

Price Regulation and Quality

By

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Abstract

A growing concern on the part of regulators is that price regulation may weaken incentives for investment in service quality. Participation by the firm in complementary, competitive markets may serve to temper this incentive. This analysis reveals that unlike revenue-share penalties that can [actually] reduce investment in quality, and profit-share penalties that can distort efficient levels of cost-reducing effort, information dissemination increases investment in quality without distorting the regulated firm's efficient investment in cost-reducing effort.

1. Introduction

The issue of service quality has recently taken on greater prominence in regulated industries—particularly telecommunications and electric power—wherein quality degradation has become a matter of serious concern to regulators. This concern derives from the fact that the substitution of price regulation for earnings regulation may provide regulated firms with incentives to cut back on service quality (Sappington, 2002 forthcoming; Sappington *et al.*, 2001; Sappington and Weisman 1996a, p. 193; Spence, 1975, note 5).¹ While there is little or no empirical evidence to suggest that the degradation in service quality is caused by the adoption of price regulation (Banerjee and Dasgupta, 2001; Ai and Sappington, 1998; Kridel, *et al.*, 1996), regulators have implemented penalty schemes to ensure compliance with service quality benchmarks.

For the most part, regulators appear less concerned with regulated firms supplying the efficient level of quality than with the prospect that they will allow quality to deteriorate under price regulation. Moreover, despite the importance that regulators attach to the service quality issue, there has been little or no formal analysis of the comparative-static properties of commonly used penalty schemes and the incentives they provide for investment in service quality. This paper seeks to fill that void in the literature.

¹ The terms price regulation and price cap regulation are used interchangeably.

There are five primary findings of this analysis. First, under price regulation, the regulated firm's incentive to invest in service quality increases with the level of the price cap, *ceteris paribus*. Second, the incentive to reduce investment in quality under price regulation may be tempered by the regulated firm's participation in complementary, competitive markets. Third, revenue-share penalties may actually provide the regulated firm with incentives to reduce investment in service quality. Fourth, profit-share penalties provide the regulated firm with unambiguous incentives to increase investment in service quality, *ceteris paribus*. Finally, increased information dissemination concerning compliance with service quality benchmarks provides the regulated firm with incentives to increase investment in quality without distorting the efficient investment in cost-reducing effort that can arise under profit-share penalties.

The outline for the remainder of this paper is as follows. The definitions and notation are presented in Section 2. Section 3 examines the incentives for provision of quality under price regulation and the disciplinary effect of multi-market participation. The comparative static properties of revenue-share penalties and profit-share penalties are derived in Sections 4 and 5, respectively. The role of information dissemination in quality provisioning is investigated in Section 6. Section 7 concludes.

2. Definitions and Notation

The regulated firm is assumed to be risk-neutral with demand given by $Q(p, q)$, where p is price and q is quality. Assume that $Q_p < 0$, $Q_{pp} \leq 0$, $Q_q > 0$ and $Q_{qq} = 0$, where the subscripts denote partial derivatives. Let revenues be denoted by $R(p, q)$ with $R_p > 0$, $R_q > 0$ and $R_{qq} = 0$. Let q have density function $f(q, k)$ and distribution function $F(q, k)$ with support on $[\underline{q}, \bar{q}]$, where k is the firm's investment in quality. The expected value

of quality is given by $\hat{q}(k) = \int_{\underline{q}}^{\bar{q}} z f(z, k) dz$. We assume that $F_k < 0$ in the sense of first-order stochastic dominance so that increased investment makes higher levels of quality more likely. Also, $F_{kk} \geq 0$ so that $\hat{q}_k > 0$ and $\hat{q}_{kk} \leq 0$. The cost function for the regulated firm is given by $C(Q, k)$ with $C_Q > 0$, $C_{QQ} \geq 0$, $C_k > 0$ and $C_{kk} \geq 0$. The cost and demand functions are not observed by the regulator. Finally, let $\Pi = R - C$ denote the expected profits for the regulated firm which, by assumption, are equal to $\Pi(\hat{q})$.

