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THE CAPITAL STRUCTURE OF REGULATED FIRMS*

by

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Abstract

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The Capital Structure of Regulated Firms

The equilibrium price, investment, and capital structure of a regulated firm are examined using a sequential model of regulation. The firm's capital structure is shown to have a significant effect on regulated prices, so that the firm's choice of debt and equity levels reflect regulatory responses. Moreover, debt financing weakens the incentive for regulators to "hold up" the firm so that leveraged firms can invest more than all-equity firms.

Journal of Economic Literature: L51, G32, G38, L9

Keywords: capital structure, regulation, investment, public utilities, bankruptcy.

1. Introduction

Regulation of public utilities in electricity, natural gas, telecommunications and other industries is subject to a fundamental paradox. Regulatory commissions attempt to set rates such that the firm's investors earn a "fair" rate of return, that is, a return that covers the cost of capital. However, the regulator's pricing policy affects the firm's expected future earnings which, in turn, affects the firm's cost of capital. The circularity of this process suggests that both firms and regulators should take into account the simultaneous determination of the cost of capital and regulated prices. This paper presents a sequential model of rate setting that explicitly accounts for regulatory policy, capital market equilibrium, and the financial strategy of the regulated firm. The analysis demonstrates that regulation affects the capital structure of firms in a manner consistent with various empirical observations, and suggests a number of additional hypotheses.

The public utilities sector in the U.S., including communications, electricity, natural gas, and sanitary services, accounted for approximately 5.97 percent of the GNP and over 18.8 percent of total business expenditures for new plant and equipment in 1989.[1] Rate-of-return regulation is practiced by fifty state regulatory commissions as well as federal regulatory agencies (such as the Federal Energy Regulatory Commission). Under rate-of-return regulation, the firm's rates are set such that expected revenues equal total

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[1]The output of the public utilities sector, including communications, equalled $246 billion in constant (1982) dollars in 1989. (Source: Department of Commerce, Bureau of Economic Analysis.) Investment in new plants and equipment totalled $106.11 billion in current dollars in 1989. (Source: Bureau of the Census.)

costs. Total costs equal variable costs (operating expenses, taxes, and depreciation), plus the allowed rate of return times the capital stock (rate base), see Spulber (1989). The allowed rate of return is generally an average of the costs of debt and equity weighted by the relative proportions of debt and equity, usually measured at book value. The cost of debt is usually taken to equal total interest payments per unit of the book value of debt. The estimated cost of equity is perhaps the most troublesome, and is arrived at in a variety of ways (see Phillips, 1988). Estimates of the cost of equity generally depend on regulatory assessment of investor expectations regarding the future performance of the firm and thus depend on future regulatory policies.[2] Alternative approaches based on comparable earnings require the regulator to identify firms with comparable risks. However, the risk of the regulated firm is also dependent upon regulatory policies.

Empirical evidence suggests that the regulated firm's capital structure affects the allowed rate of return on equity. Besley and Bolton (1990), in a survey of 27 regulatory agencies and 65 utilities, find that about 60 percent of the regulators and utilities surveyed believe that an increase in debt relative to equity increases regulated prices. Hagerman and Ratchford (1978) show that, for a sample of 79 electric utilities in 33 states, the allowed rate-of-return on equity is increasing in the debt-equity ratio. Bradley, Jarrell and Kim (1984, p. 870), in a study of 25 industries over the period 1962 through 1981, find that "regulated firms such as telephone, electric and gas utilities, and airlines are consistently among the most highly levered firms." Taggart (1985) studies state electricity and natural gas regulation in the period 1912-1922, and concludes that the establishment of regulation

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[2]See, for example, Pettway (1978), Myers (1972), and Radford (1988).

increases the utility's debt-equity ratio. Taggart attributes this in part to the reduction in the firm's risk due to regulation but cannot reject a "price influence" effect of debt on regulatory decisions. Dasgupta and Nanda (1991a,b), in a cross-section of U.S. electric utilities for the years 1980-1983, show that increased debt is associated with a regulatory environment that is harsher to shareholders. They find support for the view that debt precommitment can raise rates by causing the regulator to avoid bankruptcy costs.

The role of investment and capital structure in the strategic interaction between the regulator and the firm has not been addressed.[3] Taggart (1981) identifies a "price-influence-effect" of debt due to price increases by regulators seeking to reduce the risk of bankruptcy. The present paper presents a three-stage model of the regulatory process. The regulated firm chooses capital investment and capital structure in the initial period. The market value of the firm's debt and equity are established in competitive capital markets in the second period. Finally, in the third period, the firm's price is established by the regulator. This structure reflects the dynamic nature of the regulatory process in which regulators can observe the investment and capital structure decisions of firms as well as the capital market equilibrium. The framework recognizes the greater flexibility of regulated rates in comparison with the capital investment and capital structure commitment of the regulated firms. Moreover, it reflects the fact

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[3]Dasgupta and Nanda (1990a,b) address debt precommitment under more restrictive demand assumptions with a fixed investment level. The Averch-Johnson effect and capital structure issues are discussed by Meyer (1976) and Sherman (1977). Greenwald (1984) addresses the issue of rate base measurement in an interesting dynamic setting but does not address capital structure issues.

that regulated firms are allowed to exercise discretion in choosing their capital structure and investment level. The consequences of limited regulatory commitment are examined by Banks (1988) in the context of regulatory auditing, and by Besanko and Spulber (1990) in a model of investment. The use of debt as a commitment device has been examined in an oligopoly setting by Brander and Lewis (1988a).

