attained when the quality decision is delegated to the firm. That is, given the price function $\hat{p}(y)$, a target function $\hat{T}(y)$ exists such that the firm will choose $\hat{y}(c)$.

This Proposition indicates that the welfare losses that result when price alone is regulated can be eliminated by the use of an additional regulatory instrument $\hat{T}(y)$ that represents an incentive payment or penalty. That instrument is designed so that a firm finds it in its own best interest to employ the first-best response function when facing the regulatory price function $\hat{p}(y)$ and the target function $\hat{T}(y)$.

When a target function is used to achieve the first-best solution, the nature of regulation is altered because a direct transfer is made from (or to) consumers to (or from) the firm. The transfer however has the desirable property that its expected value is zero as indicated in the following proposition.

Proposition 5: The target function $\hat{T}(y)$ is such that

$$\int \hat{T}(\hat{y}(c))f(c)dc = 0.$$

Proof: The first-best solution $(\hat{p}(\hat{y}(c)),\hat{y}(c))$ corresponding to a particular π^* (and hence $\hat{\lambda}$) is such that (3) is satisfied or

$$\int \pi(\hat{p}(\hat{y}(c)),\hat{y}(c),c)f(c)dc = \pi^* .$$

The target function $\hat{T}(y)$ thus must be scaled such that

$$\int \hat{T}(\hat{y}(c))f(c)dc = 0 . \quad ∎$$

The optimal target function $\hat{T}(y)$ may be determined from (5) and (28) and satisfies

$$\hat{T}'(y) = \frac{1}{\hat{\lambda}} \int_{\hat{p}(y)}^{\infty} q_y dp^+ - \pi_p \hat{p}'(y)$$

$$= (\int_{\hat{p}(y)}^{\infty} q_y dp^+ - q\hat{p}'(y))/\hat{\lambda} , \quad \text{(using (4))}$$

where the right side is evaluated at $\hat{c}(y)$ obtained by inventing $y = \hat{y}(c)$. The marginal target function is thus proportional to the marginal gain to consumers from a variation in quality. The marginal gain is composed of the marginal (with respect to quality) consumer surplus less the additional expenditure $q\hat{p}'(y)$ for the good necessitated by the dependence of price on quality through the unit cost. Consequently, if the gain is positive (negative) for a given c at $y(c)$, the target function is increasing (decreasing) at $y(c)$ in order to stimulate (retard) the supply of quality.[28,29]

An issue that has as yet not been addressed is the further use of a target function to achieve welfare gains by enabling marginal cost pricing to be used. If in the first-best case lump-sum transfers can be made, then $\hat{p}(c) = \hat{y}(c)$ is the optimal price function, and the lump-sum payment is equal to $\pi^* + K$. Since profit equals $(-K)$ given $\hat{p}(y) = y$ for all y and c, the only incentive for the firm is provided by the target function. Letting $\hat{c}(y)$ denote the inverse of $\hat{y}(c)$ for this case, the target function satisfies from (5)

$$\hat{T}'(y) = \gamma\int_y^{\infty} G(p^+)dp^+ - \beta(y - \hat{c}(y))G(y) \tag{30}$$

and

$$\int \hat{T}(y(c))f(c)dc = K + \pi^* .$$

Unless the regulator has the authority to make nonnegative (expected) transfers, this solution cannot be attained when $K + \pi^* > 0$.

V. Conclusions

For the model considered here, cost-based price **functions can be** used to create an incentive to overcome the market failure resulting in the undersupply of product quality relative to the socially-optimal level. While a socially-optimal regulatory policy can be implemented when the regulator has the same information as does the firm and has the authority to regulate quality, asymmetric information resulting from a regulator's inability to measure quality and to monitor the components of cost can limit the achievement of social welfare goals. For an industry characterized by constant marginal cost and a constant price elasticity demand function the undersupply of product quality can be eliminated by setting price as a fixed markup above marginal cost. In addition, the markup can be chosen such that the resulting price is also socially optimal.

This result does not obtain for less restrictive assumptions on the elasticity of demand, so cost-based price regulation yields only a second-best solution. If however a target function can be used as a regulatory instrument, the socially optimal price and quality level can be achieved, and the target function has the desirable property that its expected value is zero. The use of such incentive functions to overcome a market failure associated with product quality is, however, not as straightforward as suggested by this analysis because the firms in this model have no opportunity to produce inefficiently. A policy that bases price on cost may create an incentive for technical inefficiency or even pure waste, and those losses must be balanced against the gains from enhancing the supply of quality.

The analysis presented here also has implications for the monitoring activities of a regulator. When the socially optimal solution can be attained through markup regulation or through the use of target functions, the regulator need not be concerned with attempting to measure *ex post* the quality provided by firms and need not monitor the components of marginal cost, since it is sufficient to monitor the marginal cost itself in order to determine that the price was set correctly and to determine the target payment.