The regulated firm is subject to a binding price cap constraint of the form $p \leq \bar{p}$, where \bar{p} is the exogenous price cap. The regulator establishes a uni-dimensional service quality benchmark, q^B , where $F(q^B, k) = \text{Prob}(q < q^B | k)$ denotes the conditional probability that the firm fails to comply with the service quality benchmark given its investment in quality, k . The financial penalty for non-compliance requires the regulated firm to forfeit a pre-determined share of revenues (s^R) or profits (s^Π). The maximum amount of this penalty is governed by a limited-liability constraint of the form $s^R R \leq L$ or $s^\Pi \Pi \leq L$.²

3. Incentives For Quality Provisioning

A. Price Regulation

A growing concern on the part of regulators is that a firm subject to price regulation will have an incentive to reduce quality. This concern derives from the fact that the firm is the residual claimant for its costs under price regulation:

² In many jurisdictions there are statutory or regulatory constraints on the maximum financial penalty that can be levied on the regulated firm.

Price-cap regulation is about constraining margins. With low margins, the regulated firm has mild incentives to provide quality. It bears the full cost of the provision of quality and reaps a small fraction of its benefits to the extent that demand expansion is multiplied by a small margin. It is for this reason that price cap regulation is often accompanied by the introduction of measurements of new indicators of quality (Laffont and Tirole, 2000, p. 88).

To examine this issue formally, let the expected profits for the firm be given by

$$(1) \Pi = Q(\bar{p}, \hat{q})\bar{p} - C(Q, k),$$

which is concave in k . Maximizing (1) with respect to k and assuming an interior solution yields:

$$(2) Q_{\hat{q}}q_{\hat{k}}[\bar{p} - C_Q] = C_k.$$

Equation (2) implicitly defines the regulated firm's profit-maximizing level of investment in quality, k^* . This condition indicates that the firm chooses a level of investment in quality such that the marginal benefit of investment in quality is equal to the marginal cost of investment in quality. The marginal benefit of quality depends on the product of demand expansion, $Q_{\hat{q}}\hat{q}_k$, and the price-cost margin, $[\bar{p} - C_Q]$. Totally differentiating (2) with respect to \bar{p} yields the following

$$(3) \frac{dk^*}{d\bar{p}} = \frac{-Q_{\hat{q}}(\bar{p}, \hat{q})q_{\hat{k}}[1 - C_{QQ}Q_{\bar{p}}] - Q_{\hat{q}\bar{p}}(\bar{p}, \hat{q})q_{\hat{k}}[\bar{p} - C_Q] + C_{kQ}Q_{\bar{p}}(\bar{p}, \hat{q})}{\Pi_{kk}}.$$

Proposition 1. $sgn\left\{\frac{dk^*}{d\bar{p}}\right\} > 0$ in the equilibrium defined by (2) when second-order effects are sufficiently "small."

Hence, ratcheting downward the price cap provides the regulated firm with an incentive to reduce investment in quality, *ceteris paribus*. The primary objective of quality penalties is to temper this incentive.

B. Multi-Market Participation

In this subsection, we show that the firm's participation in complementary, competitive markets can provide enhanced incentives to invest in quality under price regulation.³

Assume that the firm is subject to a binding price cap constraint in market X . The firm also operates in a complementary, competitive market Y , in which price is exogenous. Let $Q^X(p^X, p^Y, \hat{q}^X, \hat{q}^Y)$ and $Q^Y(p^X, p^Y, \hat{q}^X, \hat{q}^Y, \mathbf{m})$ denote the firm's demand in markets X and Y , respectively, where $Q_{\hat{q}^j}^i > 0$, $i, j = X$ and Y . Hence, higher quality in market X "spills over" to enhance demand in market Y . Also, $Q_{\hat{q}^i \hat{q}^j}^i > 0$, $q_{k^i k^j}^i \geq 0$, $i, j = X$ and Y , $i \neq j$ and $\mathbf{m} \in [0, 1]$ is a regulator-determined market participation parameter, where $Q_{\mathbf{m}}^Y > 0$, $Q_{\hat{q}^Y \mathbf{m}}^Y > 0$ and $Q_{\hat{q}^X \mathbf{m}}^Y > 0$.⁴ Finally, the cost function for investment in quality is given by $C(k^X, k^Y)$, where $C_{k^X} > 0$, $C_{k^Y} > 0$, $C_{k^i k^i} > 0$ and $C_{k^i k^j} \leq 0$, $i = X$ and Y , $i \neq j$.