The paper is organized as follows. The basic framework is given in Section 2. The regulatory process and the optimal regulated price are examined in Section 3. Rate setting and the capital market equilibrium are considered in Section 4. Equilibrium investment and the capital structure of the regulated firm are characterized in Section 5. Conclusions are given in Section 6.

2. The Basic Framework

A regulated firm produces output q at a regulated price p. The firm is a monopolist with market demand $q = Q(p)$, which is twice differentiable, downward sloping, and concave. The firm's operating cost function is $C(q,z,k)$, where k is the firm's capital stock and z is an efficiency parameter representing cost and technology shocks. The operating income of the firm is $R(p,z,k) = pQ(p) - C(Q(p),z,k)$. Assume that the income function $R(p,z,k)$ is concave in p.

The firm's cost function is twice differentiable in q, z, and k. Let subscripts denote partial derivatives. Marginal costs are positive and nondecreasing, $C_q > 0$, $C_{qq} \geq 0$. Investment reduces total and marginal operating costs, and reduces total operating costs at a decreasing rate; $C_k < 0$, $C_{qk} < 0$, and $C_{kk} > 0$. Assume that $\lim_{k \to 0} C_k(q,z,k) = -\infty$, so that some investment is always profitable.

The efficiency parameter z is a random variable distributed over the unit interval according to a density function f(z) that is positive for all z, with a cumulative distribution function F(z). Total and marginal operating costs are assumed to be decreasing in z, $C_z < 0$, $C_{qz} < 0$. Finally, average operating cost at the worst state of nature, when z = 0, is larger than the expected marginal operating costs, for all output levels, $C(q,0,k)/q > \int_0^1 C_q(q,z,k)dF(z)$.

The firm invests k dollars and finances its investment from external sources. Let E be the market value of the new shares representing a fraction $\alpha \in [0,1]$ of the firm's equity, and let B be the market value of debt with face value D. The market value of the new shares must cover investment costs, $k \leq E + B$. Equity and debt, however, cannot exceed k since regulatory commissions do not allow regulated firms to raise external funds in excess of the costs of investment in physical assets, e.g., Phillips (1988, p. 220). So, the firm's capital investment equals the market value of equity and debt,

$$k = E + B. \tag{1}$$

It is assumed that the regulated firm exercises discretion in its choice of a capital structure, which accords with general practice by regulated utilities.[4]

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[4]See Phillips (1988, p. 22>) and Dobesh (1985). The Colorado Supreme Court in <u>Re Mountain States Telephone and Telegraph Co.</u> (39 PUR 4th 222, 24?-248) stated that "a guiding principle of utility regulation is that management is to be left free to exercise its judgme~t regarding the most appropriate ratio between debt and equity." See, however, Taggart (1985) on early efforts by regulators to co~trol utility company debt.

For each debt obligation D, regulated price p, and investment k, there is a critical value of the efficiency parameter $z^* = z^*(p,k,D)$ such that the firm is able to pay its debt for all higher values of the efficiency parameter. If $R(p,0,k) \geq D$, then $z^* = 0$. Then $z^* > 0$ is defined by

$$(2) \qquad R(p,z^*,k) = D.$$

For states $z < z^*$, limited liability applies, the firm declares bankruptcy, and bondholders are the residual claimants. For states $z \geq z^*$, the firm remains solvent: the firm pays D to bondholders, and both old and new shareholders are the residual claimants. Thus, $F(z^*)$ represents the probability of bankruptcy.

Bankruptcy imposes costs on bondholders due to legal fees, and the transaction costs associated with reorganizing the firm and transferring ownership to bondholders. Bankruptcy costs are assumed to be proportional to the size of the shortfall in the firm's earnings from its debt obligation. Thus, when the firm goes bankrupt, i.e., when $z \in [0,z^*)$, bankruptcy costs are $t[D - R(p,z,k)]$, where t is the cost per unit of shortfall. Hence, expected bankruptcy costs are given by

$$(3) \qquad T(p,D,k) = t \int_0^{z^*} [D - R(p,z,k)]dF(z).$$

Brander and Lewis (1988b) posit a similar bankruptcy cost function in an oligopoly setting.

