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INVESTMENT IN FLEXIBILITY UNDER RATE REGULATION

by

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Abstract:

This paper considers the effects of a regulated firm's capital structure on the firm's choice of technology. In models of rate regulation, the firm has an incentive to adopt a technology that is too inflexible, relative to the social optimum, in the sense that it would like to choose a cost function with higher than optimal variable costs and lower than optimal fixed costs. This effect arises because regulators wish to maximize welfare, and therefore have an incentive to require that the regulated price will be set as close as possible to marginal cost. Hence, a technology with a low marginal cost is associated with a low regulated price, and is not attractive to the firm. Performance under rate regulation can be improved, however, if the firm is leveraged, because debt induces regulators to increase the regulated price to prevent the firm from becoming financially distressed. Consequently the cost of flexibility to the firm is lowered, leading it to choose a more flexible technology, closer to the socially optimal level. In the context of this model, the firm may have an incentive to goldplate (i.e., waste resources) if regulators restrict its ability to issue debt. This incentive disappears, however, when the firm is allowed to issue its most preferred capital structure.

Keywords: rate regulation, flexibility, capital structure, goldplating.

JEL Classification Numbers: L51, G32, G38

Running Head: Flexibility under rate regulation

1. INTRODUCTION

The public utilities sector in the U.S., including electricity, natural gas and telecommunication, is subject to rate regulation by state regulatory commissions as well as federal agencies. Similarly, in Britain, new regulatory bodies were established to apply price controls to the newly privatized public utilities in electricity, natural gas and telecommunications and water. Given the importance of public utilities and the magnitude of investments they require[1], it seems natural to ask what is the effect of rate regulation on the investment decisions of regulated firms. Indeed, this question was a main focus of the rate regulation literature in the last three decades. Traditionally, however, the maintained assumption in this literature is that the firm is endowed with a specific technology that is represented by a production function that depends on investment in physical capital and labor. Given this assumption, the discussion on the effects of rate regulation on investment, beginning with Averch and Johnson (1962), has centered around the question whether regulated firms invest too much or too little in physical capital.

In practice, however, firms have a variety of technologies to choose from. These technologies may differ from one another not only in their technical properties, but also in their cost structures. An electric utility, for example, can choose between different mixes of base-load and peak-load generating units, with the former having a higher capital cost, but lower operating cost than the latter (Fuss and McFadden (1978)). Similarly, a telephone company can build redundancy into its network, thereby increasing its capital costs while reducing the cost of maintaining the network. The availability of different competing technologies suggests that in analyzing the effect of rate regulation on investment, one cannot simply take the firm's technology as given and examine the magnitude of investment. Rather, one should first examine the firm's choice of a particular technology from the

[1] In the U.S., investment in new plant and equipment in the public utilities sector totalled 65.91 billion dollars in 1990 and accounted for approximately 12.34 percent of total business expenditure for new plant and equipment (Source: Department of Commerce, Bureau of the Census.)

set of available technologies.

This paper analyzes one aspect of a regulated firm's choice of technology, namely the choice of flexibility. The notion of flexibility was first introduced by Stigler (1939). Roughly speaking, according to Stigler, one technology is said to be more flexible than another if the marginal cost function associated with the former is flatter than the one associated with the latter. Thus, as the firm's technology becomes more flexible, the cost of production is less sensitive to fluctuations in output.[2] Obviously, the choice of technology becomes interesting when it involves a trade-off between low cost of producing at the expected scale (static efficiency) and minimizing the loss associated with deviations from this scale (flexibility). Such a trade-off exists, for example, when low marginal cost comes at the expense of high fixed cost. The present paper is concerned exactly with this trade-off. It argues that rate regulation induces regulated firms to choose a technology with higher marginal cost and lower fixed cost than in the first-best (i.e., the technology that a benevolent social planner would choose).

A main assumption in this paper is that regulators cannot commit to a particular rate before the firm they regulate makes an irreversible investment decision. In the U.S., this inability to commit to rates stems from the fact that, historically, courts gave regulatory commissions a great deal of leeway in choosing rates. According to the Supreme Court in the landmark Hope Natural Gas case of 1944, a regulatory agency is "not bound to the use of any single formula or combination of formulae in determining rates".[3] Moreover, in the United Railways case of 1930, the Supreme Court stated that "What will formulate a fair return in a given case is not capable of exact mathematical demonstration."[4] In Britain, the agencies that were established to regulated the newly privatized

[2] For alternative definitions of flexibility and a survey of the literature, see Carlsson (1989).

[3] Federal Power Comm. v. Hope Natural Gas Co., 320 U.S. 591, 603 (1944).

[4] United Railways & Elec. Co. v. West, 280 U.S. 234, 249, 251 (1930).

public utilities were given wide discretion in setting rates.[5] Assuming that regulators wish to maximize welfare, they have an incentive to adjust rates after the firm has invested, thereby exploiting the fact that at this point the firm cannot reverse its investment decision. When investment involves sunk cost, this regulatory opportunism, is shown in the literature to induce regulated firms to underinvest, e.g., Spulber (1989, ch. 20) and Besanko and Spulber (1990).[6]

As this paper shows, regulatory opportunism creates an additional distortion in the firm's investment decision beyond underinvestment. When regulators wish to maximize welfare, they set the regulated price as close as possible to marginal cost. In general, however, the regulated price will exceed marginal cost because otherwise, the firm may become financially distressed, a situation that creates a deadweight loss and is therefore socially undesirable. Thus, the benefits from having a low marginal cost are effectively expropriated by regulators. Since a flexible technology exhibits relatively low marginal cost, it is also associated with low regulated price and hence, is not attractive to the firm. Consequently, a regulated firm has the incentive to choose a less flexible technology than is socially desirable. As a result, the firm's cost is biased towards too high marginal cost and too low fixed cost. Unlike the underinvestment problem, this bias arises even all costs are avoidable, in which case the regulator cannot ignore them when he sets the regulated price (as he does with sunk cost) because of their effect on the expected cost of financial distress.

The distortion in the choice of flexibility, however, is alleviated when the firm is leveraged. The reason for that is the following. When the firm issues debt to outsiders it becomes more susceptible to financial distress. Since financial distress creates a deadweight loss, regulators will try

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[5] For example, the telecommunication act of 1984 allows the Director General of Telecommunications to act "In a manner he considers best calculated".

[6] The absence of regulatory commitment to rates is also explored by Banks (1992) in the context of regulatory auditing and Spiegel (1991) and Spiegel and Spulber (1991) in the context of optimal capital structure of a regulated firm.

to ensure that the firm has a sufficient cash flow by setting the regulated price sufficiently above marginal cost. Consequently, when the firm is leveraged, a flexible technology (which exhibits low marginal costs) no longer leads to as low regulated prices as before. From the firm's point of view, flexibility becomes less costly and hence, the firm chooses a technology with a degree of flexibility closer to the first-best degree. Debt, therefore, alleviates the distortion in the firms' choice of flexibility by inducing the firm to select a more flexible technology than it would select otherwise.

Regulated firms are sometimes accused of making unnecessary expenditures (goldplating) with the sole intention of inducing regulators to approve higher rates.[7] In the context of the model presented in this paper, a regulated firm may be tempted to goldplate because goldplating inflates its costs, rendering it more susceptible to a financial distress. This in turn, induces the regulator who is concerned about this possibility, to increase the regulated price. This increase may more than compensate the firm for the waste of resources. As this paper shows, goldplating may occur if regulators prevent the firm from issuing an optimal debt level. When the firm is optimally leveraged, however, the firm never goldplates. The reason for that is that debt works in a very similar way to goldplating and has the advantage of not being wasteful.