Appendix A

Properties of the First-Best Solution

The first-best solution has the properties:

a) $\hat{p}'(c) > 0$, b) $\hat{y}'(c) > 0$, and c) $\hat{r}'(c)$ is ambiguous in sign.

Proof: Substituting $\hat{y}(c) = c + \hat{r}(c)^{\beta}$ into (4) and (5) yields

$$-(1-\hat{\lambda})G(\hat{p}) + \hat{\lambda}(\hat{p} - \hat{y})G'(\hat{p}) = 0 \qquad \text{(A-1)}$$

$$\gamma\int_{\hat{p}}^{\infty} G(p^{+})dp^{+} + \hat{\lambda}(-\beta(\hat{y} - c) + (p - \hat{y})\gamma)G(\hat{p}) = 0. \qquad \text{(A-2)}$$

Differentiation yields the system, using (A-2) in the second equation,

$$\begin{pmatrix} -(1-2\hat{\lambda})G' + \hat{\lambda}G'' & -\hat{\lambda}G' \\ -\gamma[G(1-\hat{\lambda}) + \int_{\hat{p}}^{\infty} Gdp^{+}/G'] & -(\beta+\gamma)\hat{\lambda}G \end{pmatrix} \begin{pmatrix} \hat{p}'(c) \\ \hat{y}'(c) \end{pmatrix} = \begin{pmatrix} 0 \\ -\hat{\lambda}G\beta \end{pmatrix}$$

Solving yields

$$\hat{p}'(c) = -\hat{\lambda}^{2}G\beta G'/D$$

$$\hat{y}'(c) = \beta\hat{\lambda}G[(1-2\hat{\lambda})G' - \hat{\lambda}G'']/D,$$

where D is the determinant of the matrix which is positive by assumption. Consequently, $\hat{p}'(c) > 0$ and $\hat{y}'(c) > 0$, since the second-order conditions imply that

$$-(1-2\hat{\lambda})G' + \hat{\lambda}G'' < 0.$$

Since $\hat{y}'(c) = 1 + \beta\hat{r}(c)^{\beta-1}\hat{r}'(c)$, $\hat{r}'(c)$ has the sign of $\hat{y}'(c) - 1$. Evaluating yields $\hat{y}'(c) - 1 = (-\gamma G\hat{\lambda}((1-2\hat{\lambda})G' - \hat{\lambda}G'') + \hat{\lambda}G'\gamma(G(1-\hat{\lambda}) + \int_{\hat{p}}^{\infty} Gdp^{+}/G'))/D$. The first term in the numerator is negative while the second term is positive, so the sign of $\hat{r}'(c)$ is ambiguous. ∎

Appendix B

Analysis of $\hat{\pi}_{yc}$

The term $\hat{\pi}_y$ may be rewritten as

$$\hat{\pi}_y = q(1 + \varepsilon(\hat{p}(y) - y)/p)\hat{p}'(y) - q + (\hat{p}(y) - y)q_y,$$

where $\varepsilon = G'(\hat{p}(y))\hat{p}(y)/G(\hat{p}(y))$. Differentiation yields

$$\hat{\pi}_{yc} = q_c(1+\varepsilon(\hat{p}(y)-y)/\hat{p}(y))\hat{p}'(y) - q_c + (\hat{p}(y)-y)q_{yc}.$$

From (4) $(1+\varepsilon(\hat{p}(y)-y)/\hat{p}(y)) = 1/\hat{\lambda}$ and substituting yields

$$\hat{\pi}_{yc} = q_c[(\hat{p}'(y) - \hat{\lambda})/\hat{\lambda}] + (\hat{p}(y) - y)q_{yc} .$$

Since $q_{yc} = q_c(y-c)^{-1}(\gamma\beta^{-1} - 1)$,

$$\hat{\pi}_{yc} = q_c[(\hat{p}'(y) - \hat{\lambda})/\hat{\lambda} + (\hat{p}(y) - y)(y-c)^{-1}(\gamma\beta^{-1} - 1)].$$

Differentiating (4) and evaluating $(\hat{p}'(y) - \hat{\lambda})/\hat{\lambda}$ yields

$$(\hat{p}'(y)-\hat{\lambda})/\hat{\lambda} = \frac{2(1-\hat{\lambda}) - \hat{\lambda}(\hat{p}(y)-y)G''(\hat{p}(y))/G'(\hat{p}(y))}{-1 + 2\hat{\lambda} + \hat{\lambda}(\hat{p}(y)-y)G''(\hat{p}(y))/G'(\hat{p}(y))} .$$

From (4) $\hat{\lambda}(\hat{p}(y)-y) = (\hat{\lambda} - 1)G(\hat{p}(y))/G'(\hat{p}(y))$ and substituting yields

$$(\hat{p}'(y) - \hat{\lambda})/\hat{\lambda} = \frac{(1-\hat{\lambda})\left(2 + \frac{G(\hat{p}(y))G''(\hat{p}(y))}{G'(\hat{p}(y))^2}\right)}{-1 + 2\hat{\lambda} + \hat{\lambda}(\hat{p}(y) - y)G''(\hat{p}(y))/G'(\hat{p}(y))} .$$