Given the regulated price, p, and the firm's debt obligation, D, the expected profits of the firm are equal to the expected operating income net of expected bankruptcy costs,

$$\Pi(p,D,k) = \int_0^1 R(p,z,k)dF(z) - T(p,D,k). \tag{4}$$

Expected profits are the combined expected returns to shareholders (both old and new) and bondholders and are divided between them according to their respective claims.[5]

Assume that capital markets are competitive and that investors correctly anticipate the outcome of the regulatory process. Then, the firm's securities are fairly priced so that both new shareholders and bondholders earn an expected return equal to i, the risk-free interest rate. Thus,

$$E(1 + i) = \alpha \int_{z^*}^1 [R(p,z,k) - D]dF(z), \tag{5}$$

and

$$B(1 + i) = D(1 - F(z^*)) + \int_0^{z^*} R(p,z,k)dF(z) - T(p,D,k). \tag{6}$$

The right side of equation (5) represents the expected operating income of the firm net of debt payment over states of nature in which the firm remains solvent, and $\alpha \in [0,1]$ is the new shareholders' share in these profits. The first term on the right side of equation (6) represents the expected return to bondholders over states of nature in which they are paid in full. The second

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[5]Taxes are not included in the model to focus on the incentive effects of bankrupcty costs. A tax advantage for debt relative to equity can imply an optimal capital structure. See, for example, Kraus and Litzenberger (1973), Scott (1976), and Flath and Knoeber (1980).

term represents the expected operating income of the firm over states of nature in which the firm goes bankrupt. In these states, bondholders are the residual claimants. The last term on the right side of equation (6) is expected bankruptcy costs. Substituting (5) and (6) into (1) yields the capital market equilibrium condition:

$$(7) \qquad (1 + i)k = D(1 - F(z^*)) + \int_0^{z^*} R(p,z,k)dF(z) - T(p,D,k) + \alpha\int_{z^*}^{1} [R(p,z,k) - D]dF(z).$$

The expected return to outsiders is therefore equal to the opportunity cost of their investment. The <u>capital structure</u> of the regulated firm is fully characterized by a pair (α,D) that satisfies equation (7).

3. The Regulatory Process

The regulator sets rates after observing the firm's investment and capital structure and the capital market equilibrium. The regulator chooses p^* to maximize a welfare function that takes into account the interests of consumers, equity holders (original and new), and debt holders. The payoff of consumers is represented by consumers' surplus, $S(p) = \int_p^\infty Q(p)dp$. The combined payoff of equity holders and debt holders equals $\Pi(p,D,k)$. The regulator's objective function is

$$(8) \qquad W(p,D,k) = S(p) + \Pi(p,D,k).$$

The objective function reflects the notion that "the fixing of 'just and reasonable' rates involves a balancing of the investor and the consumer interests."[6]

There are three stages in the regulatory process. In stage 1, the firm chooses the level of investment k, and a mix of equity and debt to finance the investment by issuing new shares E and bonds B to outsiders. In stage 2, the market value of the firm's securities is determined in the capital market. Finally, in stage 3, the regulator establishes the regulated price, taking the firm's investment and capital structure as given. Then, the random variable z is realized, output is produced, and payments are made.

A subgame-perfect equilibrium of the regulatory process is defined by strategies $(k^*, \alpha^*, D^*, E^*, B^*, p^*)$ satisfying the following conditions.

(i) The original owners of the firm choose (k^*, α^*, D^*) to maximize their payoff

$$V(p^*, D, k) = (1 - \alpha) \int_{z^*}^{1} [R(p^*, z, k) - D]dF(z) \tag{9}$$

given the anticipated capital market equilibrium and the anticipated reaction of the regulator.

(ii) The capital market equilibrium (E^*, B^*) satisfies equations (5) and (6) given the firm's strategy (k^*, α^*, D^*) and the anticipated reaction of the regulator.

(iii) The regulator chooses the price strategy p^* given $(k^*, \alpha^*, D^*, E^*, B^*)$ to maximize $W(p, D^*, k^*)$.

The equilibrium outcome is characterized by first solving the regulator's problem. Then, the effects of the firm's investment and capital

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[6]See Federal Power Commission v. Hope Natural Gas Co., Supreme Court 1944 (320 U.S. 591, 64 S.Ct. 281). See Spulber (1989) for further discussion.

structure on the capital market equilibrium and on the regulator's decision are examined. The first order condition for the regulator's choice of the regulated price p* is $W_p(p^*,D,k) = 0$. This first order condition can be rewritten, using the definitions of Π, R, and z*, to obtain a modified Ramsey pricing rule

$$(10)\quad p^* - \int_0^1 C_q(Q(p^*),z,k)dF(z) + t\int_0^{z^*} (p^* - C_q(Q(p^*),z,k))dF(z) = tF(z^*)p^*/\eta(p^*),$$

where $\eta(p) = -pQ'(p)/Q(p)$ is the elasticity of demand, and $Q'(p) \equiv dQ(p)/dp$. This rule is similar to the Ramsey pricing rule that equates the regulated firm's relative mark-up over marginal cost to a constant times the inverse elasticity of demand. This rule is modified here due to the presence of bankruptcy costs. In Proposition 1 it is verified that the second order condition holds.