Although there exists a vast literature on investment under rate regulation, surprisingly little theoretical research has been devoted to the issue of the choice of technology by regulated firms. Laffont and Tirole (1986) develop an optimal regulatory mechanism under asymmetric information. As in the current paper, this mechanism also leads to a bias toward too high marginal cost and too low fixed cost. However, while here the bias arises because of regulatory opportunism, in their model it arises because under asymmetric information the firm produces too little output. As a result, has an incentive to keep fixed cost low even at the expense of high marginal cost. An important

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[7] For a discussion on goldplating and examination of this practice under rate-of-return regulation see Zajac (1972) and Bailey (1973).

implication of this is that in Laffont and Tirole, given its output, the firm produces efficiently, whereas here, the firm produces inefficiently at all output levels. Sappington (1983) also develops an optimal regulatory mechanism under asymmetric information, but finds the reverse bias, i.e., the optimal regulatory strategy induces the firm to adopt a technology with too much fixed cost and too little variable cost. This bias arises because, by raising fixed cost above their first-best level, the regulator is able to limit the information rents that firms command from their private information about the trade-off between fixed and variable costs.

The remainder of the paper is organized as follows. The basic model is presented in Section 2 and the regulatory process is considered in Section 3. In Section 4, the first-best solution is established as a benchmark. In Section 5, the effect of rate regulation on the firm's choice of technology is studied under the assumption that the firm is all-equity. The choice of an optimal structure, involving a positive debt level is examined in Section 6. The implication of this optimal capital structure for the choice of technology is analyzed in Section 7. Section 8 solves an explicit example and offers comparative statics results. In Section 9, the basic model is used to examine goldplating. A summary of the main results and concluding remarks are in Section 10.

2. THE MODEL

A regulated firm is assumed to be a natural monopoly producing a single product/service. The demand for the firm's output is given by $Zq(p)$, where p is the regulated price set by the regulator and z is a random demand shock. This shock is positive in the sense that high values of z are associated with a high demand and thus represent better states of nature. The demand shock, z, is distributed on the interval $[z^-, z^+]$, according to a differentiable distribution function $f(z)$ and cumulative distribution function $F(z)$. Assuming that $z^- > 0$, the demand for the firm's output is strictly positive even in the worst state of nature. To produce its output, the firm needs to invest \$k in a production facility. This facility, however, can be designed in many different ways. Each design corresponds to a different technology and is associated with a total operating cost function $C(Q, \gamma, z) = g(\gamma)Zq + \gamma$, where $\gamma \geq 0$, as explained below, is a flexibility parameter. The firm's operating cost, then, consists of a variable cost that is linear in output (constant marginal cost) and a fixed cost. The assumed properties of the demand and the cost functions are:

(A-1) $Q_p(p) < 0$, $Q_{pp}(p) \leq 0$,

(A-2) for all γ: $g(\gamma) > 0$, $g_\gamma(\gamma) < 0$,

(A-3) $\lim_{\gamma \to 0} g_\gamma(\gamma) = -\infty$, $\lim_{\gamma \to \infty} g_\gamma(\gamma) = 0$,

where subscripts denote partial derivatives. Assumptions (A-1) is a standard assumption. Assumption (A-2) states that variable cost is positive and decreasing in γ. The parameter γ can therefore be thought of as the degree of flexibility that the firm's technology exhibits. As γ increases, the firm's technology becomes more flexible: its marginal cost is lowered, while its fixed cost is increased. Finally, Assumption (A-3) ensures the existence of an interior solution for γ.

It should be pointed out that the notion of flexibility used in this paper differs slightly from the one that is typically used in the literature (e.g., Marschak and Nelson (1962), Mills (1984), Vives (1989)). In these papers, the variable cost function is quadratic in output, giving rise to a U-shaped average cost function and the measure of flexibility is the inverse of C_{QQ}. As flexibility increases, the slopes of both marginal and average cost functions are lowered, implying that the firm would like to increase its flexibility whenever output is either sufficiently larger or sufficiently smaller than the minimum efficient scale. Here in contrast, the variable cost function is linear in output, so average cost decreases in output and the measure of flexibility is the inverse of C_Q. Consequently, while an increase in flexibility still lowers the slope of the marginal function, it lowers the slope of the average cost function only when output is relatively large. Thus, under the notion of flexibility used in the current paper, a more flexible technology is preferred to a less flexible one only when output is relatively large but not otherwise. The difference between the two notions of flexibility, however, is inessential for the purpose of this paper since all the results reported here generalize to the case where the variable cost function has the form $g(\gamma)h(Q)$, where $h(Q)$ is any nonnegative and increasing function of Q.

Typically, the firm's investment decision consists of two steps. First, the firm chooses the specific technology it will employ. Second, the firm decides how much to invest in the technology it chose. This paper, however, is concerned only with the first step of the investment decision.[8] To this end, the second step of the firm's investment decision is assumed to be of a 0-1 type: the size of investment, k, is fixed and the firm can only decide whether or not to undertake it. To simplify the analysis further, k is assumed in most of the paper to be small enough so that the firm always finds it profitable to invest. This leaves the design of the production facility, i.e., the choice of γ, as the only meaningful investment decision that the firm has to make.

The sequence of events is shown in Figure 1. There are four stages. In stage 1, the firm chooses its technology by selecting a flexibility parameter, γ. This selection determines the cost structure of the firm. In stage 2, the firm chooses a mix of equity and debt needed to finance the (sunk) cost of investment, k, by issuing new shares and bonds to outsiders. Given this mix, the value of the firm's securities is determined in a competitive capital market. In stage 3, the regulator establishes the regulated price, taking the firm's technology and capital structure as given. Finally, in stage 4 the random demand shock, z, is realized, output is produced and payments are made.

Two important assumptions underlie the sequential structure of the model. The first is the assumption that the management of the regulated firm can choose the firm's investment and capital

[8] For an analysis of the second step of the investment decision in the absence of regulatory commitment to rates, see Spulber (1989), Besanko and Spulber (1990) and Spiegel and Spulber (1991).

structure at its own discretion. This assumption reflects the fact that in the U.S., courts in many states (e.g., Michigan, Oklahoma, Kansas, Delaware) restrict state commissions' scope of inquiry in security issue proceedings. Specifically, courts have directed the commissions to inquire only whether the proposed projects are within the scope of the utility's corporate activity and not whether they are "reasonable" or "necessary" (for details see Howe (1990)). Moreover, as the Colorado Supreme Court argues "...a guiding principle of utility regulation is that management is to be left free to exercise its judgment regarding the most appropriate ratio between debt and equity".[9] Even when a deviation from this guiding principle is possible, "...few commissions are willing to substitute their judgments for those of the management except in reorganization cases" (Phillips (1988, p. 226)). The assumption also reflect the philosophy in Britain of "regulation with light hand" (Vickers and Yarrow (1988)).

The second important assumption is that rates are set after the firm has made its investment and financial decisions. This assumption captures the lack of regulatory commitment to rates, that as argued in the introduction, characterizes the regulatory framework in both the U.S. and Britain. It also reflects the fact that in reality rates are adjusted much more often than either the firm investment or its capital structure.

To finance the cost of its investment, k, the firm issues equity and debt to outsiders. Let $E(\alpha)$ be the market value of the new shares representing a fraction $\alpha \in [0, 1]$ of the firm's equity, and let B(D) be the market value of debt with face value D. Assuming that the firm has no outstanding debt to begin with, D represents the debt obligation of the firm. Since E and B should cover the cost of the project, $k \leq E(\alpha) + B(D)$. There is evidence, however, to suggest that regulatory commissions do not allow regulated firms to raise external funds in excess of the costs of investment in physical assets, see e.g. Phillips (1988 p. 220). Thus,

[9] In Re Mountain StatesTeleph. & Teleg. Co. 39 PUR 4th 222, 247-248.

$$k = E(\alpha) + B(D). \tag{1}$$

Assuming that the firm has no initial outstanding debt, its capital structure is characterized by a pair (α, D) satisfying equation (1).

The operating income of the firm is $zR(p, \gamma) - \gamma$, where $R(p, \gamma) = Q(p)(p - g(\gamma))$. Given a regulated price, p, a flexibility parameter, γ, and the firm's debt obligation, D, there exists a critical state of nature, z^*, at which the firm is just able to break even. This state of nature is defined by

$$z^*(p,\gamma,D) \equiv \begin{cases} z^-, & \text{if } z^- > \dfrac{D+\gamma}{R(p,\gamma)}, \\ \dfrac{D+\gamma}{R(p,\gamma)}, & \text{if } z^- \leq \dfrac{D+\gamma}{R(p,\gamma)} \leq z^+, \\ z^+, & \text{if } z^+ < \dfrac{D+\gamma}{R(p,\gamma)}. \end{cases}$$

Since $zR(p, \gamma) - \gamma$ increases in z, the probability that the firm is not able to break even is $F(z^*)$.