Since $\hat{\lambda} \geq 1$, a necessary and sufficient condition for $(\hat{p}'(y) - \hat{\lambda})/\hat{\lambda} \leq 0$ is

$$2G'(\hat{p}(y))^2 + G(\hat{p}(y))G''(\hat{p}(y)) \geq 0.$$

For example, for $G(p) = p^{\varepsilon}$, the condition is

$$\varepsilon p^{2\varepsilon-2}(3\varepsilon - 1) > 0.$$

The term $\gamma\beta^{-1} - 1$ is nonpositive if $\gamma \leq \beta$ which will be satisfied for all $\eta \leq 1$. Since $q_c = -\gamma(y-c)^{\alpha/\beta-1}G(\hat{p}(c))n^{-1}\beta^{-1} < 0$, $\hat{\pi}_{yc}$ is likely to be non-negative.

As an alternative analysis of $\hat{\pi}_{yc}$, differentiate to obtain

$$\hat{\pi}_{yc} = \pi_{pc}\hat{p}'(y) + \pi_{yc} .$$

Substituting for $\hat{p}'(y)$ from the first-order condition yields

$$\hat{\pi}_{yc} = \pi_{pc} \left(\frac{-T'(y) - \pi_y}{\pi_p}\right) + \pi_{yc}$$

$$= -T'(y)\pi_{pc}/\pi_p + \pi_p \frac{\partial}{\partial c}\left(\frac{\pi_y}{\pi_p}\right) .$$

Since $\pi_{pc} = -(\alpha/\beta)\pi_p(y - c)^{-1}$, this is

$$\pi_{yc} = \frac{\alpha}{\beta}(y-c)^{-1}T'(y) + \pi_p \frac{\partial}{\partial c}\left(\frac{\pi_y}{\pi_p}\right).$$

The term π_y/π_p is

$$\frac{\pi_y}{\pi_p} = \frac{(-\beta(y-c) + (\hat{p}(y) - y)\gamma)(y-c)^{-1}\beta^{-1}}{1 + (\hat{p}(y) - y)G'(\hat{p}(y))/G(\hat{p}(y))} ,$$

so

$$\frac{\partial}{\partial c}\left(\frac{\pi_y}{\pi_p}\right) = \frac{(\hat{p}(y)-y)\gamma(y-c)^{-1}\beta^{-1}}{1 + (\hat{p}(y)-y)G'(\hat{p}(y))/G(\hat{p}(y))} .$$

If regulation is effective in maintaining the price below the level the firms would choose, then $\pi_p > 0$ and $\frac{\partial}{\partial c}\left(\frac{\pi_y}{\pi_p}\right) > 0$. If the target function is used to stimulate the supply of product quality, one would expect that $T'(y) > 0$ in which case $\pi_{yc} > 0$.

Appendix C

Proof of Proposition 4

First, it will be shown that a function $\hat{T}(y)$ exists such that $\hat{y}(c)$ satisfies the first-order condition in (28). Since $\hat{y}'(c) > 0$, the function $\hat{y}(c)$ can be inverted to obtain a function $c = \hat{c}(y)$. The first-order condition may now be written as a function of y as

$$\hat{\pi}_y(\hat{p}(y), y, \hat{c}(y)) + T'(y) = 0 ,$$

which can be integrated to obtain a class of functions $T(y)$ such that $\hat{y}(c)$ satisfies (28). Let $\hat{T}(y)$ be a member of this class that satisfies the expected profit constraint in (4).

Second, the first-best $\hat{y}(c)$ will be shown to be the global solution to the firm's problem

$$\max_{y \geq c} \pi(\hat{p}(y), y, c) + \hat{T}(y) \qquad \text{for all } c.$$

Suppose that for some c_1, $y_1 = \hat{y}(c_1)$ satisfying (28) is not a global optimum. Then, the indifference curve in the (y,T) plane in Figure 1, defined by

$$\pi(\hat{p}(y), y, c_1) + T \equiv \pi(\hat{p}(y_1), y_1, c_1) + \hat{T}(y_1),$$

must intersect the function $\hat{T}(y)$ at some point, say y_2.[C1] If $y_2 > y_1$, then

$$\hat{T}'(y_2) > \hat{\pi}_y(\hat{p}(y_2), y_2, c_1),$$

where $-\hat{\pi}_y$ is the slope of the indifference curve. Corresponding to y_2 is a c_2 $(c_2 > c_1)$ such that $y_2 = \hat{y}(c_2)$ and