The tradeoff between expected bankruptcy costs and higher prices is the significant aspect of the regulator's decision. The regulator wishes to avoid bankruptcy costs but faces deadweight welfare losses from pricing above expected marginal production costs. The main effects of the optimal pricing policy stem from the folowing results: the price is never increased to the point where the firm is immune from bankruptcy. However, price is set above expected marginal costs.

Proposition 1: <u>At the optimal regulated price, the probability of bankruptcy is positive</u>, $F(z^*) > 0$. <u>The optimal regulated price exceeds expected marginal costs of production</u>, $p^* > \int_0^1 C_q(Q(p^*),z,k)dF(z)$.

Proof: Suppose that $z^* = 0$. Then, from equation (10), $p^* = \int_0^1 C_q(Q(p^*),z,k)dF(z)$. By the definition of z^*, it follows that

$$R(p,0,k) = p^*Q(p^*) - C(Q(p^*),0,k) \geq D.$$

But by assumption, $C(q,0,k)/q > \int_0^1 C_q(q,z,k)dF(z)$ so that $p^* > \int_0^1 C_q(Q(p^*),z,k)dF(z)$, which is a contradiction, so $z^* > 0$. Suppose now that $p^* \leq \int_0^1 C_q(Q(p^*),z,k)dF(z)$. Since $C_{qz} < 0$, it follows that $\int_0^{z^*} (p^* - C_q(Q(p^*),z,k))dF(z) < 0$. This implies that

$$\begin{aligned} W_p(p^*,D,k) &= Q'(p^*)[p^* - \int_0^1 C(Q(p^*),z,k)dF(z)] \\ &+ Q'(p^*)t[\int_0^{z^*} [p^* - C_q(Q(p^*),z,k)]dF(z)] + tF(z^*)Q(p^*) > 0, \end{aligned}$$

which is a contradiction of the first order necessary condition. Therefore, $p^* > \int_0^1 C_q(Q(p^*),z,k)dF(z)$. It is now verified that the second order condition for a maximum is satisfied. The second derivative of the welfare function with respect to p, evaluated at $p = p^*$ is

$$\begin{aligned} W_{pp}(p^*,D,k) &= Q'(p^*)[1 - Q'(p^*) \int_0^1 C_{qq}(Q(p^*),z,k)dF(z)] \\ &+ Q''(p^*)[p^* - \int_0^1 C_q(Q(p^*),z,k)dF(z)] + t \int_0^{z^*} R_{pp}(p^*,z,k)dF(z) \\ &+ t(R_p(p^*,z^*,k))^2 f(z^*)/C_z(Q(p^*),z^*,k). \end{aligned}$$

The first term is negative since $Q' < 0$ and $C_{qq} > 0$. The second term is negative since $Q'' < 0$ and $p^* > \int_0^1 C_q(Q(p^*),z,k)dF(z)$. The third term is negative by assumption and the fourth is negative since $C_z < 0$. Q.E.D.

4. Rate Setting and the Capital Market Equilibrium

The optimal regulated price that solves equation (10) is a function of capital investment and debt, and depends parametrically on demand, production cost, bankruptcy cost, and the distribution of cost uncertainty. However, the effects of investment and debt on the regulated price cannot be examianed independently of the capital market equilibrium. By the capital market equilibrium condition (7), investment, and the market value of debt and equity are jointly determined. The regulated firm thus has only two degrees of freedom in choosing k, D, and α. The regulator's response to changes in these values therefore must be evaluated using the capital market equilibrium condition.

The capital structure of the regulated firm affects the regulated price by changing the firm's exposure to bankruptcy. To examine the consequences for the regulated price of changes in the firm's capital structure, fix the size of the investment project. Note that the market value of debt, B^*, is increasing (decreasing) in D if the probability of bankrupcty, $F(z^*)$, is less than (greater than) $1/(1 + t)$, since from equation (6) and the definition z^*,

$$\partial B^*/\partial D = [1 - (1 + t)F(z^*)]/(1 + i).$$

The firm will not raise D beyond the point at which the market value of debt declines. Thus, $F(z^*) < 1/(1 + t)$. In Propositions 2, 3, and 4, it is assumed that $R_p(p^*,z^*,k)$, the marginal operating income evaluated at the critical level z^*, is positive. This is shown below to hold at the market equilibrium.

Proposition 2: Given $R_p(p^*,z^*,k) > 0$, for an investment project of size k, the optimal regulated price increases with the firm's debt obligation, D. Correspondingly, an increase in the optimal regulated price is associated with increases in the market value of the firm's debt B^*, and in the debt-equity ratio B^*/E^*, if $F(z^*) < 1/(1 + t)$.