The critical state of nature, z^*, is illustrated in Figure 2. For states of nature above z^*, $zR(p, \gamma) > D + \gamma$, so the firm earns positive profits. For states of nature below z^*, $zR(p, \gamma) < D + \gamma$, in which case the firm is unable to pay claimholders such as debtholders, input suppliers and workers out of its earnings. Assuming that the firm has no initial liquid assets, it becomes financially distressed. Nevertheless, it is assumed throughout, that even when the firm is financially distressed, equityholders remain the residual claimants and pay claimholders in full. To fulfill its financial obligations in stage 4 of the game, the firm either borrows money from external sources, sells some of its assets, or asks the government to cover its deficit.[10] From social point of view all three options are costly: Given that regulators behave opportunistically, the capital market

[10] The option to liquidated the firm in order to pay claimholders is not considered here because it is hard to imagine that the government would let a natural monopoly to be liquidated. Ruling out the possibility of liquidation, however, is inessential for the analysis. All the results remain unchanged even if the firm is liquidated once it becomes financially distressed, as long as liquidation creates a deadweight loss.

will require the firm to pay a very high interest rate on loans if it decides to borrow money from external sources. Selling assets can also prove to be costly because the firm may fail to recover the true value of its assets. This is especially so when assets are firm-specific in the sense that their value in alternative uses is lower than their value to the firm. Finally, if the government is willing to cover the firm's losses, it may have to raise the necessary funds by imposing distorting taxes. Thus, financial distress creates a deadweight loss. This deadweight loss may in fact be exacerbated if normal production is interrupted. In light of its different potential sources, the deadweight loss is assumed to be proportional to the size of the firm's loss. That is, whenever $z \leq z^*$, the cost of financial distress is $t[D + \gamma - zR(p, \gamma)]$ where $t \in [0, 1]$. Note that sunk cost, k, has no direct effects on neither the probability nor the cost of financial distress (although it may affect them indirectly if k is financed with debt), while fixed cost, γ, has a direct effect on both. Thus, in this model, the two types of costs have a very different impact on the regulatory process and consequently on the firm's payoff despite the fact that both do not vary with output.

3. THE REGULATORY PROCESS

Consider the regulatory process that takes place in stage 3 of the game. In this process, given the firm's choice of investment level and flexibility parameter, the regulator is assumed to choose the regulated price, p, with the objective of maximizing the expected social surplus generated by the firm, given by

$$W(p,\gamma,D) = E\left[\int_p^{\infty} zQ(p)\,dp + zR(p,\gamma)\right] - \gamma - k - t\int_{z^-}^{z^*(p,\gamma,D)} [D + \gamma - zR(p,\gamma)]\,dF(z). \qquad (2)$$

The net expected social surplus, $W(p, \gamma, D)$, is the sum of consumers' surplus and the expected profits of the firm, net of the expected cost of financial distress. The regulator, then, takes into account the effects of p on both consumers' surplus, the firm's profits and the expected cost of financial distress. This characterization of the regulator's objective is consistent with Peltzman's (1976) political model of regulation and it reflects the landmark Supreme Court decision in the Hope Natural Gas case, according to which, "The fixing of 'just and reasonable' rates involves a balancing of the investor's and the consumers' interests" which should result in rates which are "Within a range of reasonableness".[11] It also reflects the regulatory framework that was established in Britain in the electricity, natural gas, telecommunications and water industries following their privatization in the 80's (e.g., Vickers and Yarrow (1988)).

The fact that the regulator cares about the cost of financial distress is consistent with Owen and Braeutigam (1978) who argue that "One of the worst fears of a regulatory agency is the bankruptcy of the firm it supervises, resulting in 'instability' of services to the public or wildly fluctuating prices." The regulator's concern about financial distress is also consistent with the situation in Britain, since as Vickers and Yarrow (1991) report, "Regulators of privatized utility companies in Britain are effectively required to ensure that they do not go bankrupt."

Let $p^* = p^*(\gamma, D)$ be the regulated price set by the regulator at the third stage of the game, given the flexibility parameter chosen by the firm in the first stage of the game and the debt the firm issued in the second stage. Then, p^* is characterized by the following first order condition

$$\frac{\partial W(p^*,\gamma,D)}{\partial p} = -\hat{z}Q(p^*) + R_p(p^*,\gamma)\left[\hat{z} + t\int_{z^-}^{z^*(p^*,\gamma,D)} z\,dF(z)\right] = 0, \tag{3}$$

where $\hat{z}$ is the mean of z and $R_p(p, \gamma) = Q(p) + Q_p(p)(p - g(\gamma))$. Following Spiegel and Spulber (1991), equation (3) can be rewritten after manipulations as

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[11] As explained by the Pennsylvania commission, the range of reasonableness "Is bounded at one level by investor interest against confiscation and the need for averting any threat to the security for the capital embarked upon the enterprise. At the other level it is bounded by consumer interest against excessive and unreasonable charges for service". (Pennsylvania Pub. Utility Comm. v. Bell Teleph. Co. of Pennsylvania, 43 PUR3d 241, 246 (Pa., 1962)).

$$\frac{p^*-g(\gamma)}{p^*} = -\frac{1}{\eta(p^*)}\left[\frac{t\int_{z^-}^{z^*(p^*,\gamma,D)} z\,dF(z)}{\hat{z}+t\int_{z^-}^{z^*(p^*,\gamma,D)} z\,dF(z)}\right], \tag{4}$$

where $\eta(p)$ is the elasticity of demand. Written in this way, the optimal regulated price can be interpreted as a modified Ramsey price: The markup of the regulated price above marginal cost is proportional to the inverse of the demand elasticity. However, unlike the traditional Ramsey price which is derived by ensuring that the firm never incur losses, here the regulator allows the firm to become financially distressed in some states, but he takes into account the cost of financial distress and maximizes expected welfare net of this cost. Using the definition of z^*, Assumption (A-1) and the fact that $p^* > g(\gamma)$, it is straightforward to show that $W_{pp}(p^*, \gamma, D) < 0$. The second order condition for p^* is therefore satisfied.

From equation (4) it is easy to see that the deviation from marginal cost pricing decreases with the elasticity of demand, but increases with the cost of financial distress and the probability that it occurs. The effect of a change in the flexibility parameter on the regulated price, however, is ambiguous. To see this, fix D and differentiate equation (3) with respect to p^* and γ to obtain

$$\frac{\partial p^*}{\partial \gamma} = \frac{1}{-W_{pp}(p^*,\gamma,D)}\Bigg\{-Q_p(p^*)g_\gamma(\gamma)\left[\hat{z}+t\int_{z^-}^{z^*(p^*,\gamma,D)} z\,dF(z)\right] \\ + tz^*(p^*,\gamma,D)R_p(p^*,\gamma)f(z^*(p^*,\gamma,D))\frac{\partial z^*(p^*,\gamma,D)}{\partial \gamma}\Bigg\}, \tag{5}$$

where from the definition of z^*, it follows that $\partial z^*/\partial\gamma = 0$ if $z^* = z^+$ or $z^* = z^-$ and otherwise,

$$\frac{\partial z^*(p^*,\gamma,D)}{\partial \gamma} = \frac{R(p^*,\gamma)+Q(p^*)g_\gamma(\gamma)[D+\gamma]}{R(p^*,\gamma)^2} = \frac{1+z^*(p^*,\gamma,D)Q(p^*)g_\gamma(\gamma)}{R(p^*,\gamma)}. \tag{6}$$

As (5) demonstrates, a change in flexibility has two effects on the regulated price. First, as γ increases, marginal cost is lowered, thereby giving the regulator who moves after the firm, an incentive to pass part of the benefits from this reduction to consumers by lowering the regulated price. This incentive is represented by the first term on the right side of (5). Second, an increase in γ also affects the probability of financial distress. The regulator, therefore, adjusts the regulated price in response to this change. This adjustment is captured by the second term on the right side of (5). Since this second effect can be either positive or negative, one cannot determine the sign of $\partial p^*/\partial\gamma$ unambiguously.

