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Investment Incentives of a Regulated Dominant Firm[1]

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Abstract
We study the investment incentives of a regulated, incumbent firm in a deregulation process. The regulator cannot commit to a long-term regulatory policy, and investment decisions are taken before optimal regulatory policies are imposed. We characterize the regulated incumbent's incentive to invest when a deregulation process is initiated and an unregulated firm enters the market as a result. The change in the marginal return to investment depends on how the investment changes the firm's virtual cost—the sum of its physical production and information costs. When the marginal return to investment increases due to deregulation, social welfare increases as a result of higher investment and more competition. Otherwise, the change in social welfare depends on the total of the effects in the fall of investment and increased competition. We also present conditions under which deregulation enhances welfare.

1. Introduction

During the past decade in many industrialized countries such as the United States and Great Britain, as well as developing countries including Chile and Mexico, many markets that were previously served by a single private or public firm have begun a process of deregulation. In the United States, these markets include long-distance phone service, express mail, rail service, electric power generation, and since the 1996 Telecommunication Act, local tele-

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phone and television cable service. Allowing new firms to compete with the incumbent firm is the main theme of deregulation, and the speculation is that these markets will eventually be completely unregulated.

In many regulated markets, technological progress, both in terms of product and process innovations, is extremely important. For example, in the markets mentioned above, it is generally agreed that the costs of providing services have dropped dramatically over time, and that this may be due to the technological advances in process innovations in these industries. Indeed, because of the fall in costs, the usual argument for the existence of a (regulated) monopoly, namely economies of scale, may no longer be compelling in these industries. It then becomes natural for regulators and policy makers to consider deregulating them.

While regulators and policy makers initiate a deregulation process, and seem to embrace the idea that competition is desirable in the long run, they often take a cautious approach. Thus, uncertain whether an unregulated environment is best and fearful of unanticipated effects, policy makers often have maintained some control in these industries. This often takes the form of *continuing* regulation on the incumbent, but allowing any entrant to be completely unregulated. This is what occurred in long-distance telephone service in the United States, and what is happening in local service also. In addition, the asymmetric treatment between the incumbent and entrant also may be justified by the claim that the near-monopoly advantage the incumbent enjoys may slow down the deregulation process. Furthermore, entry into the telecommunications and electricity generation markets were not allowed as soon as an entrant appeared.

It seems clear that, other things being equal, competition will drive down prices, and therefore opening up the market to entrants can be expected to benefit consumers in the price dimension. Nevertheless, it is less clear whether deregulation encourages or discourages investment. Will deregulation reinforce or weaken the trend of decreasing costs? In this paper, we study investment incentives of the regulated, incumbent firm in a deregulation process. We pay special attention to the incumbent firm's investment strategy to reduce its cost, and derive optimal regulatory policies as well. While an unregulated market may be the regulator's long-run goal, our paper analyzes a transitory phase for markets with rapidly changing technology.

In a now well-understood paradigm, Williamson (1975; 1985) introduced the "hold up" problem. When investments are specific, the lack of commitment may induce opportunistic behavior *ex post*. The incentive to invest *ex ante* may be reduced or become absent altogether because the returns of a sunk investment cannot be guaranteed due to the lack of commitment. The commitment problem is especially critical in a deregulatory environment, in which regulators may be charged with the responsibility of promoting competition, and tempted to reduce the regulated firm's price after it has made the investment.[2]

In this paper, we assume that the regulator is unable to commit to a long-term regulatory policy. Perhaps, the lack of commitment in a deregulatory environment superficially points to the conjecture that deregulation *reduces* the incumbent's incentive to invest. First, without commitment, a regulator will behave opportunistically once the investment has been made,

2 As emphasized by Levy and Spiller (1994) in a set of case studies, the ability of the regulator not to act arbitrarily is extremely important for the performance of a regulated industry.

extracting all available surplus without compensating the regulated firm for its sunk costs. Second, with the entrant in the market, the incumbent need not be solely relied upon to satisfy demand. This allows an even more aggressive regulatory policy on the incumbent.

Surprisingly, we show that the incentive for the regulated incumbent to invest may sometimes be higher when the market is opened up to entrants than under complete market foreclosure. To understand this possibility, we must consider the regulated firm's incentive to invest. In our model, the incumbent's investment determines a distribution of costs, and the actual realization of the cost is the incumbent's private information. Although the regulator knows the level of investment when designing a policy for the incumbent, it lacks the incumbent's cost information. This information asymmetry results in rent for the incumbent. More important, the incumbent understands that a choice of investment determines a distribution of costs and hence a distribution of information rent. Given an industry structure, the incumbent picks an investment level to maximize its return, equating the marginal cost of investment to the expected marginal information rent due to the investment. As we have just argued, the incumbent will be asked to reduce its production level when the market is deregulated. As a result, the level of its expected information rent becomes lower. Nevertheless, this does *not* imply that the expected marginal information rent must become lower. In fact, we show that the incumbent's expected marginal information rent may become higher when the regime is switched from monopoly to oligopoly. Put alternatively, the incumbent's loss of information rent when the market is deregulated may be *decreasing* in investment. As entry occurs, the incumbent will increase its investment to make the loss smaller.

In situations where investment increases when the market is opened to rivals, deregulation clearly increases welfare: the increases in competition intensity and investment both work favorably. When deregulation induces the incumbent to choose a lower investment level, welfare still may increase. In this case, the beneficial effect of a second source outweighs the undesirable effect of lower investment. Generally, the change in welfare is ambiguous. Thus, we demonstrate a potential tradeoff in an environment of deregulation. Although the price may drop as a result of another firm in the market, the regulated incumbent may increase or decrease its process innovation. The change in welfare is a combination of these two effects.

Our model and results establish a framework for assessing the large number of claims by policy makers and analysts about the deregulation of previously closed or regulated markets. When pro-deregulation commentators provide details for these claims, they envision a deregulated market as one in which many firms compete with each other on equal footing, and which gives consumers the benefits in terms of lower prices and more product varieties. Although these may be the goals, and may actually happen in the long run, we argue that the transition to complete deregulation may not be obviously attractive. Indeed, we find that under some conditions welfare is higher in the transition phase compared to the closed market: prices are lower, and the incumbent firm makes a larger investment to reduce its cost. Under other conditions, however, the incumbent's investment is lower and welfare is lower when the market is partially regulated. The main point is that deregulation may *not* be a costless process. A deregulation process that begins with a reduction of consumer welfare may well be something to be expected. Policy makers that see lower welfare at the initial stage of a deregulation should not instantly react by stopping the process.