The expected profits for the firm are given by:

$$(4) \Pi = Q^X(\bar{p}^X, p^Y, \hat{q}^X, \hat{q}^Y)[\bar{p}^X - c^X] + Q^Y(\bar{p}^X, p^Y, \hat{q}^X, \hat{q}^Y, \mathbf{m})[p^Y - c^Y] - C(k^X, k^Y),$$

³ For example, while local exchange telephone companies are subject to price regulation for local telephone service, these firms also participate in complementary, competitive markets, including long-distance, wireless and Internet access. A reputation for poor quality in the provision of local exchange telephone service can spill-over to adversely affect sales in these complementary markets, wherein customers have ample choice of service providers and customer switching costs are minimal.

⁴ For example, the Regional Bell Operating Companies (RBOCs) participate in the intraLATA long distance market. Under §271 of the 1996 Telecommunications Act, the RBOCs may petition regulators for permission to participate in the interLATA long distance market. Hence, within certain bounds, regulators control the degree to which the RBOCs participate in the long distance market.

where c^X and c^Y are the constant marginal costs in markets X and Y , respectively.

Assuming an interior solution, the first-order conditions for k^X and k^Y are given, respectively, by:

$$(5) k^X: Q_{\hat{q}^X}^X \hat{q}_{k^X}^X [\bar{p}^X - c^X] + Q_{\hat{q}^X}^Y \hat{q}_{k^X}^X [p^Y - c^Y] - C_{k^X} = 0; \text{ and}$$

$$(6) k^Y: Q_{\hat{q}^Y}^X \hat{q}_{k^Y}^Y [\bar{p}^X - c^X] + Q_{\hat{q}^Y}^Y \hat{q}_{k^Y}^Y [p^Y - c^Y] - C_{k^Y} = 0.$$

Totally differentiating (5) and (6) with respect to m yields:

$$(7) \begin{bmatrix} \Pi_{k^X k^X} & \Pi_{k^X k^Y} \\ \Pi_{k^Y k^X} & \Pi_{k^Y k^Y} \end{bmatrix} \begin{bmatrix} \frac{dk^{X*}}{dm} \\ \frac{dk^{Y*}}{dm} \end{bmatrix} = \begin{bmatrix} -Q_{\hat{q}^X m}^X \hat{q}_{k^X}^X [p^Y - c^Y] \\ -Q_{\hat{q}^Y m}^Y \hat{q}_{k^Y}^Y [p^Y - c^Y] \end{bmatrix}.$$

The sufficient second-order conditions for a maximum require that $\Pi_{k^X k^X} < 0$ and $\Pi_{k^X k^X} \Pi_{k^Y k^Y} - (\Pi_{k^X k^Y})^2 > 0$, which imply that $\Pi_{k^Y k^Y} < 0$. Using Cramer's rule and recognizing that $\Pi_{k^X k^Y} > 0$ yields the following proposition:

Proposition 2. $\text{sgn} \left\{ \frac{dk^{X*}}{dm} \right\} > 0$ in the equilibrium defined by (5) and (6).

Hence, the firm's investment in quality in market X is increasing with its ability to participate in market Y , *ceteris paribus*.

4. Revenue-Share Penalties

In this section, we show that revenue-share penalties can give rise to incentives for the regulated firm to cut back on investment in quality.

Let the expected profits for the regulated firm be given by:

$$(8) \Pi = [R(\bar{p}, \hat{q})][1 - F(q^B, k) \times s^R] - C(Q, k),$$

where the limited-liability constraint is initially assumed not to bind. Differentiating (8) with respect to k , assuming an interior solution, and rearranging terms yields:

$$(9) -F_k s^R R + [1 - F s^R] R_{\hat{q}} \hat{q}_k - C_Q Q_{\hat{q}} \hat{q}_k - C_k = 0.$$

Totally differentiating (9) with respect to the revenue-share parameter, s^R , yields

$$(10) \frac{dk^*}{ds^R} = \frac{F_k R + F R_{\hat{q}} \hat{q}_k}{\Pi_{kk}}.$$

The denominator is negative by the concavity of the profit function, but the two terms in the numerator are of different signs—reflecting countervailing effects. Hence, it is ambiguous, in general, as to whether revenue-share penalties will induce the regulated firm to increase investment in quality.⁵