4. THE FIRST-BEST SOLUTION

In this section, the first-best solution is established as a benchmark. The first-best is achieved in this model if the flexibility parameter γ and the capital structure of the firm are chosen by a benevolent social planner whose objective is the maximization of $W(p, \gamma, D)$. Clearly, since D affects social welfare only through its impact on the probability and cost of financial distress, both of which are increasing in D, $W(p, \gamma, D)$ is maximized when $D = 0$. Thus, the first-best regulated price, p^{fb}, and flexibility parameter, γ^{fb}, are found by maximizing $W(p, \gamma, 0)$ with respect to p and γ.

Since at the first-best, $D = 0$, the first-best regulated price is $p^{fb} = p^*(\gamma^{fb}, 0)$, i.e., the modified Ramsey price evaluated at $D = 0$ and at the first-best flexibility parameter, γ^{fb}. Substituting for $D = 0$ in $W(p^{fb}, \gamma, D)$ and using the definition of z^*, the first order condition for γ^{fb}, is:

$$\frac{\partial W(p^{fb},\gamma^{fb},0)}{\partial\gamma} = Q(p^{fb})g_{\gamma}(\gamma^{fb})\left[\hat{z} + t\int_{z^-}^{z^*(p^{fb},\gamma^{fb},0)} z\,dF(z)\right] - \left[1 + tF(z^*(p^{fb},\gamma^{fb},0))\right] = 0. \tag{7}$$

The existence of an interior solution for γ^{fb} is ensured by Assumption (A-3). Equation (7) shows that γ^{fb} is chosen by trading off variable cost (evaluated at $Q(p^{fb})$) and fixed cost.

5. THE CHOICE OF FLEXIBILITY UNDER ALL-EQUITY FINANCING

In this section, the firm's choice of technology is analyzed under the assumption that k is financed entirely by equity. Recalling that the firm is assumed to have no outstanding debt to begin with, this implies that $D = 0$, so the firm is all-equity. This case is a natural starting point for the analysis because the assumption that the firm is all-equity is implicitly made in virtually all the literature on rate regulation. Optimal capital structure and its implications on the firm's technology are examined in sections 6 and 7, respectively.

Let p^E denote the regulated price when the firm is all-equity. p^E is the modified Ramsey price evaluated at $D = 0$ and γ^E, i.e., $p^E = p^*(\gamma^E, 0)$. Whenever $\gamma^{fb} = \gamma^E$, p^E coincides with p^{fb}. However, since γ^E is typically different than its first-best level, so is p^E.

Consider now the second stage of the game. In this stage, the firm issues equity to outsiders to raise \$k. Assuming that capital markets are competitive and that investors correctly anticipate the outcome of the regulatory process, new equityholders earn an expected return equal to the risk free interest rate, which without loss of generality is normalized to 0. Thus, using equation (1),

$$k = E(\alpha) = \alpha\left[\hat{z}R(p^E,\gamma) - \gamma + mt\int_{z^-}^{z^*(p^E,\gamma,0)}\left[zR(p^E,\gamma) - \gamma\right]dF(z)\right], \tag{8}$$

where $m \in [0, 1]$ represents the share of the cost of financial distress borne by the firm. At one extreme, if the cost of financial distress is due to a high interest rate that the firm is paying on a loan it takes to finance its loses, then $m = 1$. At the other extreme, if the cost of financial distress represent the shadow cost of public funds, then $m = 0$. When the cost of financial distress is due to a sale of assets, m can be either 1 or less than 1 depending on whether these assets affect the quality of the firm's output. The right side of equation (8) represents the share of new equityholders in the expected operating income of the firm net of the expected cost of financial distress.

Anticipating the outcome of the regulatory process and the equilibrium in the capital market, and given the capital structure of the firm (α, 0), the original owners of the firm choose in stage one of the game a flexibility parameter, γ^E, to maximize their expected payoff given by

$$Y(\gamma,\alpha,0) = (1-\alpha)\Big[\hat{z}R(p^E,\gamma) - \gamma + mt\int_{z^-}^{z^*(p^E,\gamma,0)}[zR(p^E,\gamma)-\gamma]dF(z)\Big]. \tag{9}$$

Substituting for α from (8) into (9):

$$Y(\gamma,0) = \hat{z}R(p^E,\gamma) - \gamma - k + mt\int_{z^-}^{z^*(p^E,\gamma,0)}[zR(p^E,\gamma)-\gamma]dF(z). \tag{10}$$

Using the definition of z*, the first order condition for γ^E is

$$\frac{\partial Y(\gamma^E,0)}{\partial\gamma} = \left[R_p(p^E,\gamma^E)\frac{\partial p^E}{\partial\gamma} - Q(p^E)g_\gamma(\gamma^E)\right]\left[\hat{z} + mt\int_{z^-}^{z^*(p^E,\gamma^E,0)} z\,dF(z)\right] - [1 + mtF(z^*(p^E,\gamma^E,0))] \le 0, \tag{11}$$

where $\partial p^E/\partial\gamma$ is given by (5). Equation (11) indicates that a marginal change in the degree of flexibility has two effects on $Y(\gamma, 0)$. The first is an indirect effect due to an adjustment in the regulated price induced by a change in γ. This indirect effect is represented by the first term in the square brackets on left side of (11). The second effect is a direct effect due to a change in the firm's cost structure and it has two components: the first, described by the second term in the square brackets is due to the decrease in variable cost, while the second, described by the last term on the left side of equation (11) is due to the increase in fixed cost. The solution for γ^E is characterized by the following Proposition.

Proposition 1: *Assume that the firm is all-equity and $Y(\gamma, 0)$ is strictly concave in γ. Then, the inability of regulators to commit to rates before the firm chooses its technology induces the firm to select the least flexible technology available to it, i.e., $\gamma^E = 0$. Since $\gamma^{fb} > 0$, the firm's technology is too inflexible.*

Proof: Evaluate $\partial Y(\gamma, 0)/\partial\gamma$ at $\gamma = 0$. In this case, the firm has no fixed cost, so its operating income is $zQ(p^E)(p^E - g(0))$ which is nonnegative in all states of nature because $p^E \geq g(\gamma)$ for all γ. Since $D = 0$, this means that the firm never becomes financially distressed, i.e., $z^* = z^-$. But, as (4) shows, in this case $p^E = g(0)$, so $R_p(p^E, 0) = Q(p^E)$ and $\partial p^E/\partial\gamma = g_\gamma(0)$. Substituting in the right side of (11), $\partial Y(0, 0)/\partial\gamma = -1$. Since $Y(\gamma, 0)$ is strictly concave in γ, $\gamma^E = 0$. ■

As the proposition 1 shows, $\gamma^E = 0$, so the firm has no fixed cost. Since the regulated price is larger or equal to marginal cost and since the firm has no debt, it always generates a nonnegative cash flow. Thus,

Proposition 2: *An all-equity regulated firm never becomes financially distressed, i.e.,* $z^*(p^E, 0, 0) = z^-$.

Given the result of proposition 2, equation (4) shows that when the firm is all-equity, the regulator uses marginal cost pricing, i.e., $p^E = g(0)$. Hence, the payoff of the original equityholders is $Y(0, 0) = -k$. Thus, the firm does not invest at all when $k > 0$, unless the government is willing to subsidize investment, or finds a way to commit to fully reimburse the firm for its investment. In the next two section it will be shown that by allowing the firm to issue an optimal capital structure, the regulators are able to overcome their inability to commit.