While generally the change in welfare due to deregulation may be ambiguous, we can provide two clear conditions that can provide guidance to policy makers when deciding on whether to deregulate a market. The first condition looks at a special case of our model when investment is discrete. This is a natural assumption in many industries such as electric power generation and telecommunications, where large parts of the physical plant must be replaced all at once. The cost of capital equipment has dropped dramatically in both of these industries; in electricity this is due to the invention of gas turbine generators, while for telecommunications the drop in the price of computing and fiber optics has greatly reduced the costs of making phone calls. It was not until there was a large drop in the capital costs that entry was allowed in these markets even though there were potential entrants that wanted to get into the market. A possible interpretation for the delay in deregulating the market is that once the capital costs dropped so precipitously the regulators knew that the incumbent firms would adopt the new technologies even if there was entry in the market. Thus, policy makers may only want to allow entry when it is clear that the incumbent will not reduce its investment in new technology. The second condition has to do with the innate ability of an incumbent firm. We find that if R&D is either successful or not and that if firms that are more likely to be successful also have lower costs even before conducting R&D, then entry may be beneficial if the entrant's costs are not low. This is because the presence of the entrant is unlikely to affect the incumbent's marginal returns from investment; the investment level therefore remains the same, and entry improves welfare.

In our formal model of regulation, we incorporate both "hidden information" and "hidden action:" the regulated incumbent takes an action (investment choice), and obtains private information about its costs as a result. For any given investment level, we derive the optimal policy when the entrant's reaction is taken into account. We discover that the optimal policy always depresses the incumbent's quantity compared to the regulated monopoly regime. This reflects the fact that in the deregulated oligopoly regime, the incumbent is no longer the sole source. Interestingly, the *total* market quantity may increase or decrease (again, compared to the regulated monopoly regime) when the entrant behaves as a Stackelberg follower. In our quantity-setting model, the incumbent's and the entrant's quantities are strategic substitutes. When the entrant's cost is lower, there will be an efficiency gain to shift production from the incumbent to the entrant. To achieve a large shift, the incumbent's quantity may be reduced by so much that the entrant's production does not compensate, resulting in a lower total quantity.

A great deal of work has been done on the optimal regulation of a monopolist under incomplete cost information since the seminal papers by Baron and Myerson (1982), and Laffont and Tirole (1986); most of the papers in the formal literature extend the models but continue to assume that the incumbent is the only firm in the industry. Riordan (1987), Spulber (1989), and Tirole (1986) examine models where a regulated monopolist's investment generates private information about its cost, and the regulator chooses its optimal policy after the firm has made its investment. Because of the lack of commitment and the presence of private information, the firm's investment is less than the first best. Besanko and Spulber (1992) examine a model where the firm has private information about a cost parameter before it chooses its investment; in the sequential equilibrium of this signaling model, the investment may be more or less than the first best level. Laffont and Tirole (1993, 86-93) extend their regulation model (Laffont and Tirole 1986) to include investment decisions, but their extension differs from our model significantly. First, Laffont and Tirole continue to assume the monopoly industry structure. Second, in their extensive form, the firm's investment and the regulator's incentive scheme decisions are made simultaneously. This endows the regulator with commitment power, which is absent in our model. Thus, the regulator may commit not to change the firm's incentive scheme after it has made an investment even when it is efficient to do so.[3]

There has been little theoretical research examining the issues involved with the deregulation of a previously foreclosed market. Cailliaud (1990) extends the Baron-Myerson framework to allow a set of competitive fringe firms to compete with the regulated dominant firm *ex post*. In Biglaiser and Ma (1995), we investigate the optimal policies under demand uncertainty when the regulated incumbent firm competes with an unregulated entrant. In both of these models firms' private information is exogenously given.[4] Here, we explicitly include both hidden action and hidden information: the regulated incumbent's investment decision determines a distribution of costs, whose realization is the firm's private information.

From a methodological point of view, our paper is closest in spirit to Riordan and Sappington (1989). In a procurement model, Riordan and Sappington consider the investment decision of a developer when the regulator may transfer the knowledge of the cost and final production to a second source. The developer's research determines the distribution of the time-lags in the development stage. In addition, before regulatory policies are imposed the developer learns the marginal cost of production, which is drawn from an exogenously given distribution. Riordan and Sappington show that second sourcing always reduces the developer's investment incentive because it eliminates the developer's information rent from learning the production costs. The Riordan and Sappington model differs from ours in several dimensions. First, the entrant in our model behaves as a Stackelberg follower in a quantity-setting game, and possesses market power; thus, we do not treat the entrant as a replacement of the incumbent. Second, in our model the incumbent's investment determines the distribution of its costs, and is its source of private information; thus, unlike Riordan and Sappington, in our model the incumbent's private information is determined endogenously.

The paper proceeds as follows: In section 2, we present the model. We derive the optimal regulatory policy for a given investment level in the following section. Then in section 4, we derive the investment choices by the incumbent firm in the regulated monopoly and deregulated oligopoly regimes, and make welfare comparisons across equilibria in these two regimes. Conclusions and other remarks are in the final section.

2. The Model

In this section, we describe the model. We study two industry structures within a regulatory framework. In addition to regulating an incumbent firm, a regulator also must consider letting another firm enter this previously foreclosed market. We begin by describing the technological details of the model. The incumbent, Firm 1, as well as a potential entrant, Firm 2, each

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3 When the regulator has commitment power and *ex post* participation constraints are absent, the firm can be delegated to make the socially efficient investment decision: paying the firm a lump sum and then making it bear the entire cost and benefit forces it to internalize the social surplus. When *ex post* participation constraints are included, then the efficiency properties of the equilibria depend on whether investment is contractible.

4 Auriol and Laffont (1992), Dana and Spier (1994), and McGuire and Riordan (1995) analyze optimal industry structure. There are two firms and the regulator's decision is whether to allow one or both firms in the market. Anton and Yao (1989;1992) analyze split award auctions.

may produce a homogenous good. While Firm 2 has a given technology with a constant marginal cost of production, c_e, Firm 1's constant marginal cost is the result of its investment and a random variable.[5] For any given investment, I, Firm 1's marginal cost is distributed on the support $[c_L, c_H]$ with distribution function $F(c,I)$, and density function $f(c,I)$. The "hazard rate," $h(c,I) \equiv F(c,I)/f(c,I)$, is assumed strictly increasing in c. An increase in investment is assumed to improve costs in the sense of first-order stochastic dominance: $\partial F(c,I)/\partial I \geq 0$, for any c. The actual cost for Firm 1 is its private information, but its investment is common knowledge. A Firm 1 with cost c sometimes is called a type-c Firm 1.

We view Firm 2 as an existing firm in another industry with a known technology. If Firm 1's market is open, Firm 2 will enter with its current technology if it can make positive profits. Firm 2 may make an investment before entry, but this consideration is beyond the scope of our analysis. We concentrate on the incumbent's investment incentives, although we are confident that our method can be adapted to analyze this more general situation. We believe our model reflects salient features of some of the markets mentioned in the introduction.[6]

The two firms compete by setting quantities. For tractibility, we use a linear demand function: if Q denotes the total quantity produced by the firms, then $\alpha - \beta Q \equiv P(Q)$ is the price that will clear the market, where α and β are both positive. We assume that $\alpha > c_H > c_L$.