The explanation for this ambiguity is straightforward upon further examination of the numerator in (10). The first term, $F_k R < 0$, represents the expected reduction in the financial penalty for non-compliance associated with a marginal increase in k . This effect suggests that a “small” increase in s^R increases the penalty for non-compliance and induces greater investment in service quality, *ceteris paribus*. The second term, $F R_{\hat{q}} \hat{q}_k > 0$, represents the increased share of incremental revenues resulting from a marginal increase in k that the regulated firm expects to forfeit due to non-compliance with the quality benchmark. This effect suggests that a “small” increase in s^R will induce less investment in quality, *ceteris paribus*.⁶

⁵ It can be shown that a Q-factor embedded in the price cap formula (to augment the X-factor in the event of non-compliance with quality benchmarks) has similar incentive properties. It is important to point out that a Q-factor in the price cap formula may be consistent with the emulation of a competitive market outcome and yet still fail to provide enhanced incentives for investment in quality.

⁶ Revenue sharing forces the firm to bear all of the costs associated with investment in quality while it retains only a fraction of the corresponding revenues (Sappington and Weisman, 1996b). While profit sharing was prominent in the early incentive regulation plans in the telecommunications industry (Sappington, 2002 forthcoming), only two states, Idaho and Oregon, experimented with revenue sharing. It

Suppose now that the limited-liability constraint is binding in equilibrium so that $s^R R = L$. Substituting into (9) and totally differentiating with respect to s^R yields

$$(11) \frac{dk^*}{ds^R} = \frac{FR_{\hat{q}} \hat{q}_k}{\Pi_{kk}} < 0.$$

A comparison of (10) and (11) reveals that the inducement to invest in quality to reduce the expected financial penalty is absent when the limited-liability constraint binds because the financial penalty is no longer increasing in s^R .

These findings are summarized in the following proposition:

Proposition 3. (i) $\text{sgn} \left\{ \frac{dk^*}{ds^R} \right\} \leq (\geq) 0$ and (ii) $\text{sgn} \left\{ \frac{dk^*}{ds^R} \right\} < 0$ in equilibrium when the limited liability constraint binds.

Finally, note that revenue-share penalties, a special case of revenue sharing, do not distort the regulated firm's efficient investment in cost-reducing effort (Sappington and Weisman, 1996b).

5. Profit-Share Penalties

In this section, we show that profit-share penalties unambiguously provide enhanced incentives for investment in quality.

Let the expected profits for the firm be given by

$$(12) \Pi = [R(\bar{p}, \hat{q}) - C(Q, k)][1 - F(q^B, k) \times s^\Pi],$$

where the limited-liability constraint is initially assumed not to bind. Differentiating with respect to k , assuming an interior solution, and rearranging terms yields

is noteworthy that revenue sharing was subsequently abandoned in both states due to problems with service quality. In the electric power industry, most incentive regulation plans continue to incorporate some form of profit sharing, but not revenue sharing (Sappington *et al.*, 2001).

$$(13) -[R - C][F_k \times s^\Pi] + [R_{\hat{q}} \hat{q}_k - C_Q Q_{\hat{q}} \hat{q}_k - C_k][1 - F \times s^\Pi] = 0.$$

Recognize that (13) implies that $R_{\hat{q}} \hat{q}_k - C_Q Q_{\hat{q}} \hat{q}_k - C_k < 0$. This “over-investment” in quality derives from the firm’s incentive to avoid the penalty for non-compliance.

Totally differentiating (13) with respect to the profit-share parameter, s^Π , yields

$$(14) \frac{dk^*}{ds^\Pi} = \frac{[R - C]F_k + [R_{\hat{q}} \hat{q}_k - C_Q Q_{\hat{q}} \hat{q}_k - C_k]F}{\Pi_{kk}} > 0,$$

since both terms in the numerator of (14) are negative and the denominator is negative by the concavity of the profit function. The first term in the numerator of (14) represents the expected reduction in the penalty for non-compliance associated with a marginal increase in k . Hence, a “small” increase in s^Π increases the penalty for non-compliance and induces greater investment in quality, *ceteris paribus*. The second term in the numerator of (14) represents the expected reduction in the regulated firm’s share of the cost (net of revenue expansion) associated with a marginal increase in k . Hence, a “small” increase in s^Π reduces the regulated firm’s share of the net marginal cost of investment in service quality and thereby induces greater investment in service quality, *ceteris paribus*.