6. OPTIMAL CAPITAL STRUCTURE

In this section, the optimal capital structure of the firm (α^L, D^L) is characterized. Let p^L denote the regulated price that is induced by an optimal capital structure, i.e., $p^L = p^*(\gamma^L, D^L)$. Now, in the second stage of the game, the firm issues new equity and debt to outsiders to raise \$k. Since by assumption the firm always fulfills its financial obligations, the firm's debt is riskless, i.e., $B(D) = D$. This however is not to say that debt is costless from the firm's perspective: Since debt adds to the financial obligations of the firm, it makes financial distress more likely to occur and therefore raises the expected cost of financial distress. Since capital markets are assumed to be competitive and investors are assumed to correctly anticipate the outcome of the regulatory process, both new equityholders and debtholders earn a zero expected return on their investment. Using equation (1), the equilibrium in the capital market is characterized by

$$k = \alpha\left[\hat{z}R(p^L,\gamma) - D - \gamma + mt\int_{z^-}^{z^*(p^L,\gamma,0)}\left[zR(p^L,\gamma) - \gamma\right]dF(z)\right] + D. \tag{12}$$

The left side of equation (12) is the market value of the firm's securities which due to the regulatory constraint, exactly covers the cost of the project, k. The first term on the right side of equation (12) represents the share of new equityholders in the firm's expected operating income net of the cost of financial distress. The second term on the right side of the equation is the payoff of debtholders that equals the face value of their claim. The capital structure of the firm is fully characterized by a pair (α, D) that satisfies equation (12).

Anticipating the outcome of the regulatory process and the equilibrium in the capital market, and given γ, the owners of the firm choose a pair (α, D) to maximize their expected payoff given by

$$Y(\gamma,\alpha,D) = (1-\alpha)\left[\hat{z}R(p^L,\gamma) - D - \gamma + mt\int_{z^-}^{z^*(p^L,\gamma,0)}\left[zR(p^L,\gamma) - \gamma\right]dF(z)\right]. \tag{13}$$

Substituting for α from equation (12),

$$Y(\gamma,D) = \hat{z}R(p^L,\gamma) - \gamma - k - mt\int_{z^-}^{z^*(p^L,\gamma,D)}\left[D + \gamma - zR(p^L,\gamma)\right]dF(z). \tag{14}$$

Thus, the choice of an optimal capital structure becomes one of choosing an optimal debt level, D^L. Using the definition of z*, the first order condition for an interior solution for D^L is

$$\frac{\partial Y(\gamma,D^L)}{\partial D} = R_p(p^L,\gamma)\left[\hat{z} + mt\int_{z^-}^{z^*(p^L,\gamma,D^L)} z\,dF(z)\right]\frac{\partial p^L}{\partial D} - mtF(z^*(p^L,\gamma,D^L)) = 0, \tag{15}$$

where by differentiating equation (3) with respect to p^L and D and using the definition of z*, yields

$\partial p^L/\partial D = 0$ for $z^* = z^-$ or $z^* = z^+$, and otherwise,

$$\frac{\partial p^L}{\partial D} = \frac{tz^*(p^L,\gamma,D)R_p(p^L,\gamma)f(z^*(p^L,\gamma,D))}{-R(p^L,\gamma)W_{pp}(p^L,\gamma,D)}. \tag{16}$$

Note that this last expression is positive since by equation (3) $R_p(p, \gamma) > 0$, $W_{pp}(p^L, \gamma, D^L) < 0$ and $z^* \geq z^- > 0$. Thus, an increase in debt always leads to a rate increase which in turn, since $R_p(p, \gamma) > 0$, increases the firm's operating income. Thus, the first term on the right side of (15) represents the marginal benefit of debt from the firm's perspective. The second term on the right side of (15) represents the marginal cost of debt and is due to the increase in the expected cost of financial distress. At an interior optimum, the two term are equal. The following proposition shows that (15) indeed has an interior solution.

Proposition 3: *The optimal level of debt is strictly positive, but less than $z^+R(p^L, \gamma) - \gamma$, i.e., $0 < D^L < z^+R(p^L, \gamma) - \gamma$. Consequently, in equilibrium, $z^* < z^+$, that is, the equilibrium probability of financial distress is strictly less than one. Moreover, D^L decreases with the firm's share in the cost of financial distress, i.e., $\partial D^L/\partial m < 0$.*

Proof: To prove the first part of the proposition, assume by way of negation that the firm is all-equity. Then, by Proposition 2, $F(z^*) = 0$, so the second term on the left side of (15) vanishes. Since the first term is positive for all D, then $\partial Y(\gamma, 0)/\partial D > 0$, a contradiction to the optimality of $D = 0$. To prove that $D^L < z^+R(p^L, \gamma) - \gamma$, notice that the definition of z^* implies that otherwise, $z^* = z^+$. In this case, $\partial p^L/\partial D = 0$, so $\partial Y(\gamma, D^L)/\partial D = -mt < 0$. Therefore, the firm never issues debt to the point where $D^L \leq z^+R(p^L, \gamma) - \gamma$. As a result, in equilibrium, $z^* < z^+$. To prove the second part of the proposition, note that the cost of debt, $mtF(z^*)$, increases with m, while the benefit of debt is independent of m. Consequently, D^L decreases with m. ■

Proposition 3 shows that some debt (but not too much) always improves on the payoff of the original owners of the firm. In equilibrium, the firm issues debt with face value $\min\{D^L, k\}$. To simplify the analysis, however, assume that k is large enough so that $D^L \leq k$ (but not too large to render the entire project unprofitable). Equity, then, is issued by the firm to finance $k - D^L$, which is the difference between the cost of investment and the amount raised by issuing debt. The firm issues a positive amount of debt in this model because at least for small amounts of debt the benefits associated with the increase in the regulated price exceeds the firm's share in the cost of financial distress. Of course, in reality, the firm is likely to issue debt for many additional reasons such as its effect on taxes, its ability to signal private information, its effect on agency costs and for corporate control reasons.[12] Nevertheless, Proposition 3 shows that even when all these reasons are absent, rate regulation is sufficient to induce the firm to issue debt.

Another implication of Proposition 3 is that for a given flexibility parameter, $p^{fb} < p^L$. The reason for this is that from (16) it follows that the regulated price increases with the firm debt. Since at the first-best $D = 0$, while in equilibrium $D^L > 0$, the result follows.

7. THE CHOICE OF FLEXIBILITY UNDER OPTIMAL CAPITAL STRUCTURE

The last section established that contrary to the assumption of Section 5 (and in most of the literature on rate regulation), at the optimum, the firm is leveraged. This section explores the implications of an optimal capital structure for a regulated firm's choice of technology. In this case, the firm chooses a flexibility parameter, γ^L, to maximize $Y(\gamma, D^L)$. Using the definition of z^*, the first order condition for γ^L is

[12] For an excellent survey of the literature on capital structure, see Harris and Raviv (1991).

$$\frac{\partial Y(\gamma^L,D^L)}{\partial\gamma}=\left[R_p(p^L,\gamma^L)\frac{\partial p^L}{\partial\gamma}-Q(p^L)g_\gamma(\gamma^L)\right]\left[\hat{z}+mt\int_{z^-}^{z^*(p^L,\gamma^L,D^L)}zdF(z)\right] \tag{17}$$
$$-\left[1+mtF(z^*(p^L,\gamma^L,D^L))\right]=0,$$

where the expression $\partial p^L/\partial\gamma$ is given by (5) when it is evaluated at $D = D^L$. The existence of an interior solution for γ is ensured by Assumption (A-3). Equation (17) has similar interpretation to equation (11): A change in γ has an effect on both the regulated price and on the firm's technology. The first effect is represented by the argument $R_p(p^L, \gamma)\partial p^L/\partial\gamma$, while the rest of the expression represents the latter effect. The next proposition offers a comparison between γ^L and γ^E and γ^{fb}.