Our major objective is to study investment incentives. We take a long-term perspective on investments. Quantity or pricing regulatory commitment may be incredible over a long period of time, and a firm may have to make an investment knowing that the actual policies may only be determined later. Nevertheless, a regulated firm may be more certain about the future structure of a regulated industry. In particular, we allow the regulatory authority to commit to the design of the industry structure—whether a market remains foreclosed or is made available to an entrant. Our interpretation is that a "deregulation" process is almost always initiated and determined by the legislature. A general, legal policy that allows an incumbent's monopoly position to continue, or one that ends it *is* a credible commitment. But the actual, detailed regulatory scheme, such as transfers, quantities, or prices are the responsibilities of a regulatory agency, which is unable to make binding long-term commitments.[7,8]

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5 At the end of the next section, we will discuss the case of the entrant's cost being uncertain.

6 For instance, the major long-distance telephone companies in the U.S. have entered the local telephone market. These companies' technologies and costs are determined in large part by their investment in the long-distance market. Entrants interested in the local market may use strategies requiring relatively little sunk investment, without having to replicate the incumbent's entire network. The 1996 Telecommunications Act provides two such possible strategies: one is a resale strategy, where the entrant gets to use the incumbent's facilities at a discount. The second is via unbundled network element (UNE) strategy, where the entrant can lease crucial elements like the incumbent's loop at a regulated price. Facing these entrants, the incumbent local telephone companies may have to consider making new investments. Although one might argue that such new investments are necessary to compete with new entrants (who may have lower costs), incumbents still benefit from their private information about costs as long as they are regulated.

7 Our interpretation of the regulatory process is consistent with the 1996 Telecommunications Act. The Act specified that the markets should be open, but left it to the Federal Communications Commission to write the regulations implementing the Act. Clearly, the agency could not commit to regulations while the Act

We focus on two industry structures. In the first, *the monopoly regime*, the market is foreclosed, and the incumbent will remain the only firm. In the second, *the oligopoly regime*, the market will be opened and an unregulated entrant is allowed into the market at some specified date in the future. The extensive form for our analysis is as follows. In Stage 1, the industry structure—monopoly or oligopoly—is decided by the regulator. In Stage 2, the incumbent Firm 1 chooses an investment, I. Then Firm 1's cost is realized and becomes its private information. In Stage 3, knowing Firm 1's investment but not its cost, the regulator imposes a regulatory scheme, which consists of a menu of transfer (that Firm 1 receives) and quantity (that Firm 1 is required to produce), and Firm 1 must pick an item from the menu. Finally, in Stage 4, Firm 2 chooses its production level. The quantity in the market consists of the total amount produced by Firms 1 and 2, and the price will adjust to clear the market.

We discuss the extensive form now. We already have motivated the difference in the regulator's commitment abilities with respect to industry structure and the regulatory scheme. In our interpretation above, the legislature may decide on the industry structure in Stage 1, while an agency is responsible for the regulatory mechanism in Stage 3. The assumption that the investment is undertaken in Stage 2 simply means that the incumbent firm's investment decision can be based on its expectation of the industry structure, but not on the actual regulatory scheme.

Investment is observable, but not verifiable, and transfers and quantities in the regulatory policies cannot be based on investment explicitly. Explicit directives by regulatory authorities are subject to manipulation and omissions, and investment quality is often hard to describe to use in an enforceable contract. Nevertheless, investment may be observable ex post, and the design of a scheme can implicitly make use of this information (so that the only uncertainty facing the regulator is Firm 1's cost). Finally, the entrant is a Stackelberg follower in the quantity-setting game. This assumption means that the unregulated firm can react to the regulated firm's quantity. Regulated firms simply cannot adjust their quantities as fast as unregulated firms, since they must go through an administrative process to make significant changes in the regulatory policy.

We now continue defining the details of the model. A regulatory scheme is a menu $\{(q(c),t(c)) \mid c \in [c_L,c_H]\}$. If Firm 1 picks item $(q(c),t(c))$, it is required to produce $q(c)$ and receives from the regulator a transfer $t(c)$. The regulatory scheme must guarantee Firm 1 a nonnegative profit. Let q_e denote the quantity produced by the entrant Firm 2 in the oligopoly regime. When Firm 1 picks item $(q(c),t(c))$ and the entrant produces q_e, the total quantity will be written as $Q(c) \equiv q(c) + q_e$.

The regulator uses a weighted average of consumer surplus, and firms' profits as a welfare index, which is more conveniently written in terms of social surplus and profits. Suppose Firm 1's cost is c, it picks item $(q(c),t(c))$ from the menu, and subsequently Firm 2 produces q_e (so that total quantity is $Q = q(c) + q_e$ and price $P(Q)$ is $\alpha - \beta Q$). Profits at Firms 1 and 2 will be given by $(P(Q) - c)q(c) + t(c)$ and $[(P(Q) - c_e)q_e]$, respectively. We ignore Firm 1's

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was in Congress.

8 If investment is verifiable, oligopoly regime must be preferred to monopoly. The regulator can simply dictate the level of investment (setting the same level of investment, for example, for both regimes), but the incumbent's information rent will be less under oligopoly.

investment I in its profit expression here, since I is a sunk cost when regulatory policies are imposed. The regulator's utility is given by

$$\int_0^Q (\alpha - \beta x)dx - cq(c) - q_e c_e - \theta_1[(P(Q) - c)q(c) + t(c)] - \theta_2[(P(Q) - c_e)q_e], \qquad (1)$$

where θ_1, and θ_2 are between 0 and 1. For the monopoly regime θ_2 and q_e will be set to zero.

The welfare expression in (1) is an *interim* measure of welfare: the investment cost I incurred by the firm is sunk when the regulator designs the policy, and hence is not taken into account. In other words, the only difference between our interim measure and the *ex ante* welfare measure, commonly used by other papers in the regulation literature, is Firm 1's investment cost I. We argue that the interim measure is often appropriate, sometimes even predictive. Suppose, as we have suggested above, the industry structure is determined by the legislature. But the legislature may lack the expertise to make a good decision, and must rely on the regulator's recommendation. If the regulator's objective is summarized by (1), then it will lobby for the industry structure that maximizes (1). In any case, the ex ante and interim measures will be identical if $\theta_1 = 1$; the two measures will be approximately equal for θ_1 close to 1.

In the oligopoly regime, Firm 2 is a Stackelberg follower, and it will choose q_e as a best response against Firm 1's quantity. We will denote this by $q_e(c)$. This best response maximizes its profit:

$$\max_{q_e \geq 0} [(\alpha - \beta(q(c) + q_e)) - c_e]\, q_e.$$

Straightforward computation gives

$$q_e(c) = \begin{cases} \dfrac{\alpha - \beta q(c) - c_e}{2\beta} & \text{if } q(c) \leq \dfrac{\alpha - c_e}{\beta} \\ 0 & \text{otherwise.} \end{cases} \qquad (2)$$

Once Firm 1's quantity is chosen and less than $(\alpha - c_e)/\beta$, Firm 2's best response will be given by the first part of (2), and the market price is $\alpha - \beta[q(c) + (\alpha - \beta q(c) - c_e)/2beta]$ $= (\alpha - \beta q(c) - c_e)/2 \equiv p(c)$. If Firm 1's quantity is more than $(\alpha - c_e)/\beta$, then $p(c) = \alpha - \beta q(c)$.