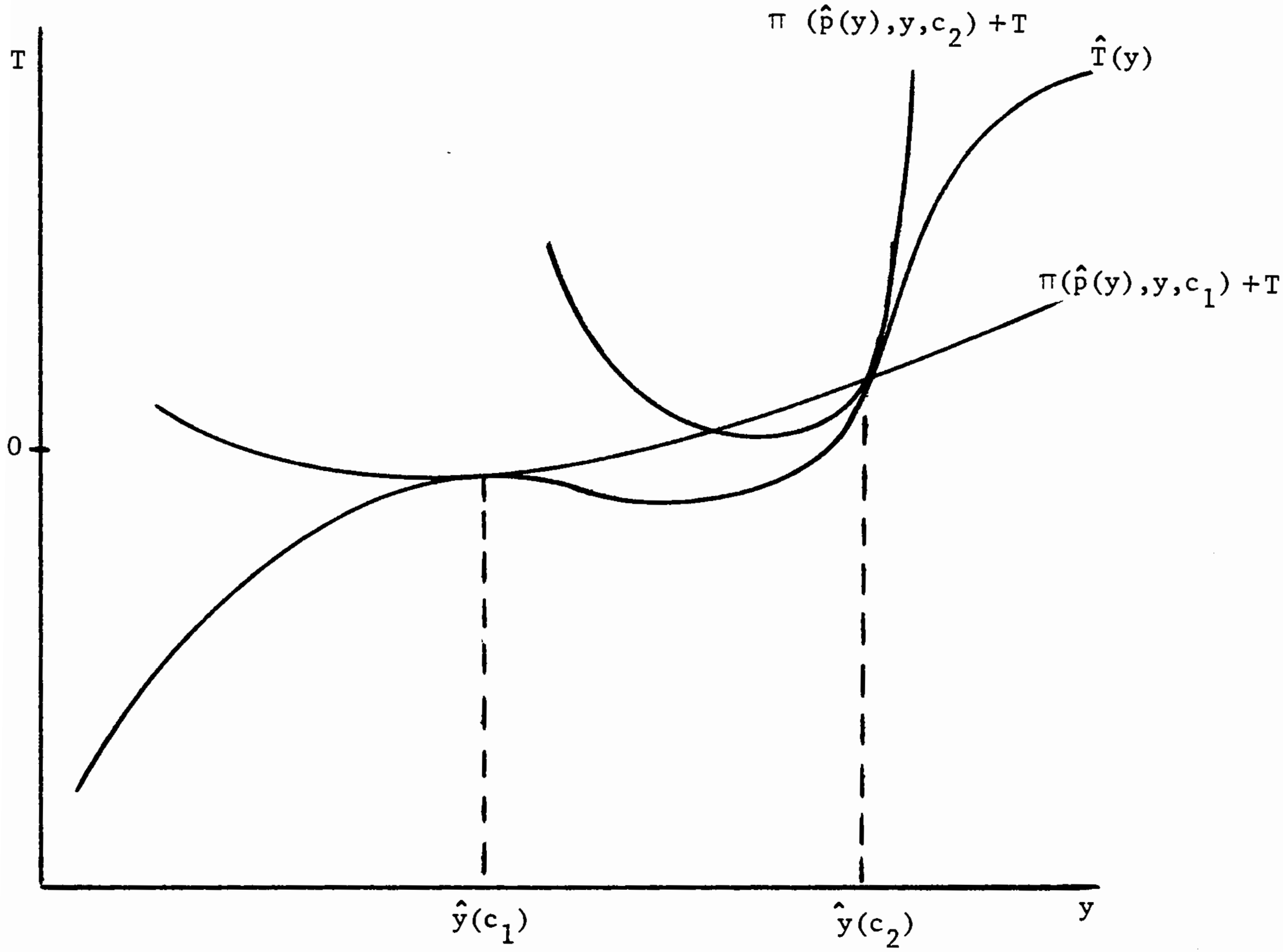
$$\pi_y(\hat{p}(y_2), y_2, c_2) + \hat{T}'(y_2) = 0 .$$

Consequently,

$$-\hat{\pi}_y(\hat{p}(y_2), y_2, c_2) > -\hat{\pi}_y(\hat{p}(y_2), y_2, c_1).$$

This however contradicts the condition that $\hat{\pi}_{yc} \geq 0$. An analogous argument holds if $y_2 < y_1$. Consequently, $\hat{y}(c)$ is a global optimum to the firm's problem, and the firms will thus choose $\hat{y}(c)$ when the authority uses $(\hat{p}(y), \hat{T}(y))$.[C2]

Figure 1



Footnotes

C1. This argument requires that the indiffference curve is convex or equivalently that $\pi(\hat{p}(y),y,c) + T$ is quasiconcave in (y,T). It thus must be shown that for all $(y_1,T_1),(y_2,T_2)$ pairs and for all $\alpha \varepsilon (0,1)$

$$\pi(\hat{p}(\alpha y_1 + (1-\alpha)y_2), \alpha y_1 + (1-\alpha)y_2,c) + \alpha T_1 + (1-\alpha)T_2$$

$$\geq \min [\pi(\hat{p}(y_1),y_1,c) + T_1, \pi(\hat{p}(y_2),y_2,c) + T_2] .$$

For the case of a constant elasticity demand function, $\hat{p}(y)$ is linear so

$$\hat{p}(\alpha y_1 + (1-\alpha)y_2) = \alpha\hat{p}(y_1) + (1-\alpha)\hat{p}(y_2) .$$