Proof: From the optimality condition $W(p^*,D,k) = 0$, it follows that $\partial p^*/\partial D = -W_{pD}(p^*,D,k)/W_{pp}(p^*,D,k)$. Note that $W_{pD}(p^*,D,k) = -tR_p(p^*,z^*,k)f(z^*)/C_z(Q(p^*),z^*,k)$, since $\partial z^*/dD = -1/C_z > 0$. By the proof of Proposition 1, $W_{pp}(p^*,D,k) < 0$. Therefore, sign $\partial p^*/\partial D$ = sign $W_{pD}(p^*,z^*,k)$ = sign $R_p(p^*,z^*,k)$, so that $\partial p^*/\partial D > 0$ since $R_p(p^*,z^*,k) > 0$. Furthermore, since $B^*/E^* = B^*/(k - B^*)$, $\partial(B^*/E^*)/\partial D = [k/(k - B^*)^2](\partial B^*/\partial D)$. Thus, $\partial p^*/\partial B^* > 0$ and $\partial p^*/\partial(B^*/E^*) > 0$ since $\partial B^*/\partial D > 0$ for $F(z^*) < 1/(1 + t)$.Q.E.D.

Therefore, the optimal regulated price is increased by substituting debt for equity in financing a given project. This implies that the regulated firm will have an incentive to take on increased debt. This provides a partial explanation for the empirical analyses that suggest that regulated firms are relatively highly leveraged.

Corresponding to increased debt, note also from equation (7) that

$$\frac{\partial \alpha^*}{\partial D} = \frac{F(z^*)(t + 1 - \alpha) - (1 - \alpha)}{\int_{z^*}^{1} [R(p,z,k) - D]\, dF(z)}$$

so that $\partial\alpha^*/\partial D$ <(>) 0 as $F(z^*)$ <(>) $[(1 - \alpha)/(t + 1 - \alpha)]$. Thus, the regulated price is increasing or decreasing in the equity share α depending on the likelihood of bankruptcy. With a high risk of bankruptcy,

$[(1 - \alpha)/(t + 1 - \alpha)] < F(z^*) < 1/(1 + t)$, higher prices can be associated with higher equity share.

The level of investment affects the regulated price directly by reducing costs and indirectly by increasing the market value of a given debt obligation. To highlight these effects, fix the debt obligation D.

<u>Proposition 3</u>: <u>Given</u> $R_p(p^*,z^*,k) > 0$, <u>for a debt obligation of size</u> D, <u>the optimal regulated price is decreasing in the firm's investment</u>, k. <u>Correspondingly, the optimal regulated price is decreasing in the market value of the firm's debt</u> B.

<u>Proof</u>: From $W_p(p^*,D,k) = 0$, it follows that $\partial p^*/\partial k = -W_{pk}(p^*,D,k)/W_{pp}(p^*,D,k)$, where

$$W_{pk}(p^*,D,k) = -Q'(p^*)[\int_0^1 C_{kq}(Q(p^*),z,k)dF(z) + t \int_0^{z^*} C_{kq}(Q(p^*),z,k)dF(z)]$$
$$+ tR_p(p^*,z^*,k)f(z^*)(\partial z^*/\partial k).$$

From equation (2), $\partial z^*/\partial k = -C_k/C_z < 0$. Also, $R_p(p^*,z^*,k) > 0$ by assumption. So, $W_{pk}(p^*,D,k) < 0$ and $\partial p^*/\partial k < 0$. Moreover, from equations (5) and (6), and the definition of z^*,

$$(11) \qquad \partial B^*/\partial k = -(1 + t) \int_0^{z^*} C_k(Q(p),z,k)dF(z)/(1 + i) > 0.$$

Therefore, $\partial p^*/\partial B^* < 0$. Q.E.D.

A comparison of Propositions 2 and 3 implies that the optimal regulated price does not depend on capital structure in a simple manner. Rather, the optimal regulated price is increasing in the debt-equity ratio only if the effects of increased debt outweigh the effects of greater productive investment.

From equation (7), for a fixed debt obligation,

$$\frac{\partial \alpha *}{\partial k} = \frac{[1 + i + (1 + t)\int_0^{z*} C_k(Q(p),z,k)\,dF(z) + \alpha \int_{z*}^1 C_k(Q(p),z,k)\,dF(z)]}{\int_{z*}^1 [R(p,z,k) - D]\,dF(z)}.$$

The denominator is positive by the definition of z^*. Thus, an increase in investment is accompanied by a rise (fall) in equity as $(1 + i) <(>) -(1 + t) \int_0^{z^*} C_k(Q(p),z,k)dF - \alpha \int_{z^*}^1 C_k(Q(p),z,k)dF$. The equity requirement depends on the relative size of the risk free rate of return and the weighted marginal productivity of capital. The optimal regulated price then decreases (increases) with the equity share α, as the risk free rate is greater than (less than) the weighted marginal productivity of capital.