We will consider incentive-compatible regulatory policies. If Firm 1's marginal cost is c and picks an item $(q(c'),t(c'))$ from the menu, its profits is $(p(c') - c)q(c') + t(c')$. The menu $\{(q(c),t(c))\}$ is *incentive compatible* if

$$\pi(c) \equiv (p(c) - c)q(c) + t(c)) \geq (p(c') - c)q(c') + t(c') \equiv pi(c,c') \quad \text{for all } c,c'.$$

It is easy to verify that (3) implies that $q(c)$ is nonincreasing. Standard "envelope" arguments[9] can be applied (see Baron and Myerson 1982) to obtain the following repre-

9 By definition, $\pi(c) = \pi(c;c)$. Hence $d\pi(c) = \pi_1(c;c)dc' + \pi_2(c;c)dc$, where the ith subscript denotes the partial derivative with respect to the ith argument. Now, according to the incentive compatibility

sentation of (3):

$$\pi(c) = \pi(c_H) + \int_c^{c_H} q(x)\, dx. \tag{4}$$

This is the incumbent's *information rent*, and inversely related to its marginal cost. If $\pi(c_H) \geq 0$, all types of Firm 1 will be guaranteed a nonnegative profit. Because the welfare index puts more weights on consumer surplus than profits, in any optimal scheme, the transfers will be chosen to minimize the incumbent's information rent. So the transfer will make $\pi(c_H)$ zero. We then use (4) to replace $t(c)$ in any given policy. Substituting (4) into (1), we can write the welfare index as

$$\int_0^Q (\alpha - \beta x)dx - cq(c) - q_e c_e - \theta_1 \int_c^{c_H} q(x)dx - \theta_2[(P(Q) - c_e)q_e]. \tag{5}$$

Taking expectation with respect to c (given I) and using integration by parts, the expected welfare index is

$$\int_{c_L}^{c_H} \left\{ \int_0^Q (\alpha - \beta x)dx - (c + \theta_1 h(c,I))q(c) - q_e c_e - \theta_2[(P(Q) - c_e)q_e] \right\} f(c,I)dc. \tag{6}$$

3. Optimal Regulation under Monopoly and Oligopoly

Now we derive the optimal regulatory policies for the monopoly and oligopoly regimes. We will take as given Firm 1's investment level when calculating the regulator's decision in Stage 3, and, for brevity in this section, will drop the investment argument I in the distribution and density functions (F and f).

3.1. Monopoly

In this regime we can set the entrant's quantity at zero ($q_e = 0$). The optimal regulatory policy maximizes the expected welfare index subject to the incentive compatibility and nonnegative profit constraints. We already have simplified the incentive and nonnegative profits constraints and substituted them to the welfare index (see (6)). Without Firm 2, this expression becomes

$$\int_{c_L}^{c_H} \left\{ \int_0^{q(c)} (\alpha - \beta x)dx - (c + \theta_1 h(c))q(c) \right\} f(c)dc. \tag{7}$$

The optimal policy under monopoly simply maximizes (7) with respect to $q(c)$ subject to the requirement that Firm 1's quantity $q(c)$ is nonincreasing. The following proposition, whose proof consists of solving first-order conditions from pointwise optimization and using the monotonicity of the hazard rate, summarizes the optimal scheme in the monopoly regime.

constraints (3), $\pi(c';c)$ is maximized at $c' = c$, which implies that $\pi_1(c';c) = 0$ for $c' = c$. Hence, $\pi'(c) = \pi_2(c;c) = -q(c)$. Then equation (4) follows.

Proposition 1. The optimal quantity for Firm 1 in the monopoly regime is given by:

$$q^*(c) = \frac{\alpha - c - \theta_1 h(c)}{\beta}. \tag{8}$$

Proposition 1 has the usual interpretation. Under complete information, the first-best policy would implement marginal cost pricing: the monopolist would be required to produce a quantity so that the price would equal marginal cost. Because of the firm's superior information about cost, the implementation of marginal cost pricing leaves too much profit for the firm: a low-cost firm can produce a quantity that is meant for a high-cost firm. This incentive to misrepresent information forces the regulator to leave some rent for the firm, and to distort the quantity downward. The expression for the second-best quantity in (8) says that the information rent is captured by the term $\theta_1 h(c)$. To the regulator, the best policy under asymmetric information is to treat a firm with cost parameter c as if it was a firm with cost $c + \theta_1 h(c)$, and to implement a quantity so that price equals to marginal cost adjusted upward by the information rent, or *virtual cost*.[10]

Because the hazard rate, h, is increasing in c, $q^*(c)$ in (8) is strictly decreasing in c. For a relevant range of the support $[c_L, c_H]$, then there will exist $\hat{c}$ such that

$$q^*(c) > \frac{\alpha - c_e}{\beta} \text{ if and only if } c < \hat{c}. \tag{9}$$

This observation will be used for characterizing the optimal policy in the oligopoly regime. When Firm 1's cost c is less than $\hat{c}$, the optimal mechanism will implement such a large quantity from Firm 1 that Firm 2's best response is not to produce at all even if it is in the market; see (2). Hence, for optimal regulation in Stage 3 the existence of the entrant is relevant only when the incumbent's cost is not very small.

3.2. Oligopoly

In this, we derive the optimal regulatory policy for the incumbent Firm 1 when Firm 2 is allowed into the market. Suppose under a regulatory policy $\{(q(c), t(c)\}$, Firm 2 will produce a positive amount at some c in the support $[c_L, c_H]$. When Firm 1 produces $q(c) < (\alpha - c_e)/\beta$, Firm 2's best response is given by $q_e(c)$ in the first part of (2). From this, we can compute Firm 2's profit, $\pi_e(c)$:

$$\pi_e(c) = \frac{(\alpha - \beta q(c) - c_e)^2}{4\beta}.$$

We are interested in incentive-compatible regulatory policies that allow Firm 2 to enter the market (to produce a strictly positive $q_e(c)$ as a best response) for some values of c. So we consider those regulatory policies $\{(q(c), t(c))\}$ with $q(c)$ nonincreasing in c, and with $q(\hat{c}) = (\alpha - c_e)/\beta$ for some $\hat{c}$ in $[c_L, c_H]$. From (9), we know that Firm 2 will enter if and only

10 The term is Roger Myerson's, see Myerson (1981).

if Firm 1's cost is above $\hat{c}$.

For c between c_L and $\hat{c}$, the regulator's expected welfare index is the same as (7); otherwise, we substitute Firm 2's best response function $q_e(c)$ and its profits into (6). The welfare index in the oligopoly regime becomes:

$$\int_{c_L}^{\hat{c}} \left\{ \int_0^{q(c)} (\alpha - \beta x)dx - (c + \theta_1 h(c))q(c) \right\} f(c)dc +$$
$$\int_{\hat{c}}^{c_H} \left\{ \int_0^{Q(c)} (\alpha - \beta x)dx - (c + \theta_1 h(c))q(c) - c_e \left[\frac{\alpha - \beta q(c) - c_e}{2\beta} \right] - \theta_2 \left[\frac{(\alpha - \beta q(c) - c_e)^2}{4\beta} \right] \right\} f(c)dc, \tag{10}$$

where $Q(c) = q(c) + q_e(c) = (\alpha + \beta q(c) - c_e)/(2\beta)$.