Concavity of π in p and y then implies that

$$\pi(\alpha\hat{p}(y_1)+(1-\alpha)\hat{p}(y_2),\alpha y_1 + (1-\alpha)y_2,c) \geq \alpha\pi(\hat{p}(y_1),y_1,c) + (1-\alpha)\pi(\hat{p}(y_2),y_2,c).$$

Adding $\alpha T_1 + (1-\alpha)T_2$ on both sides of the inequality and noting that the right side is at least as great for all $\alpha \varepsilon (0,1)$ as

$$\min[\pi(\hat{p}(y_1),y_1,c) + T_1, \pi(\hat{p}(y_2),y_2,c) + T_2] ,$$

establishes the result. For a more general demand function the same result obtains if $\hat{p}(y)$ is concave or not "too convex."

C2. More generally, this demonstration indicates that any nondecreasing response function y(c) can be attained if $\pi_{yc} \geq 0$.

Footnotes

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1. Baron and De Bondt (1979a)(1979b) have analyzed the incentive problems associated with average cost pass-throughs and have characterized the optimal pass-through function when a regulator has a limited ability to monitor the performance of a firm.

2. Robicheck (1978) discusses the revenue requirements approach for public utilities.

3. The incentive problem created by the dependence of price on cost is assumed to affect only the firm's quality supply decision and not to affect factor input decisions. The price function may also induce pure waste or may bias the input choices as in Baron and De Bondt (1979b) but those possibilities will not be considered here.

4. An analysis of these contracts is provided in Baron and De Bondt (1979c).

5. Using a model descriptive of this situation, Schmalensee (1977) has demonstrated that an increase in price does not increase the accounting rate of return for firms, but reduces the load factor and may increase or decrease total industry profits depending on the elasticity of demand and the percentage price markup above marginal cost.

6. Joskow (1972) and Hagerman and Ratchford (1978) have provided empirical studies of the behavior of state regulatory commissions.

7. Spence (1976) has shown that the presence of fixed costs limits product variety.

8. This formulation is analogous to that used by Schmalensee (1976) and Baesemann, Moses, and Roberts. Levin (1978) uses a different demand formulation with quality, or in his model transportation modes, represented by a vector of characteristics or attributes. In studies of the airline industry quality is often represented by the time dimension as in DeVany (1975), Douglas and Miller (1973), and Panzar (1975).

9. As in Weitzman's (1978) model there is no opportunity here for pure waste or for technical inefficiency.

10. Schmalensee (1976) justifies this type of model as follows:

> Throughout, we make the strong Chamberlinian assumption that these firms are as alike as is possible in an industry producing differentiated products. That is, all are assumed to have the same production costs, to be able to acquire real promotion on the same terms, to charge the same fixed price, P, and to face symmetric demand functions. This strong symmetry assumption permits us to obtain an explicit formula for equilibrium promotional spending and greatly simplifies the entire analysis. (p. 494).

11. The existence of a symmetric equilibrium in a similar model is demonstrated by Schmalensee (1976). Roberts and Sonnenschein (1976) have considered the existence issue in the context of a Cournot quantity-setting model and shown that a symmetric equilibrium exists under constant returns to scale and competitive factor markets.

12. In an analogous situation Weitzman (p. 684) states:

> An essential feature of the regulatory environment I am trying to describe is uncertainty about the exact specification of each firm's cost function. In most cases even the managers and engineers most closely associated with production would be unable to precisely specify beforehand the cheapest way of generating various hypothetical output levels. Because they are yet further removed from the production process, the regulators are likely to be vaguer still about a firm's cost function.

13. Weitzman has analyzed a delegation model for the case in which there is no choice of product quality but the regulation does not know a firm's costs. In his model a constant price for the output of the firm and a quadratic target function based on the difference between actual and target output are sufficient regulatory instruments to achieve a first-best regulatory solution.

14. Income effects are ignored here under the assumption that they are small. A justification of this assumption is presented by Willig (1976).

15. Bailey (1976, p. 394) states:

> To suggest to a commission that it might wish to maximize an objective including the benefits to producers is to suggest a sort of behavior that smacks of Stigler's 'capture' theory of regulatory agencies, and is at odds with the 'public interest' view with which a commission is likely to pride itself [see Posner (1974)]. Thus, my reason for choosing the objective that considered only the position of consumers is that it seemed closer to the stated charter of a regulatory commission.