Suppose now that both capital and debt can vary. The effects of investment on the regulated price become even more complex depending upon whether it is accompanied by a higher or lower debt. Debt can be lowered if capital is sufficiently productive at the margin. To highlight this effect fix the firm's debt to equity ratio.

<u>Proposition 4</u>: <u>Given</u> $R_p(p^*,z^*,k) > 0$, <u>for a fixed capital structure</u> B/E, <u>if</u>

$$B(1 + i) < -k(1 + t) \int_0^{z^*} C_k(Q(p),k,z)dF(z)$$

then the optimal regulated price is decreasing in investment, k, and correspondingly, increasing in debt, D.

Proof: Given s = B/E, by equation (1) k = B(1 + 1/s). From equation (6),

$$\frac{\partial D}{\partial k} = \frac{(1 + i) + (1 + t)(1 + 1/s)\int_0^{z*} C_k(Q,k,z)\,dF(z)}{(1 + 1/s)[1 - (1 + t)F(z*)]},$$

so by hypothesis, $\partial D/\partial k < 0$. Note that $dp*/dk = \partial p*/\partial k + (\partial p*/\partial D)(\partial D/\partial k)$. Since $\partial p*/\partial k < 0$ and $\partial p*/\partial D > 0$, it follows that $dp*/dk < 0$. Correspondingly, $dp*/dD = \partial p*/\partial D + (\partial p*/\partial k)(\partial k/\partial D)$ so that $dp*/dD > 0$. Q.E.D.

Higher investment raises the market value of both debt and equity with a fixed capital structure. This is accompanied by higher regulated rates under the conditions of the proposition.

An interesting finding reported by Besley and Bolten (1990) is that about 80 percent of the regulators and 63 percent of the utilities they survey believe that rates increase when the quality of debt deteriorates. To examine this issue in our model, the quality of debt can be represented in terms of either the risk of bankruptcy or the costs of bankruptcy. Let the distribution of z be given by F(z,a) where a is a shift parameter satisfying $F_a(z,a) > 0$. Hence, when a increases, low values of z, associated with bad states of nature, are more likely to be realized. Consequently, an increase in a increases the probability that the firm's costs will be high. Other things equal, this leads to a higher probability that the firm will not be able to meet its debt obligation and therefore to a greater riskiness of the firm's debt. An increase in a therefore can be thought of as leading to a deterioration in the quality of the firm's debt. Comparative statics analysis of the regulated price is obtained for given levels of investment and debt. The following result provides an explanation for Besley and Bolten's observation.

Proposition 5: The optimal regulated price is increased by a deterioration in the firm's debt due to an increase in the shift parameter, a, or due to an increase in bankruptcy costs, t.

The proposition can be proved by differentiating equation (9) with respect to a and t. The regulator responds to the deterioration in debt by an increase in price so as to lower the expected costs of bankruptcy.

5. Equilibrium Investment and Capital Structure

The payoff to the original owners of the firm can be written using equations (7) and (9),

$$V(p^*,D,k) = \Pi(p^*,D,k) - (1 + i)k. \tag{12}$$

The owners of the firm thus choose D^* and k^* to maximize $V(p^*,D,k)$ given the regulator's strategy $p^*(D,k)$. Noting that $\Pi_p(p^*,D,k) = W_p(p^*,D,k) + Q(p^*) = Q(p^*)$, the first order conditions for an interior solution can be written as

$$Q(p^*)\partial p^*/\partial D - tF(z^*) = 0, \tag{13}$$

$$Q(p^*)\partial p^*/\partial k - \int_0^1 C_k(Q(p^*),z,k^*)dF(z) - t\int_0^{z^*} C_k(Q(p^*),z,k^*)dF(z) - (1 + i) = 0. \tag{14}$$

Equation (13) reveals that the regulated firm optimally chooses debt by trading off the marginal increase in p^* due to debt against the marginal increase in expected bankruptcy costs. This implies that, in the present full-information framework, an unregulated firm would issue no debt since debt would only serve to create expected bankruptcy costs.

<u>Proposition 6</u>: <u>The regulated firm issues a positive amount of debt</u>.

<u>Proof</u>: The first order condition for debt for any given level of capital is $Q(p^*)\partial p^*/\partial D - tF(z^*) \leq 0$. Suppose that $D^* = 0$, which implies that $z^* = 0$. Then, from the regulator's first order condition $p^* = \int_0^1 C_q(Q(p^*),z,k)dF(z)$. Since $C_{qz} < 0$, $p^* < C_q(Q(p^*),0,k)$. Therefore, $R_p(p^*,0,k) > 0$. Recall that sign $\partial p^*/\partial D$ = sign $R_p(p^*,z^*,k^*)$ so that $\partial p^*/\partial D$ evaluated at $z^* = 0$ is positive. This implies that $\partial V(p^*,0,k)/\partial D = Q(p^*)\partial p^*/\partial D > 0$, which contradicts the optimality of $D^* = 0$. Therefore, $D^* > 0$ and $z^* > 0$. Q.E.D.