An optimal regulatory policy in the oligopoly regime maximizes (10) with respect to $q(c)$ subject to the requirement that $q(c)$ is nonincreasing. Pointwise optimization and simplification of the first-order conditions yield the following result.

Proposition 2. For $c \leq \hat{c}$, where $c_e = \hat{c} + \theta_1 h(\hat{c})$, Firm 2 does not produce, and the optimal quantity for Firm 1, $q^+(c)$, is given by

$$q^+(c) = \frac{\alpha - c - \theta_1 h(c)}{\beta}. \tag{11}$$

For $c > \hat{c}$, the optimal quantity for Firm 1, $q^+(c)$, is given by

$$q^+(c) = \frac{\alpha - c - \theta_1 h(c)}{\beta} + \frac{1}{\beta}\left[\frac{2\theta_2 - 3}{2\theta_2 + 1}\right](c + \theta_1 h(c) - c_e). \tag{12}$$

Furthermore, the total quantity produced by Firms 1 and 2 is given by

$$Q^+(c) = q^+(c) + q_e(c) = \frac{\alpha - c - \theta_1 h(c)}{\beta} + \frac{1}{\beta}\left[\frac{2\theta_2 - 1}{2\theta_2 + 1}\right](c + \theta_1 h(c) - c_e). \tag{13}$$

For $c > \hat{c}$, the market quantity under oligopoly ($Q^+(c)$) is bigger than that under monopoly ($q^*(c)$) if and only if $\theta_2 > 0.5$.

Proposition 2 describes the optimal quantities in the oligopoly regime. Figure 1 depicts the optimal quantity for Firm 1 in the first best, and second-best monopoly and oligopoly regimes. First, the entrant, Firm 2, cannot produce profitably if the incumbent's virtual cost $(c + \theta_1 h(c))$ is lower than its cost (c_e). Second, the regulator implements a lower quantity from the incumbent compared to the monopoly regime whenever the entrant is active, and the decrease of its quantity is directly related to the difference between its virtual cost and the entrant's cost, as well to the value of θ_2. Third, the total market quantity can be *lower* under oligopoly! This will be the case when θ_2 is less than one half.

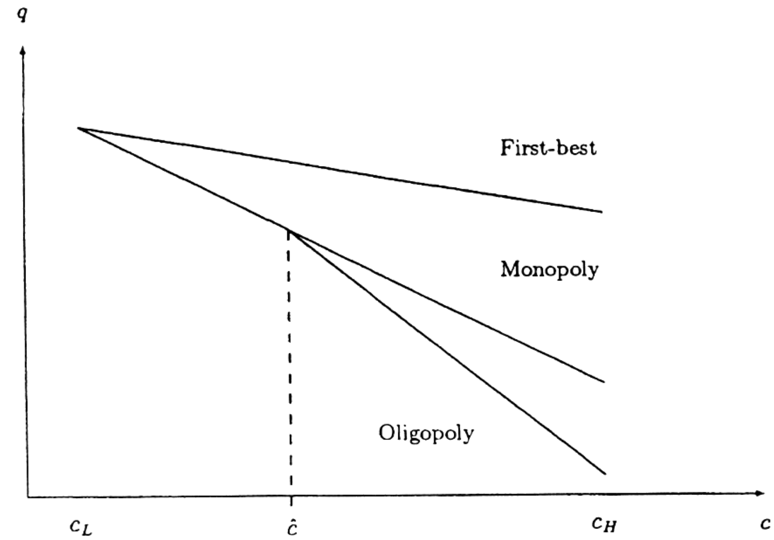

Figure 1. Optimal Quantities for the Incumbent (Firm 1) in the First Best, and Monopoly and Oligopoly Regimes

We now explain the intuition behind the results. First, the regulatory policy always can impose a quantity on the incumbent, Firm 1, so that the market price is equal to its virtual cost $(c + \theta_1 h(c))$. This will mimic the allocation in the monopoly regime, and the quantity will correspond to the virtual-cost pricing rule. If the entrant's cost is higher than Firm 1's virtual cost, it will be inefficient to let it produce. This explains the first part of Proposition 2. Second, Firm 1's information rent is positively related to its production level. So whenever it is efficient for the entrant to produce, information rent will be reduced if Firm 1's production level is depressed from the monopoly level. This explains equation (12), which states that $q^+(c)$ in the oligopoly regime must be lower than the corresponding quantity if the incumbent is a monopoly.

The most surprising result in Proposition 2 is the possibility that the total market quantity falls when Firm 2 enters the market. To explain why, first consider the case in which the regulator values the entrant's profit relatively highly; that is, θ_2 close to 0. Consider implementing a given quantity from the incumbent, and suppose that the entrant's cost is lower than the incumbent's virtual cost. Even if total market quantity stays at this constant level, welfare will improve if some of the production is shifted from Firm 1 to Firm 2. Given that Firm 2 is a Stackelberg follower in a quantity-setting model, this production shift requires a reduction of Firm 1's output. When Firm 2's profits do not represent a significant social loss (θ_2 close to 0), shifting more production to Firm 2 will increase welfare. But this requires a more than proportional reduction[11] in Firm 1's production, resulting in a fall in the total quantity in the market.

Finally, we briefly discuss the case when the entrant's cost is uncertain. Here, given an item from the regulatory menu, from the incumbent's point of view, the entrant's best

11 In our linear demand model, it requires a two-fold reduction in Firm 1's production.

response is uncertain. But because the demand function is linear, the entrant's best response is linear in its cost c_e. Therefore, the incumbent's profit can be expressed as a function of the expected market price. The basic incentive constraint (3) continues to hold once $p(c)$ and $p(c')$ are redefined to be the expected market prices. Similarly, the welfare index will be redefined to take into account the uncertainty of the entrant's cost; also, the entrant's decision to enter will be contingent on its cost being sufficiently low. Once these steps are taken into consideration, our model can be applied.

4. Investment Incentives and Welfare

We now examine the investment decisions of the regulated Firm 1 under the monopoly and oligopoly regimes, and their welfare implications. We will explicitly include investment in functions $F(c,I)$, $f(c,I)$, and $h(c,I)$ to make clear the comparison between investment levels in the regimes. Anticipating the equilibrium regulatory policy in Stage 3, Firm 1 chooses investment, I, to maximize profits. Because of asymmetric information, the incumbent still earns some rent from the regulatory policy. In Stage 2, when Firm 1 makes its investment decisions, the expected information rent then determines the returns to the investment. We now compare these returns in the monopoly and oligopoly regimes.