16. It may be more reasonable to model the firm's decision to produce or not to produce as depending on the level of *ex post* profit π^i instead of an *ex ante* expected profit as is done here. The design of a second-best price function for the *ex post* case is complicated by the following type of consideration. Suppose that for a given price function p(y), the realization of c is such that $\pi^i < \pi^i_*$. The firm then has an incentive to reveal c to the authority, but since the authority recognizes that the firm may not have an incentive to truthfully report c, it must either attempt to verify the realization of c (see Townsend (1976)) presumably at some cost or to design a regulatory mechanism such

that the firm finds it in its own best interests to reveal the true c. This latter case has been considered by Myerson (1978), Harris and Townsend (1978), and Holmström (1978) and will not be addressed in the present paper. The situation considered here may be thought of as representative of Belgium where severance payments to employees can outweigh the losses from continuing to produce in the short run when profit is below π_*^i.

17. Weitzman is concerned with finding the optimal revenue function given a social benefits function, but there is no explicit consideration of the firm's decision to contract to provide the regulated good. In the present paper this is incorporated by assuming that both the regulator and the firms have the same probability beliefs about c and hence if $\pi_* \geq 0$, the firm prefers or is indifferent to providing the good. If the firms are committed to supply independent of the level of expected profit, f(c) can be interpreted as representing the regulator's expectations.

18. The term "first-best" is used here to refer to the best possible solution to the regulator's problem as stated above rather than to the policy that maximizes total surplus.

19. Expected consumer surplus is not a straightforward extension of consumer surplus as indicated by Schmalansee (1972).

20. For the case in which the regulator has the requisite authority and is able to observe any two of c, y, and r the first-best solution can be achieved by forcing the firm to adopt $\hat{r}(c)$ when the price $\hat{p}(c)$ is set. For example, if c and y can be observed, r can be deduced from the relationship $r = (y-c)^{1/\beta}$, and the regulator may adopt the policy

$$p(c) = \begin{cases} \hat{p}(c) & \text{if } r(c) = \hat{r}(c) \\ 0 & \text{if } r(c) \neq \hat{r}(c) \end{cases},$$

which achieves the first-best solution.

21. This result is not in conflict with Spence's Proposition 1, since that proposition pertains to a monopolist that is able to choose price while the result here provides a comparison for a fixed price.

22. Entry will not solve this problem because quality is undersupplied for all n although $r(c)$ is increasing in γ and hence in n.

23. Differentiating (9) yields

$$\frac{d\hat{p}(c)}{d\lambda} = -\hat{p}(c)/(\hat{\lambda}(\hat{\lambda}(\varepsilon+1)-1)) > 0.$$

24. Raymond De Bondt indicates that margarine in Belgium is priced using a constant markup m^* so that $p(y) = y + m^*$. With this type of markup the first-best solution corresponding to $\hat{\lambda} = 1$ cannot be attained through the choice of m^*. In this case

$$r^*(c)^{\beta} = \frac{-\gamma(c+m^*)}{\beta\varepsilon+\gamma} \quad \text{and} \quad p^*(c) = \frac{\beta\varepsilon(c+m^*)}{\beta\varepsilon+\gamma}.$$

If the markup m^* is set at

$$m^* = \frac{c\gamma}{\varepsilon(\beta(\varepsilon+1) + \gamma)},$$

the first-best price $\hat{p}(c)$ is achieved, but quality is undersupplied.

Similarly, if a "sectorial contract" is used so that $p = (1+m)(\Sigma y_i/n)$, a markup $m = -1/(\varepsilon+1)$ will yield the first-best quality level for the constant elasticity case if $\varepsilon \leq -2$. (If $\varepsilon > -2$, profit is negative for all $K \geq 0$.) For that case the resulting price is however greater than the first-best price.

25. Riley (1975) has presented a similar analysis

26. With $y'(c) > 0$ and $\pi_p > 0$, a sufficient condition for $\pi_y < 0$ is from (20) that $\rho'(c) > 0$, which seems plausible.

27. It is also possible to base the target on profit, but such a target cannot be used to achieve welfare improvements.

28. This target function is similar to the regulatory instrument used by Loeb and Magat (1978) although they do not consider nonprice competition.

29. It is easily verified that for the constant elasticity case, $\hat{T}'(y) = 0$ for all y, so that no incentive is needed to attain the first-best solution.