Proposition 4: *Assume that $Y(\gamma, D^L)$ is strictly concave in γ. Then, a regulated firm with an optimal capital structure selects a more flexible technology than an all-equity regulated firm. Assuming that t is not too large, the selected degree of flexibility is still below the first-best degree.*

Proof: To prove the first part of the proposition, note that by Assumption (A-3), $\gamma^L > 0$, while as Proposition 1 shows $\gamma^E = 0$. To prove the second part of the proposition, substitute for $W_{pp}(p^L, \gamma, D^L)$ from the first order condition for D^L in equation (15) into (5), substitute back into equation (17) and rearrange terms to obtain

$$\frac{\partial Y(\gamma^L,D^L)}{\partial\gamma}=\frac{-Q_p(p^L)g_\gamma(\gamma^L)\left[\hat{z}+t\int_{z^-}^{z^*(p^L,\gamma^L,D^L)}zdF(z)\right]R(p^L,\gamma^L)mF(z^*(p^L,\gamma^L,D^L))}{R_p(p^L,\gamma^L)z^*(p^L,\gamma^L,D^L)f(z^*(p^L,\gamma^L,D^L))} \tag{18}$$
$$-Q(p^L)g_\gamma(\gamma^L)\left[\hat{z}+mt\int_{z^-}^{z^*(p^L,\gamma^L,D^L)}(z-z^*(p^L,\gamma^L,D^L))dF(z)\right]-1=0.$$

Now, evaluate $\partial Y(\gamma, D^L)/\partial\gamma$ at $\gamma = \gamma^{fb}$. Using equation (7),

$$\frac{\partial Y(\gamma^{fb},D^L)}{\partial\gamma} = \frac{-Q_p(p^L)g_\gamma(\gamma^{fb})\left[\hat{z}+t\int_{z^-}^{z^*(p^L,\gamma^{fb},D^L)}zdF(z)\right]R(p^L,\gamma^{fb})mF(z^*(p^L,\gamma^{fb},D^L))}{R_p(p^L,\gamma^{fb})z^*(p^L,\gamma^{fb},D^L)f(z^*(p^L,\gamma^{fb},D^L))}$$

$$+Q(p^L)g_\gamma(\gamma^{fb})mt\int_{z^-}^{z^*(p^L,\gamma^{fb},D^L)}(z^*(p^L,\gamma^{fb},D^L)-z)dF(z) \tag{19}$$

$$+Q(p^{fb})g_\gamma(\gamma^{fb})t\int_{z^-}^{z^*(p^{fb},\gamma^{fb},0)}zdF(z)+\hat{z}g_\gamma(\gamma^{fb})[Q(p^{fb})-Q(p^L)]$$

$$+tF(z^*(p^{fb},\gamma^{fb},0)).$$

With the exception of the last term, all the terms in (19) are negative: The first three terms are negative because $g_\gamma(\gamma) < 0$ and because equation (3) implies that $R_p(p^L, \gamma) > 0$. The forth term is negative because as argued in the last section, $p^{fb} < p^L$, so that $Q(p^{fb}) > Q(p^L)$. Now, as long as the fifth term is not too large, a requirement which is equivalent to requiring t to be not too large, $\partial Y(\gamma^{fb}, D^L)/\partial\gamma < 0$. Since $Y(\gamma, D^L)$ is strictly concave in γ, $\gamma^{fb} > \gamma^L$. ■

The intuition behind Proposition 4 is straightforward. Whenever it is leveraged, a regulated firm is allowed to charge a price in excess of its marginal operating cost, and as a result, it extracts some, but not all of the benefits from flexibility. In contrast, when the firm is all-equity, it does not extracts any benefits from flexible technology. Consequently, a leveraged firm chooses a more flexible technology than an all-equity firm. At the same time, since the firm does not extract all the social benefits from flexibility but still bares the entire cost, its choice is less than optimal.

To evaluate the welfare consequences of debt, observe that since $\partial Y(\gamma, D)/\partial D > 0$ for small enough D, equityholders' payoff is larger when the firm is leveraged than it is when the firm is all-equity. Thus, a leveraged firm has a stronger incentive to invest than does an all-equity firm. Thus, debt is welfare improving. Moreover, debt may enhance welfare even further if the social benefits from the increase in flexibility outweigh the cost of the increase in the probability of financial distress.

8. AN EXAMPLE

Unfortunately, although the model is rather simple, it is too complicated to allow a comparative statics analysis. To facilitate such an analysis, consider the following highly specific variant of the model. There is a continuum of potential consumers for the firm's output with a total mass that is normalized to one. The utility function of a representative consumer is defined over the regulated service, x and a numeraire good, y and is given by $U(x, y) = z V \ln(x) + y$, where z is a random taste parameter distributed uniformly over the interval [0, L]. Given this utility function, the demand for the firm's output is $zQ = zV/p$ and consumers surplus is $z[V \ln (V/p) - V]$. The cost function continues to be given by $C = g(\gamma)zQ + \gamma$. Given the assumptions on the demand and cost functions, the critical state of nature below which the firm becomes financially distressed is

$z^*(p, \gamma, D) = (D + \gamma)/zQ(p - g(\gamma))$ for $z^* < L$. This specification allows for solving the regulator's problem in a closed form.[13]

Given these assumptions, the surplus generated by the firm is given by

$$W(p,\gamma,D) = \frac{L}{2}\left[V\ln\left(\frac{V}{p}\right) - V - \frac{V}{p}g(\gamma)\right] - \gamma - k - \frac{t}{L}\int_0^{z^*(p,\gamma,D)}\left[D + \gamma - \frac{zV(p-g(\gamma))}{p}\right]dz. \tag{20}$$

Differentiating this expression with respect p, the first order condition for the regulated price p*, is

$$\frac{\partial W(p^*,\gamma,D)}{\partial p} = -\frac{LV(V-g(\gamma))}{p^{*2}} + \frac{tg(\gamma)(D+\gamma)^2}{LV(p^*-g(\gamma))^2} = 0. \tag{21}$$

Solving for p* as a function of the firm's debt, D, and its flexibility parameter, γ,

[13] Note that the example differs from the model considered up to now in that the demand function is convex in p rather than concave and in that the lower bound of the distribution of z is 0 rather than $z^- > 0$. These differences are inessential and are made in order to simplify the analysis.

$$p^*(\gamma,D) = \frac{LVg(\gamma)}{LV-\phi(D+\gamma)}; \qquad \phi = \sqrt{\frac{tg(\gamma)}{(V-g(\gamma))}}. \tag{22}$$

To ensure that the demand for the firm's output is nonnegative, one has to make sure that $p^* \geq 0$. A necessary and sufficient condition for this is that for all γ, $LV \geq \phi(k + \gamma)$. Given this assumption, it is straightforward to show that the second order condition for p^* is satisfied.

Now, given a flexibility parameter γ and the firm's debt, D, the original owner's payoff is

$$Y(\gamma,D) = \frac{LV(p-g(\gamma))}{2p} - \gamma - \frac{mt}{L}\int_0^{z^*(p,\gamma,D)}\left[D+\gamma-\frac{zV(p-g(\gamma))}{p}\right]dz - k. \tag{23}$$

Substituting $p = p^*$, solving for the integral and rearranging terms,

$$Y(\gamma,D) = \left[\frac{\phi^2-mt}{2\phi}\right](D+\gamma) - \gamma - k. \tag{24}$$

From (24) it is clear that $Y(\gamma, D)$ increases in D if and only if $\phi^2 > mt$.