4.1. Monopoly

Recall that from equation (8) a type-c Firm 1's information rent is $\int_c^{c_H} q(c)dc$. From Proposition 1, for a given investment level I, the optimal policy implements the quantity $q^*(c) = (\alpha - c - \theta_1 h(c,I))/\beta$ for a type-c Firm 1. Thus, the firm's expected information rent, net of investment cost, is

$$E(\pi(I)) = \frac{1}{\beta}\int_{c_L}^{c_H}\int_{c}^{c_H} (\alpha - x - \theta_1 h(x,I))\, dx\, f(c,I)\, dc.$$

Simplifying this by integration by parts, we obtain

$$E(\pi(I)) = \frac{1}{\beta}\int_{c_L}^{c_H} F(c,I)(\alpha - c - \theta_1 h(c,I))\, dc. \tag{14}$$

Define I^* as the investment level that maximizes $E(\pi(I)) - I$, Firm 1's net profit.

It is useful to examine the firm's marginal return of investment because that determines Firm 1's investment decision. The derivative of expected information rent $E(\pi(I)$ is

$$\frac{\partial E(\pi(I))}{\partial I} = \frac{1}{\beta}\int_{c_L}^{c_H}\left[F_I(c,I)(\alpha - c - \theta_1 h(c,I)) - \theta_1 h_I(c,I)F(c,I)\right] dc. \tag{15}$$

From (15), we find that investment's effect on Firm 1's profits can be separated into two components. For a given regulatory policy $q^*(c)$, the firm increases its information rent by moving probability mass to the left via a first order stochastic dominating shift in the distribution $F(c,I)$—the first part of the integrand of (15). The second part of (15) demonstrates the effect of the regulator's lack of commitment on the firm's expected rent. By increasing its investment, the firm changes its virtual cost, $c + \theta_1 h(c,I)$, by $\theta_1 h_I(c,I)$. If $h_I(c,I) > 0$ at c, then the regulator will lower the firm's output for cost level c and reduce the firm's information rent for this cost. On the other hand, if $h_I(c,I) < 0$ at c, the regulator will allow the firm to increase its output at c, since the virtual cost is now lower.[12]

4.2. Oligopoly

In this regime, the unregulated Firm 2 can enter the market once Firm 1 has made its investment decision and the regulator has set its regulatory policy. The optimal regulation in Stage 3 then implements $q^+(c)$, as defined by Proposition 2. Given the optimal regulation, Firm 1's expected profit, net of investment cost, is

$$E(\pi(I;c_e)) = \frac{1}{\beta}\int_{c_L}^{c_H}\int_{c}^{c_H}(\alpha - x - \theta_1 h(x,I))\,dx\,f(c,I)dc -$$
$$\frac{1}{\beta}\left[\frac{3-2\theta_2}{2\theta_2+1}\right]\int_{\hat{c}}^{c_H}\int_{c}^{c_H}(x + \theta_1 h(x,I) - c_e)\,dx\,f(c,I)\,dc.$$

Integrating by parts, we obtain

$$E(\pi(I;c_e)) = \frac{1}{\beta}\int_{c_L}^{c_H}[F(c,I)(\alpha - c - \theta_1 h(c,I)]\,dc -$$
$$\frac{1}{\beta}\left(\frac{3-2\theta_2}{2\theta_2+1}\right)\int_{\hat{c}}^{c_H}[F(c,I)\,(c + \theta_1 h(c,I) - c_e)]\,dc. \tag{16}$$

Notice that the first part of (16):

$$\frac{1}{\beta}\int_{c_L}^{c_H}[F(c,I)\,(\alpha - c - \theta_1 h(c,I)]dc \equiv U(I)$$

is exactly Firm 1's expected information rent in the monopoly regime; see (14). The second part of (16),

$$\frac{1}{\beta}\left(\frac{3-2\theta_2}{2\theta_2+1}\right)\int_{\hat{c}}^{c_H}[F(c,I)\,(c + \theta_1 h(c,I) - c_e)]\,dc \equiv V(I),$$

is always positive, since $\hat{c}$ is defined by $c_e = \hat{c} + \theta_1 h(\hat{c},I)$ and $\theta_2 \leq 1$. Therefore, $V(I)$ is Firm 1's loss of information rents when entry by Firm 2 is allowed.

The marginal return of Firm 1's investment when entry is allowed is[13]

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12 For $h_I(c,I)$ to be positive (negative), then
$\partial(\ln F(c,I))/\partial I > (<)\ \partial(\ln f(c,I))]/\partial I$.
That is, if the rate of change in the distribution at c is larger (smaller) than the rate of change of the density at c, then the incumbent's virtual cost increases (decreases).

13 Note that the derivative of $\hat{c}$ with respect to I equals 0.

$$\frac{\partial E(\pi(I;c_e))}{\partial I} = U'(I) - V'(I),$$

where $U'(I)$ is the same as (15), and

$$V'(I) \equiv \frac{1}{\beta}\left(\frac{3-2\theta_2}{2\theta_2+1}\right)\int_{\hat{c}}^{c_H} [F_I(c,I)\,(c+\theta_1 h(c,I) - c_e) + F(c,I)\theta_1 h_I(c,I)]\,dc. \tag{17}$$

The expression $V'(I)$ is the difference in Firm 1's *marginal* returns of investment between oligopoly and monopoly regimes. The first term in $V'(I)$ represents a first order stochastic dominating shift in the distribution, $F_I(c,I)$, times the reduction in Firm 1's output due to entry, $(3-2\theta_2)/(\beta(2\theta_2+1))\,(c+\theta_1 h(c,I) - c_e) = q^*(c) - q^+(c)$. This term captures the fact that the incumbent receives less information rent because its output always becomes lower as a result of entry. The remaining term in $V'(I)$ is the change in Firm 1's expected output because of the change in the optimal regulatory mechanism, which is directly related to the change in virtual cost $h_I(c,I)$. If $h_I(c,I)$ is positive, then Firm 1's virtual cost increases with more investment, resulting in a lower output. This further reduces Firm 1's marginal return of investment. Conversely, if $h_I(c,I)$ is negative, then Firm 1's marginal return from investing may be higher.

Define I^+ as the investment that maximizes $E(\pi(I;\, c_e)) - I$. For Firm 1 to be choosing I^* and I^+ optimally respectively in the monopoly and oligopoly regimes, we must have:

$$U(I^*) - I^* \geq U(I^+) - I^+$$

$$U(I^+) - V(I^+) - I^+ \geq U(I^*) - V(I^*) - I^*.$$

Adding these two inequalities and simplifying, we obtain

$$V(I^+) \leq V(I^*).$$

Thus, the comparison between the different investment levels across the two regimes depends on the behavior of $V(I)$. In the following proposition we can show that if $V(I)$ is monotone, then we can compare I^* and I^+ easily:

Proposition 3. If $V(I)$ is increasing, then $I^* \geq I^+$. Conversely, if $V(I)$ is decreasing, then $I^* \leq I^+$.