Since the firm issues a positive amount of debt in equilibrium it follows from equation (13) that $\partial p^*/\partial D = tF(z^*)/Q(p^*)$. This implies that the equilibrium regulated price is increasing in debt so that the "price-influence effect" (Taggart 1981, 1985) is observed. Note also that, since $\partial p^*/\partial D > 0$ in equilibrium, the marginal operating income of the firm at the break-even efficiency level is positive, $R_p(p^*,z^*,k^*) > 0$. The hypotheses of Propositions 2, 3 and 4 are thus satisfied in equilibrium.

The regulator may wish to constrain the firm's debt to reduce the price influence effect. A constraint on debt would require a binding commitment by the regulator at the time the firm's financing decision is made. The objective of the regulator at that time would then reflect the interests of consumers and original equity holders,

$$w(p,D,k) = S(p) + V(p,D,k) = S(p) + \Pi(p,D,k) - (1 + i)k.$$

Let equilibrium strategies p^* and k^* be functions of the debt ceiling D. Then, since $W_p(p^*,D,k) = 0$ and $\Pi_k(p^*,D,k) = 1 + i$, it follows from the envelope theorem that $dw(p,D,k)/dD = -tF(z^*) - Q(p)(\partial p/\partial k)(\partial k/\partial D)$. So, at $D = 0$, $dw/dD = -Q(p)(\partial p/\partial k)(\partial k/\partial D)$. Since $\partial p/\partial k < 0$, this is positive if the firm's investment is increased by debt at small debt levels ($\partial k/\partial D > 0$).

<u>Proposition 7</u>: <u>If</u> $\partial k/\partial D > 0$ <u>for small D</u>, <u>the regulator will permit a positive level of debt</u>.

This result is due to the equilibrium investment behavior of the firm and the equilibrium price-setting behavior of the regulator. Without the investment effect, the regulator would prefer a zero debt limit since additional debt serves to raise the equilibrium price and contributes to expected bankruptcy costs. However, the offsetting effects on investment may create benefits from allowing positive debt.

The optimal regulated price is decreasing in investment. This is due to the regulator acting after the firm has committed resources to investment and reflects "opportunistic behavior" by the regulator. It is apparent from equation (14) that, since investment lowers the regulated price, the firm invests to the point where the marginal productivity of capital is above the risk free rate of return, $\Pi_k(p^*,k^*,D^*) > 1 + i$. Since profit is concave in investment,[7] this implies that the regulated firm under-invests relative to the profit-maximizing level for the equilibrium output $Q(p^*)$ and debt level D^*.

Moreover, the regulated firm's equilibrium investment can be shown to be below the socially optimal level. The socially optimal investment k^0 and price p^0 are defined by two conditions; price equals expected marginal cost and the marginal productivity of investment equals the risk-free rate of return:

$$p^0 = \int_0^1 C_q(Q(p^0), z, k^0)dF(z),$$

$$-\int_0^1 C_k(Q(p^0), z, k^0) = 1 + i.$$

<u>Proposition 8</u>: (a) <u>The regulated firm invests less than is socially optimal</u>, $k^* < k^0$. (b) <u>The regulated price is above the socially optimal price</u>, $p^* > p^0$.

<u>Proof</u>: (a) Since $\partial p^*/\partial k = -W_{pk}(p^*, D, k)/W_{pp}(p^*, D, k)$ and $\partial p^*/\partial D = -W_{pD}(p^*, D, k)/W_{pp}(p^*, D, k)$, it can be shown that

$$\partial p^*/\partial k = (Q'(p^*)/W_{pp}(p^*, D, k))[\int_0^1 C_{kq}(Q(p^*), z, k)dF(z)$$
$$+ t \int_0^{z^*} C_{kq}(Q(p^*), z, k)dF(z)] + C_k(Q(p^*, z^*, k)(\partial p^*/\partial D).$$

Substitute for $\partial p^*/\partial k$ into equation (14) and use equation (13),

[7] Note that $\Pi_{kk} = -\int_0^1 C_{kk}(Q(p), z^*, k)dF - t \int_0^{z^*} C_{kk}(Q(p), z^*, k)dF + tC_k(Q(p), z^*, k)\ \partial z^*/\partial k < 0$. This follows from $C_k < 0$, $C_{kk} > 0$, and $\partial z^*/\partial k < 0$.

$$V_k(p^*,D^*,k) = (Q'(p^*)/W_{pp}(p^*,D,k))Q(p^*)[\int_0^1 C_{kq}(Q(p^*),z,k)dF(z)$$
$$+ t\int_0^{z^*} C_{kq}(Q(p^*),z,k)dF(z)] + C_k(Q(p^*),z^*,k)tF(z^*)$$
$$-[\int_0^1 C_k(Q(p^*),z,k)dF(z) + t\int_0^{z^*} C_k(Q(p^*),z,k)dF(z)] - (1+i).$$