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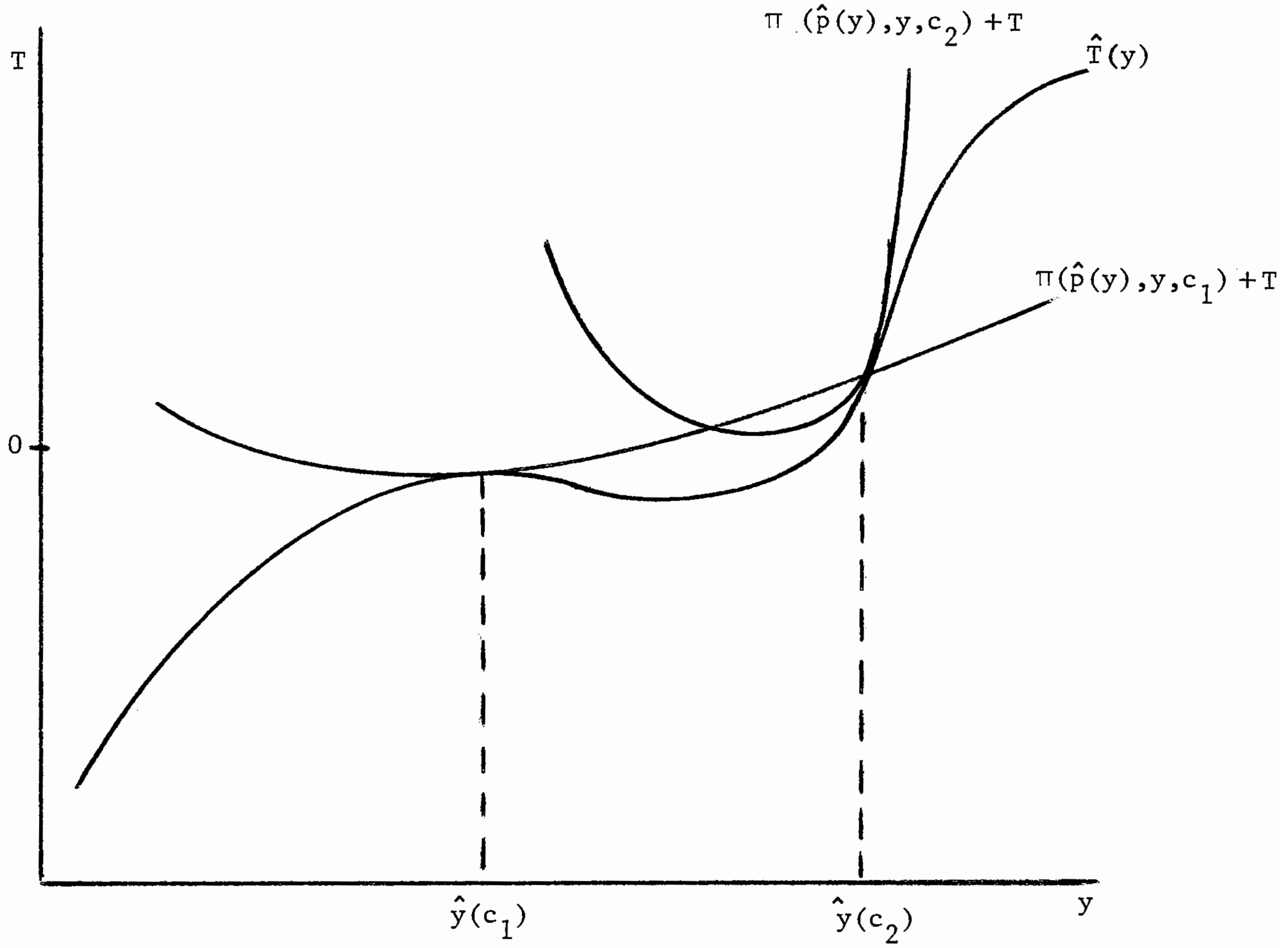
Direct economic regulation of prices at the firm or industry level involves rules that specify prices based on the costs or profits of those firms or on exogenous factors affecting their performance. These rules may be explicit functions, such as fuel adjustment clauses that automatically adjust electricity rates in response to changes in fuel costs,[1] or they may be implicit rules such as those that yield prices based on estimates of "test year" costs and "revenue requirements."[2] A common characteristic of these price-setting procedures is that prices are to some extent based on the costs actually incurred by the firms being regulated, and when those costs depend on the actions of the firms, an incentive problem arises that can affect performance. Usually, such an incentive problem is lamented and economists strive to create mechanisms to eliminate or at least lessen its consequences. This paper argues, however, that the incentive problem created by a cost-based pricing rule can be used constructively to achieve welfare gains when output has a quality dimension and the regulator lacks the statutory authority or the information to implement a first-best policy.

The model to be considered pertains to an individual firm or an industry that is subject to price regulation and is able to choose the quality of its output. Given a fixed price, the firm or industry will supply a level of product quality that is below the socially-optimal level. If the regulatory commission has the statutory authority and the information to enable it to control product quality, the socially-optimal quality can be achieved. The commission may not however be granted the authority to regulate quality, and even if it has the requisite authority, it may have difficulty measuring quality and determining the cost of producing outputs of different quality levels. In either case firms are likely to have better information regarding quality and costs than does a regulator, and a regulatory policy formulated to deal with the undersupply of quality must necessarily be based on limited and asymmetric information. One response to this problem is for the regulator to extend its authority over the quality dimension and to attempt to reduce or eliminate its informational disadvantage by hiring staff, forcing information disclosure, increasing required reporting, and monitoring the decisions taken by the firms it regulates. The alternative to this all too customary response is to delegate the quality supply decision to the firms and to attempt to induce them to make appropriate decisions through the relationship it sets between price and costs.[3] For example, by setting price as an increasing function of average cost, the supply of product quality can be stimulated at the expense of giving firms some degree of control over price. This paper is concerned with the design of such a regulatory policy under delegation to deal with the supply of product quality when the regulatory commission has an informational disadvantage relative to the firms it regulates.