A sufficient condition for $V'(I)$ to be positive, and hence $I^+ < I^*$, is $h_I(c,I) > 0$ for all c. Even if $h_I(c,I)$ is sometimes negative, if its absolute value is small compared with the first part of (17), $V'(I)$ may still be positive. Conversely, a necessary condition for $I^+ > I^*$ is $h_I(c,I) < 0$ for some subset in $[c_L, c_H]$. Clearly, when V is nonmonotone, the comparison between I^* and I^+ would be even more difficult.

It is well known that when one distribution dominates another (in the sense of first order stochastic dominance), often the dominating distribution has a higher hazard rate.[14] For example, the normal and the exponential distributions satisfy this. As we have shown above, when $F_I(c,I)$ and $h_I(c,I)$ are both positive, $V'(I) > 0$ and Firm 1's equilibrium investment will be reduced because of entry. But, in many examples, a dominating distribution may have a lower hazard rate.[15] Thus, the hazard rate, and consequently the firm's virtual cost, can actually be lower while investment improves costs in the sense of first order stochastic dominance.

We are now ready to address whether deregulation will increase welfare. Obviously, Firm 1's information rent will always be lower when entry is allowed, and for a given level of information rent, higher levels of investment are always preferred by the regulator. Furthermore, for a given level of investment, the regulator always prefers entry, since if Firm 1's virtual cost is higher than c_e then the regulator can lower Firm 1's output and hence induce an increase in Firm 2's output from (2), Firm 2's best response function. Thus, using Proposition 3 for the case of $I^+ > I^*$, we have the following:

Proposition 4. If $V(I)$ is decreasing, then welfare is higher in oligopoly than monopoly.

If $V(I)$ is increasing, then welfare may be higher or lower when entry is allowed. Investment is higher under monopoly, but under oligopoly Firm 1's information rent is always lower, and production efficiency increases.

Propostion 5. If $V(I)$ is increasing, then welfare may be either higher or lower in oligopoly.

Simple examples to illustrate Proposition 5 can be given. For a given I between 0 and 1, let the density function of the cost be $f(c,I) = 1 + I - 2cI$, for $0 \leq c \leq 1$. Thus, for $I = 0$, the distribution is uniform on the interval $[0,1]$. As investment I increases, the density function tilts in a linear fashion to move probability mass to smaller values of c. Here, $h_I(c,I) > 0$ so that $V'(I) > 0$. Let the demand function be $p(Q) = 25 - Q$ (so that $\alpha = 25$, and $\beta = 1$). The values of θ_1 and θ_2 are assumed to be 1 and 0, respectively: the welfare loss due to the incumbent's profit is the highest, while the opposite is true for the entrant's profit.[16] For the monopoly regime, the equilibrium investment, I^*, turns out to be 0.864, generating a welfare of 288.546.

Two examples from two values of c_e are provided. First, when $c_e = 0.25$, the equilibrium investment in the oligopoly regime, I^+, is 0.499, with $\hat{c} = 0.122$ (that is, Firm 2 enters whenever Firm 1's cost is higher than 0.122). Welfare is 289.993, higher than that in the monopoly regime. In this example, the entrant's cost is relatively low, and the incumbent's equilibrium investment falls from 0.864 to 0.499. We now turn to the second example. Here, the entrant's cost, c_e, is assumed to be 2, much bigger than the incumbent's maximum

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14 See for example page 77 in Laffont and Tirole (1993).

15 For convenience, take two discrete distributions F^1 and F^2. Each of them has mass on the set $\{.1, .2, .3, ... ,1\}$. Let F^1 be a uniform distribution with density of .1 at each point. Let F^2's density function have values of .08 from .1 to .9, and .28 on 1. Straightforward calculations show that F^1 dominates F^2, but F^2 has a higher hazard rate.

16 Notice that because θ_1 is set at 1, the interim and ex ante welfare measures equal each other in the examples here.

marginal cost. In this example, the equilibrium investment level, I^{+}, is 0.603, still lower than that in the monopoly regime, and $\hat{c} = 0.753$—Firm 2 is much less likely to enter. Welfare in equilibrium is 288.437, smaller than the level under monopoly.[17]

In the two numerical examples above, welfare is higher under oligopoly when the entrant's cost is lower. One might suspect that this is true in general. Unfortunately, this does not appear to be the case. The entrant having a lower cost obviously may be desirable for the usual reasons: lower information rent for the incumbent Firm 1, and more efficient production. But it may have an ambiguous effect on Firm 1's investment decision. The change in Firm 1's marginal return of investment with respect to (c_e) is

$$\frac{\partial^2 E(\pi(I;c_e))}{\partial c_e \partial I} = \frac{1}{\beta}\left(\frac{3-2\theta_2}{2\theta_2+1}\right)\left[\int_{\hat{c}}^{c_H} F_I(c,I)dc + \frac{\partial \hat{c}}{\partial c_e} F(\hat{c},I)\theta_1 h_I(\hat{c},I)\right].$$

If the change in the hazard rate at $\hat{c}$ is sufficiently negative, then the firm will invest more due to reduction in the entrant's cost. Thus, welfare would unambiguously increase due to the reduction in the entrant's cost. On the other hand, if the change in the hazard rate at $\hat{c}$ is positive, then the marginal return of investing is lower if the entrant's costs falls. This results in a lower investment by the incumbent, reducing welfare. The net effect is in general ambiguous.[18]

We now describe a class of models where welfare improves as the industry is deregulated. Suppose that the improvement of costs due to investment occurs only for lower realizations of costs in the support $[c_L, c_H]$. We introduce

Assumption 1. For all I, $F_I(c;I) \le 0$ for $c \le \bar{c}$ with strict inequality for some c, and $F_I(c,I) = 0$ otherwise.

In words, investment only improves the cost distribution when costs are lower than a threshold; investment does not affect the distribution of high costs. This assumption is not implausible. Suppose firms vary in their abilities to conduct R&D, but they do not know their abilities before making an investment. Firms that are good at conducting R&D will have a positive probability of achieving lower costs, while firms that are bad will not. Now, suppose that some firms are more efficient than others across a broad class of activities; that is, firms that may succeed in R&D will have lower costs regardless of the R&D outcome. Then an improvement in the distribution of costs only occurs at low levels of cost.

Under Assumption (1), that for any c_e sufficiently big, welfare under oligopoly is always higher than monopoly, and our model yields a clear policy implication. Consider the value of the incumbent's cost at which the entrant just begins to produce (the variable $\hat{c}$). For ease of notation, we let a function $\gamma(c_e)$ represent this value of the incumbent's cost given the entrant's cost c_e. That is, the equation $c_e = \gamma(c_e) + \theta_1 h(\gamma(c_e),I)$ implicitly defines the value of

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17 The *Mathematica* programs for these simulations are available from the authors.