Now, suppose that in equilibrium $\phi^2 \leq mt$. Then, the firm is all-equity. Substituting $D = 0$ in (24) and differentiating with respect to γ yields,

$$\frac{\partial Y(\gamma,0)}{\partial\gamma} = \left[\frac{\phi^2-mt}{2\phi}\right] + \left[\frac{\phi^2+mt}{2\phi^2}\right]\gamma\,\phi_\gamma - 1, \tag{25}$$

where,

$$\phi_\gamma = \frac{tVg_\gamma(\gamma)}{2\phi(V-g(\gamma))^2} < 0. \tag{26}$$

Since $\phi^2 \leq mt$, $\partial Y(\gamma, 0)/\partial\gamma < 0$ for all γ, implying that in equilibrium, as was proved in Proposition 1, $\gamma = 0$. Now, substituting $\gamma = D = 0$ in (24), $Y(0, 0) = -k$, so the firm is better off not investing at all. Hence, in equilibrium, $\phi^2 > mt$. Since in this case, $Y(\gamma, D)$ increases in D, the firm finances its investment entirely by debt, so $D^L = k$. The payoff of the original owners is therefore given by

$Y(\gamma, k)$. The firm chooses γ^L to maximize $Y(\gamma, k)$. The first order condition for γ^L is

$$\frac{\partial Y(\gamma^L,k)}{\partial\gamma} = \frac{\phi}{2} + \frac{\phi_\gamma(k+\gamma^L)}{2} - 1 - \frac{mt(\phi - \phi_\gamma(k+\gamma^L))}{\phi^2} = 0, \tag{27}$$

where ϕ_γ is given by (26). The existence of an interior solution for γ^L is ensured by Assumption (A-3). Thus at the optimum, $Y_{\gamma\gamma}(\gamma^L, k) < 0$. The first three terms in (27) describe the effect of flexibility on the firm's expected operating income, through its effect on the cost structure of the firm and on the regulated price. The last term represents the effect of flexibility on the firm's share in the expected cost of financial distress. Note that this last effect is negative because an increase in flexibility means that the firm's fixed cost are larger, so it is more susceptible to financial distress.

Having characterized the equilibrium choice of flexibility, it is now possible to turn to comparative statics analysis. The exogenous variables in this example are the upper bound of the demand shock, L, consumers' valuation of the product, V, the per-dollar-of-deficit cost of financial distress t and the firm's share in this cost, m.

Consider first the variable L which affects the variability and size of the demand for the firm's output. From (24) it is clear that L has no effect on the payoff of the original owners. Hence, γ^L is invariant with respect to L. This result is surprising, because the results in Stigler (1939), Marschak and Nelson (1962) and Mills (1984), who find that competitive unregulated firms increase their flexibility in response to an increase in demand fluctuations, lead one to expect that the regulated firm in this model will increase its flexibility in response to an increase in L.

Now, consider consumers' valuation V. Since an increase in V leads to an increase in consumers' surplus, the regulator would like to stimulate demand by lowering the regulated price, p*. This has two opposing effects on the firm. On the one hand, a decrease in p* leads to an increase in firm's output and thus in variable cost. Consequently, the firm would try to lower its variable cost by selecting a more flexible technology. On the other hand, a decrease in p* makes the firm more likely to become financially distressed, so the firm would like to decrease its fixed cost by selecting a less flexible technology in order to offset this negative effect. To determine which effect dominates, differentiate (27) with respect to V and γ^L, to obtain

$$\frac{\partial \gamma^L}{\partial V} = \frac{\left[\frac{\phi^2 + mt}{2\phi^2}\right]\left(\phi_V + (k+\gamma^L)\phi_{\gamma V}\right) - \frac{mt(k+\gamma^L)\phi_\gamma \phi_V}{\phi^3}}{-Y_{\gamma\gamma}(\gamma^L,k)}, \tag{28}$$

where,

$$\phi_V = \frac{-\phi}{2(V-g(\gamma))} < 0, \tag{29}$$

and,

$$\phi_{\gamma V} = \frac{-tg_\gamma(\gamma)(V+2g(\gamma))}{4\phi(V-g(\gamma))^3} > 0. \tag{30}$$

Since the first term in the numerator of (28) has an ambiguous sign, it is impossible, in general, to determine the sign of $\partial\gamma^L/\partial V$. One can show, however, that γ^L decreases in V if V is large relative to $g(\gamma)$ and m is sufficiently close to one. This is because in this case a reduction in variable costs is not very attractive to the firm while financial distress consideration favor a reduction in fixed cost.

Next, consider what happens to γ^L as t increases. Intuitively, since the regulator cannot commit to a regulated price before the firm selects its technology, he has an incentive to set a low regulated price whenever the firm adopts a flexible technology with low marginal cost. An increase in t, however, weakens this incentive because the regulator is more concerned about the possibility that a low regulated price will make the firm financially distressed. Thus, as t increases, the firm gets to keep a larger share of the benefits from flexibility (in the form of low marginal cost), and therefore, it increases its flexibility. Formally, differentiating (27) with respect to γ^L and t, yields

$$\frac{\partial\gamma^L}{\partial t}=\left[\frac{(\phi^2+mt)\phi_t-m\phi}{2\phi^2}\right]+\left[\frac{\phi^2+mt}{2\phi^2}\right](k+\gamma^L)\phi_{\gamma t} \tag{31}$$

where $\phi_t = \phi/2t > 0$, and $\phi_{\gamma t} = \phi_\gamma/2t < 0$. Using equation (27) and rearranging terms, (31) becomes,

$$\frac{\partial\gamma^L}{\partial t}=\frac{1}{2t}>0. \tag{32}$$

Finally, an increase in m makes the firm more concerned about financial distress. Now, as γ increases, the firm has more fixed cost and is therefore more susceptible to financial distress. Consequently, an increase in m induces the firm to reduce its fixed cost and become more flexible. To prove this result formally, differentiate (27) with respect to γ^L and m, to obtain

$$\frac{\partial\gamma^L}{\partial m}=\frac{-\frac{t}{2\phi^2}\left[\phi-\gamma^L\phi_\gamma\right]}{-Y_{\gamma\gamma}(\gamma^L,k)}<0. \tag{33}$$

9. GOLDPLATING

Thus far, this paper has examined how a regulated firm chooses its cost structure by looking at the trade-off between fixed and marginal costs. This section examines another aspect of the choice of cost structure by a regulated firm, namely goldplating. As is sometimes argued, regulated firms have an incentive to inflate their costs, i.e., goldplate, by wasting resources or even by colluding with equipment suppliers, so as to induce regulators to increase the regulated rates. In the context of a rate-of-return model, goldplating may have the advantage of inflating the firm's rate base, thereby relaxing the regulatory constraint on the firm's allowed rate of return. However, as Zajac (1972) and Bailey (1973) show, a firm subject to rate-of-return regulation will not engage in goldplating so long as the firm can invest in productive capital.

To examine the issue of goldplating in the current model, assume that in the stage 1 of the game, before the regulatory process takes place, the firm may commit to an expenditure of G in stage 4. This expenditure is wasteful as it has no effect on the production process and it therefore can be thought of as goldplating. It may represent, for example, the cost of renting and maintaining luxurious offices, the cost of hiring too many employees or excessive expenditure on R&D.[14] Obviously, in the first-best solution, $G = 0$. The reason why the firm may nevertheless choose a positive level of G is that this makes it more susceptible to financial distressed, thereby inducing the regulator to increase the regulated price. Such an increase may more than compensate the firm for G.

When $G > 0$, the critical state of nature at which the firm is just able to break even is

$$z^*(p,\gamma,D,G) \equiv \begin{cases} z^-, & \text{if } z^- > \dfrac{D+\gamma+G}{R(p,\gamma)}, \\ \dfrac{D+\gamma+G}{R(p,\gamma)}, & \text{if } z^- \leq \dfrac{D+\gamma+G}{R(p,\gamma)} \leq z^+, \\ z^+, & \text{if } z^+ < \dfrac{D+\gamma+G}{R(p,\gamma)}. \end{cases}$$

Clearly, $z^*(p, \gamma, D, G)$ increases in G, implying that the probability of financial distress also increases in G. Now, the regulated price is defined implicitly by (3) with $z^*(p, \gamma, D, G)$ replacing $z^*(p, \gamma, D)$.