In the special case of a constant price elasticity demand function a regulatory policy that sets price as a constant percentage markup above marginal cost can yield the socially-optimal price and quality levels that would be implemented if the regulator had the same information as the firm and had the authority to specify both price and quality. In general, however, the socially-optimal solution cannot be attained through cost-based price regulation when there is an informational asymmetry, and hence, only a second-best solution can be attained. If an additional regulatory instrument analogous to Weitzman's (1978) quantities or targets can be utilized, however, it will be shown that the socially-optimal solution can be achieved for the model considered here. Furthermore, optimality is achieved by using a target function that has the property that the expected target payment is zero.

Figure 1



that the firm finds it in its own best interests to reveal the true c. This latter case has been considered by Myerson (1978), Harris and Townsend (1978), and Holmström (1978) and will not be addressed in the present paper. The situation considered here may be thought of as representative of Belgium where severance payments to employees can outweigh the losses from continuing to produce in the short run when profit is below π_*^i.

17. Weitzman is concerned with finding the optimal revenue function given a social benefits function, but there is no explicit consideration of the firm's decision to contract to provide the regulated good. In the present paper this is incorporated by assuming that both the regulator and the firms have the same probability beliefs about c and hence if $\pi_* \geq 0$, the firm prefers or is indifferent to providing the good. If the firms are committed to supply independent of the level of expected profit, f(c) can be interpreted as representing the regulator's expectations.

18. The term "first-best" is used here to refer to the best possible solution to the regulator's problem as stated above rather than to the policy that maximizes total surplus.

19. Expected consumer surplus is not a straightforward extension of consumer surplus as indicated by Schmalansee (1972).

20. For the case in which the regulator has the requisite authority and is able to observe any two of c, y, and r the first-best solution can be achieved by forcing the firm to adopt $\hat{r}(c)$ when the price $\hat{p}(c)$ is set. For example, if c and y can be observed, r can be deduced from the relationship $r = (y-c)^{1/\beta}$, and the regulator may adopt the policy

$$p(c) = \begin{cases} \hat{p}(c) & \text{if } r(c) = \hat{r}(c) \\ 0 & \text{if } r(c) \neq \hat{r}(c), \end{cases}$$

which achieves the first-best solution.

21. This result is not in conflict with Spence's Proposition 1, since that proposition pertains to a monopolist that is able to choose price while the result here provides a comparison for a fixed price.

22. Entry will not solve this problem because quality is undersupplied for all n although r(c) is increasing in γ and hence in n.

23. Differentiating (9) yields

$$\frac{d\hat{p}(c)}{d\lambda} = -\hat{p}(c)/(\hat{\lambda}(\hat{\lambda}(\varepsilon+1)-1)) > 0.$$

24. Raymond De Bondt indicates that margarine in Belgium is priced using a constant markup m* so that p(y) = y + m*. With this type of markup the first-best solution corresponding to $\hat{\lambda} = 1$ cannot be attained through the choice of m*. In this case

$$r^*(c)^\beta = \frac{-\gamma(c+m^*)}{\beta\varepsilon+\gamma} \quad \text{and} \quad p^*(c) = \frac{\beta\varepsilon(c+m^*)}{\beta\varepsilon+\gamma} .$$

If the markup m* is set at

$$m^* = \frac{c\gamma}{\varepsilon(\beta(\varepsilon+1)+\gamma)},$$

the first-best price $\hat{p}(c)$ is achieved, but quality is undersupplied.

Similarly, if a "sectorial contract" is used so that $p = (1+m)(\Sigma y_i/n)$, a markup $m = -1/(\varepsilon+1)$ will yield the first-best quality level for the constant elasticity case if $\varepsilon \leq -2$. (If $\varepsilon > -2$, profit is negative for all $K \geq 0$.) For that case the resulting price is however greater than the first-best price.

25. Riley (1975) has presented a similar analysis

26. With $y'(c) > 0$ and $\pi_p > 0$, a sufficient condition for $\pi_y < 0$ is from (20) that $\rho'(c) > 0$,which seems plausible.

27. It is also possible to base the target on profit, but such a target cannot be used to achieve welfare improvements.

28. This target function is similar to the regulatory instrument used by Loeb and Magat (1978) although they do not consider nonprice competition.

29. It is easily verified that for the constant elasticity case, $\hat{T}'(y) = 0$ for all y, so that no incentive is needed to attain the first-best solution.