Suppose now that the limited-liability constraint is binding in equilibrium so that $s^\Pi \Pi = L$. Substituting into (13) and totally differentiating with respect to s^Π yields

$$(15) \frac{dk^*}{ds^\Pi} = \frac{[R_{\hat{q}} \hat{q}_k - C_Q Q_{\hat{q}} \hat{q}_k - C_k]F}{\Pi_{kk}} > 0.$$

A comparison of (14) and (15) reveals that that the incentive to invest in quality to reduce the expected financial penalty is absent when the limited-liability constraint binds because the financial penalty is no longer increasing in s^Π .

We summarize these findings in the following proposition:

Proposition 4. $\text{sgn}\left\{\frac{dk^*}{ds^\Pi}\right\} > 0$ in equilibrium.

Finally, note that profit-share penalties, a special case of profit sharing, distort the regulated firm's efficient investment in cost-reducing effort (Weisman, 1993).

6. Information Dissemination

In this section, we explore the role of information dissemination in motivating the regulated firm to invest in quality. The term “information dissemination” refers to any method used by the regulator to inform consumers of the regulated firm's compliance with quality benchmarks, including website postings and bill inserts.

The profit function for the regulated firm is given by

$$(16) \quad \Pi = F(q^B, k)R(\bar{p}, \hat{q}, I^-) + [1 - F(q^B, k)]R(\bar{p}, \hat{q}, I^+) - C(Q, k),$$

where $I^{+/-}$ is a binary information signal that indicates whether or not the regulated firm is in compliance with the quality benchmark. Maximizing (16) with respect to k and simplifying yields

$$(17) \quad -F_k(R^+ - R^-) + [FR_{\hat{q}}^- + (1 - F)R_{\hat{q}}^+] \hat{q}_k - C_k = 0,$$

where R^+ and R^- indicate revenue when the information signal is positive and negative, respectively. Totally differentiating (17) with respect to I yields

$$(18) \quad \frac{dk^*}{dI} = \frac{F_k(R_{I^+}^+ - R_{I^-}^-) - [FR_{\hat{q}I^-}^- + (1 - F)R_{\hat{q}I^+}^+] \hat{q}_k}{\Pi_{kk}}.$$

We assume that $R_{I^+}^+ > 0$ and $R_{I^-}^- < 0$ reflecting the effect on revenue of a “small” increase in the dissemination of positive and negative information, respectively. Hence, the first term in the numerator of (18) is negative. The second term in the numerator of

(18) represents the net effect of increased information dissemination on the expected change in revenue associated with a “small” increase in investment, k . The sign of this term is ambiguous.

Proposition 5. $\text{sgn}\left\{\frac{dk^*}{dI}\right\} > 0$ in equilibrium when second-order effects are sufficiently “small.”

Hence, a “small” increase in the dissemination of information regarding the regulated firm’s compliance with quality benchmarks can be expected to increase the regulated firm’s investment in quality, *ceteris paribus*. Finally, information dissemination is not subject to limited-liability constraints and does not distort the regulated firm’s efficient investment in cost-reducing effort.⁷

7. Conclusion

A growing concern on the part of regulators is that price regulation may weaken incentives for investment in service quality. Participation by the firm in complementary, competitive markets may temper this incentive. This analysis reveals that unlike revenue-share penalties that can [actually] reduce investment in quality, and profit-share penalties that can distort efficient levels of cost-reducing effort, information dissemination provides the regulated firm with an incentive to increase investment in quality without distorting efficient investment in cost-reducing effort.

⁷ To see this formally, let e denote the regulated firm’s cost-reducing effort and $\mathbf{y}(e)$ denote the cost of effort with $\mathbf{y}'(e) > 0$ and $\mathbf{y}''(e) > 0$. Rewriting (16) to reflect the inclusion of cost-reducing effort, the profit function is given by $\Pi = F(q^B, k)R(\bar{p}, \hat{q}, I^-) + [1 - F(q^B, k)]R(\bar{p}, \hat{q}, I^+) - C(Q, k, e) - \mathbf{y}(e)$, where $C_e < 0$ and $C_{ee} > 0$. Maximizing Π with respect to e yields $C_e(Q, k, e) = \mathbf{y}'(e)$, which implies that the regulated firm invests in the first-best level of cost-reducing effort.

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