Since $Q' < 0$, $W_{pp}(p^*,D,k) < 0$, and $C_{kq} < 0$, the first term is negative. Further, since $C_{kz} < 0$, $C_k(Q(p^*),z^*,k)tF(z^*) < t\int_0^{z^*} C_k(Q(p^*),z,k)dF(z)$. So, $V_k(p^*,D^*,k) < -\int_0^1 C_k(Q(p^*),z,k)dF(z) - (1+i)$. Since $\partial p^*/\partial D > 0$ in equilibrium, $p^*(k,0) < p^*(k,D^*)$, so that $p^0 = p^*(k^0,0) < p^*(k^0,D^*)$, and thus $Q(p^0) > Q(p^*(k^0,D^*))$. Since $C_{kq} < 0$,

$$-\int_0^1 C_k(Q(p^*(k^0,D^*)),z,k)dF(z) < -\int_0^1 C_k(Q(p^0),z,k)dF(z).$$

Therefore, $V_k(p^*,D^*,k^0) < 0$.

(b) Since $\partial p^*/\partial k < 0$ in equilibrium, and $k^* < k^0$, it follows that $p^0 < p^*(k^0,D^*) < p^*(k^*,D^*) = p^*$. Q.E.D.

Define k^E,p^E as the investment and price for an all-equity regulated firm. It is straightforward to establish the following result.

Corollary: (a) An all-equity regulated firm invests less than is socially optimal, $k^E < k^0$. (b) For an all-equity related firm, the regulated price is above the socially optimal price, $p^E > p^0$.

The corollary implies that requiring the regulated firm to rely only on equity will not eliminate the problem of underinvestment.

The issuance of debt, however, can reduce the incentives for underinvestment in equilibrium. To demonstrate this effect, consider the cost function $C(q,z,k) = (1/k + 1/z)q + 1/k$. Then, the investment level of an all-equity regulated firm is simply

$$k^E = (1 + i)^{-1/2}.$$

Now, evaluate the marginal return to original shareholders at this investment level,

$$V_k(p^*,D^*,k^E) = Q(p^*)(\partial p^*/\partial k) + (1/k^E)^2 Q(p^*)(1 + tF(z^*)) + (1/k^E)^2 tF(z^*).$$

Substituting for $\partial p^*/\partial k$, rearranging terms and simplifying yields

$$V_k(p*,D*,k^E) = \frac{-Q(p*)}{[W_{pp}(p*,D*,k^E)]^2}[-Q'(p*)(1 + tF(z*)) - W_{pp}(p*,D*,k^E)].$$

Now substitute for $W_{pp}(p^*,D^*,k^E)$ to obtain

$$\begin{aligned} V_k(p*,D*,k^E) = {} & \frac{-Q(p*)}{[W_{pp}(p*,D*,k^E)]^2}[-Q''(p - \int_0^1 C_q dF) \\ & - t\int_0^{z*}[(p - C_q)(Q(p*),z*,k^E)Q''(p*) + Q'(p*)] \\ & - t(R_p(p*,z*,k^E))^2 f/C_z(Q(p*),z*,k^E)] > 0. \end{aligned}$$

Therefore, it follows that <u>the issuance of debt causes equilibrium investment to exceed that of the all-equity regulated firm</u>, $k^* > k^E$. Clearly, the benefits of additional investment are offset by expected costs of bankruptcy. Debt raises the regulated price above expected marginal cost so that the regulator cannot appropriate fully the cost savings from investment. This allows the regulated firm to earn a greater marginal return from investment, thus reducing the incentive to underinvest.

6. Conclusion

The three-stage model of the regulatory process presented here shows that capital structure can play a role in the strategic interaction between regulators and firms. The regulated firm will take on a positive level of debt in equilibrium as a consequence of regulation despite the presence of bankruptcy costs and in the absence of tax advantages for debt. Debt serves to raise the regulated rates as the regulator seeks to reduce expected bankruptcy costs although the likelihood of bankruptcy is positive at the equilibrium. This result is confirmed by empirical analyses of the effect of debt on regulated rates cited previously.

The model allows regulators to set rates after the firm selects its investment and capital structure and after capital markets clear. The regulated firm is shown to invest less than the socially optimal level which in turn raises regulated rates above the optimal level. However, by reducing the regulator's ability to act in an opportunistic manner, the issuance of debt can allow the firm to increase investment above that of an all-equity firm. The strategic issuance of debt creates incentives for regulators to place limits on debt as a means of controlling the risk of bankruptcy. However, it is generally asserted that capital structure can serve to provide information regarding the costs and the performance of the firm. This suggests the need for additional investigation of the informational aspects of capital structure in regulated industries.

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