18 It should be noted that if $\hat{c}$ is originally close to c_H and the hazard rate does not change much at $\hat{c}$, then welfare improves by a reduction in c_e since the direct effect due to the entrant's lower cost dominates the indirect effect on the investment by the incumbent. Interested readers may contact the authors for examples.

the incumbent's cost at which the entrant begins to produce.[19] For now, assume that the value of c_e is such that $\gamma(c_e) \geq \bar{c}$. It is easy to see that the incumbent will choose the identical level of investment in the monopoly and oligopoly regimes. Consider again the expression of $V(I)$:

$$\frac{1}{\beta}\left(\frac{3-2\theta_2}{2\theta_2+1}\right)\int_{\hat{c}}^{c_H}[F(c,I)(c+\theta_1 h(c,I)-c_e)]\,dc \equiv V(I)\,.$$

Because we consider those higher values of c_e, we have $\hat{c} = \gamma(c_e) \geq \bar{c}$, the above expression is actually independently of I by Assumption 1. Therefore, the equilibrium investment levels are identical in the monopoly and oligopoly regimes. As a result, welfare is higher under oligopoly due to either the reduced price or reduced information rent, or both.

Obviously, for distributions that do not satisfy Assumption 1, but have values of F_I that are uniformly bounded from above when c_e is big, then the above result continues to hold. This is because when c_e is sufficiently big, the equilibrium values of investment in the monopoly and oligopoly regimes cannot differ very much, and the welfare improvement from competition from the entrant must dominate.

Although we have shown that, under Assumption 1, when c_e is sufficiently big, deregulation must increase welfare, it is entirely possible that Assumption 1 may not hold. We now present a result on welfare comparisons when the incumbent's investment level is a discrete variable. Let us now assume that there are N levels of investment, $I_1 < \ldots < I_N$. Whereas the continuous case is a more general, the discrete version may actually be quite plausible; most investments in regulated industries are quite lumpy, examples being generating plants for the electricity industry and the costs of loops and switches in the telecommunications industry. Consider first the monopoly regime. The investment that maximizes the incumbent's information rent, I_j, is generically unique. In other words, generically, the incumbent *strictly* prefers to pick I_j to other investment levels: for $k \neq j$, $U(I_j) - I_j > U(I_k) - I_k$. For $c_e > c_H + \theta_1 h(c_H, I_j) \equiv \bar{c}_H$, the incumbent's investment is not influenced by the presence of the entrant. This is because when $c_{f}e$ is higher than $c_H + \theta_1 h(c_H, I_j)$, the entrant will not find it profitable to enter even if the market is deregulated. As c_e falls below $\bar{c}_H$, there must exist an $\varepsilon > 0$ such that for $c_e > \bar{c}_H - \varepsilon$, the above inequality remains true, and the incumbent's best investment remains at I_j. So in this case, the entrant's presence will not affect the incumbent's investment level, but reduce information rent and possibly increase total output. We can state

Proposition 6. If investment is discrete, then generically there exists an $\varepsilon > 0$ such that if $c_e \in (\bar{c}_H - \varepsilon, \bar{c}_H]$, then welfare is improved by allowing entry.

If investment is very lumpy in the sense that the differences between possible investment levels are large, then the incumbent's investment choice is unlikely to vary with entry, and as a result, deregulation may raise welfare. Lumpiness of investment levels could occur when there are only a few possible technologies to choose from. For example, there may only be

19 Obviously, γ is a function of I also, but for our purpose we can suppress that argument.

two possible technologies. One is an incremental change in the current technology that will require relatively little capital and promise a relatively small reduction in costs, while the other is a completely new technology that will be quite costly but will result in a large expected drop in costs. Two of the industries where deregulation is occurring are electric power generation and local telecommunications. In each of these industries the cost of capital equipment has dropped dramatically. In electricity this is due to the invention of gas turbine generators, while for telecommunications the drop in the price of computing and fiber optics has greatly reduced the costs of making phone calls. It was not until there was a large drop in the capital costs that entry was allowed in these markets. A possible interpretation for the delay is that once the capital costs dropped so precipitously the regulators knew that the incumbent firms would adopt the new technologies even if there was entry in the market.

Finally, we briefly consider the optimal regulation of the entrant. Because we have assumed that the entrant's cost is known,[20] if the entrant is also regulated, the market price will be the lower of the entrant's cost c_e and the incumbent's virtual cost $c + \theta_1 h(c,I)$: the equilibrium policy will either let the incumbent produce at price $c + \theta_1 h(c,I)$, or the entrant produce at price c_e. This will reduce the incumbent's information rents, since the incumbent's information rent is proportional to its quantity and it does not produce when its virtual cost is greater than the entrant's cost. Generally it is unclear whether the incumbent's marginal return to investing is higher or lower than when the entrant is unregulated or the incumbent remains the monopolist. Thus, with the regulator's commitment to leave the entrant unregulated, welfare could improve either from the monopoly regime, or from the regime in which the entrant is subject to regulation. If Assumption 1 is adopted, then for c_e above $\bar{c}$, welfare is highest when the entrant is allowed into the market but faces optimal regulation. This result follows from the same intuition as above. The incumbent's investment is the same whether it is a monopolist, or faces a regulated entrant, or an unregulated entrant.

5. Conclusions

In this paper, we have analyzed the investment incentives of a regulated, incumbent firm when entry is allowed in the market and the regulator has limited commitment ability. We have shown that deregulation may create a tradeoff for the regulatory authority—the introduction of competition may result in lower prices and more efficient production, but may reduce the incumbent's innovation in the market. We have pointed out, contrary to previous research, the incumbent's investment incentive (the marginal return of investment) depends on the way investment affects virtual cost—the sum of the physical and the emph{information} cost a regulator must consider when designing an optimal policy under incomplete information. We demonstrate that deregulation may raise or lower welfare. In the process of characterizing the equilibrium investment, we also determine the optimal regulatory policy in a deregulated environment.

The model that we have investigated is simple: there are only two firms, they make identical products and compete in quantities, and the market demand function is linear. Using these assumptions, we have obtained closed-form solutions for the optimal regulatory policy.

20 Auriol and Laffont (1992) consider optimal market structure when the entrant's cost is unknown.

We speculate that the tradeoff that we have discovered holds in much more general settings. For example, suppose that the firms produce differentiated products, and assume a Hotelling-type model with firms located at the ends of the line. Now let the firms compete in prices. The main difference is that the competitive instrument (prices) are now strategic complements, whereas in the current model, they (quantities) are strategic substitutes. To reduce the entrant's profits in this model, the regulator must reduce the incumbent's price.[21] When making its investment decision, the incumbent must take into account the entrant's effect on its information rent. Again, we expect that in the model with differentiated products, the incumbent's incentives to make an investment will depend on the relationship between its virtual cost and its investment.

We have focused our attention on the incumbent's investment decisions during the deregulation process, while the incumbent is still regulated. Nevertheless, the incumbent may believe that eventually it be completely unregulated, and that the virtual-cost pricing rule will be lifted. In this case, an additional incentive to invest arises: the incumbent may invest more in order to generate a very low marginal cost and either deter entry completely or reduce the level of competition if there is entry. We think that this is an interesting research avenue to explore in the future.

Our analysis concentrated on the incumbent's incentives to make an investment. This is often a reasonable approximation of what happens in the short run during deregulation. In future research, it may be interesting to take explicit account of entrants' investment decisions.

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21 See Biglaiser and Ma (1995) for related issues.

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