In the stage 1 of the game, the objective of the firm's owners is to choose γ, D and G to maximize their payoff given by

$$Y(\gamma,D,G) = ER(p^L,\gamma,z) - G - mt\int_{z^-}^{z^*(p^L,\gamma,D,G)} [D - R(p^L,\gamma,z) + G]\,dF(z) - k. \tag{34}$$

Let G^* be the equilibrium choice of goldplating. Note that G and D have the same effect on the regulated price (both affect the regulated price only through their effect on z^* and from the definition of z^* it is clear that $\partial z^*/\partial D = \partial z^*/\partial G$). Thus, $\partial p^L/\partial D = \partial p^L/\partial G$. Using this equality, it

[14] Alternatively, it can be assumed that G yields a benefit of bG to the firm's management, but that $b < 1$. In this case, G may represent managerial perquisites such as unnecessary travels, chauffeurs and secretaries or simply managerial slack. The assumption that $b = 0$, however, entails no loss of generality.

is easy to show that the first order condition for G* is

$$\frac{\partial Y(\gamma,D,G^*)}{\partial G} = \frac{\partial Y(\gamma,D,G^*)}{\partial D} - 1 \leq 0. \tag{35}$$

Now, consider an optimally leveraged firm. Using equation (15), the first order condition for G^* when $D = D^L$ becomes $\partial Y(\gamma, D^L, G^*)/\partial G = -1$, implying that in this case, $G^* = 0$. Thus, an optimally leveraged firm does not goldplate. Next, consider a regulated firm with a less than optimal debt level. For such a firm, $\partial Y(\gamma, D, G)/\partial D > 0$ for all G. Using this inequality, a sufficient condition for such a firm to goldplate is $\partial Y(\gamma, D, 0)/\partial D > 1$. Thus,

Proposition 5: *A regulated firm with an optimal capital structure never goldplates. If, however, the firm has a less than optimal debt level than it may goldplate if $\partial Y(\gamma, D, 0)/\partial D > 1$.*

The intuition behind Proposition 5 is straightforward. In order to induce the regulator to increase the regulated price, a regulated firm can either issue debt or goldplate. Debt, however, is preferable to goldplating because it is not wasteful: debtholders are buying the firm debt for B(D) and this amount is part of the equityholders' payoff. Thus, a regulated firm with an optimal capital structure does not need to goldplate, whereas a regulated firm with too little debt may goldplate provided that the increase in the regulated price outweigh the loss due to wasting resources.

Recall that an all-equity firm chooses the least flexible technology, i.e., $\gamma^E = 0$. Thus, if $G = 0$, the firm has no fixed cost, so as Proposition 2 indicates, the firm never becomes financially distressed. Consequently, the regulator set $p^E = g(0)$ which implies in turn that $R(p^E, 0) = 0$. Substituting in (16), this yields $\partial p^L/\partial D = \infty$. Since $\partial p^L/\partial G = \partial p^L/\partial D$ this implies that an all-equity firm always find it profitable to use some goldplating. Thus,

Proposition 6: *An all-equity regulated firm chooses a positive amount of goldplating.*

11. CONCLUSION

The choice of flexibility by a regulated firm has been examined using a sequential game between the firm and a regulator. The main insight of the paper is that the inability of the regulator to commit to particular rates before the firm makes an irreversible investment decision, induces the firm to select a technology which is too inflexible, in the sense that it give rise to a cost function with higher marginal cost and lower fixed cost than is socially optimal. This distortion arises because the regulated price is chosen by the regulator to maximize welfare and is therefore decreasing in marginal cost, but unaffected by the level of fixed cost. In addition, the lack of regulatory commitment may discourage the firm from investing at all if investment involves sunk cost.

The distortion in the choice of technology, however, is alleviated when the firm is leveraged. In this case, the firm is more likely to become financially distressed, so the regulated price no longer decreases with marginal cost by as much as in the case of an all-equity firm. Consequently, a technology with low marginal cost becomes more attractive to the firm. Although the distortion is alleviated, it is not solved completely: Given that financial distress is not too costly, the firm still selects in equilibrium a too inflexible technology. Since debt leads to a higher regulated price, it may induce the firm to invest even if investment involves sunk cost. Thus, debt may be welfare-improving.

A comparative static analysis of a specific example shows that changes in the demand fluctuations have no effect on the equilibrium flexibility parameter and that a change in consumers' valuation has an ambiguous effect on it. The firm increases its flexibility, however, as the total cost of financial distress increases, but lowers its flexibility as its share in this cost becomes larger.

Finally, it was shown that although a regulated firm may be tempted to waste resources, i.e., goldplate, in order to induce the regulator to increase rates, they never do so if their capital structure is optimal. Goldplating, however, may occur if a regulated firm is not allowed to issue an optimal amount of debt. In particular, an all-equity regulated firm chooses a positive amount of goldplating.

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FIGURE 1: THE SEQUENCE OF EVENTS

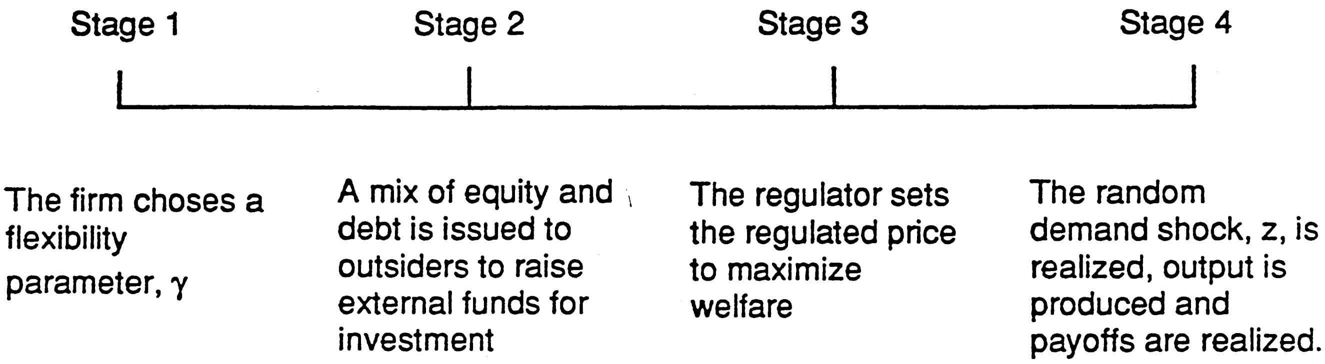
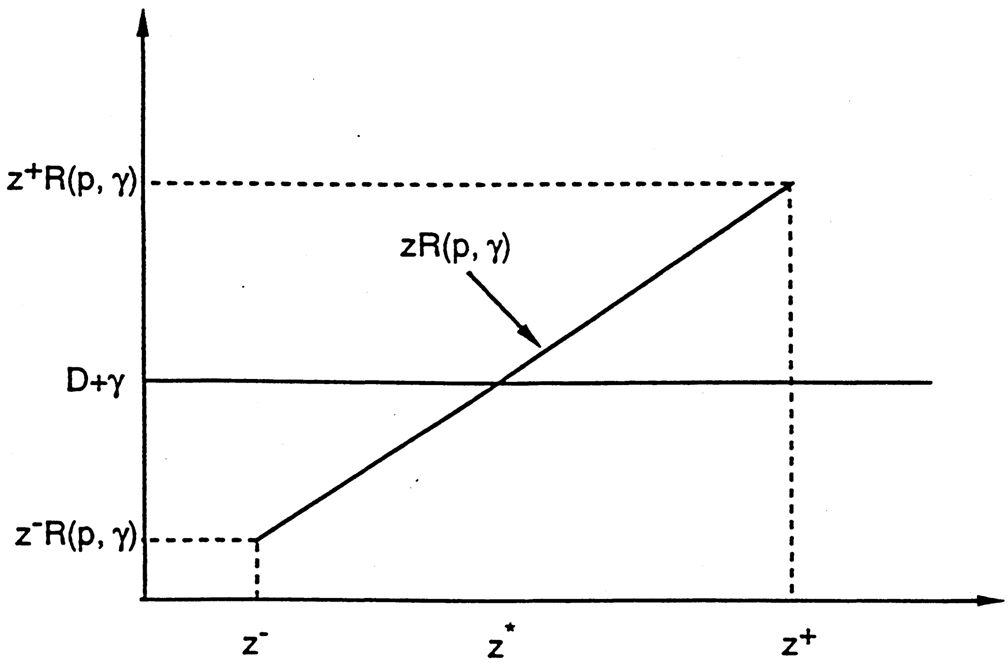


FIGURE 2: THE CRITICAL STATE OF NATURE, Z*, BELOW WHICH THE FIRM BECOMES FINANCIALLY DISTRESSED, GIVEN P, γ AND D.



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