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Regulatory Risk, Investment and Welfare

Woroch, Glenn A.

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Abstract

The allocative and distributional effects caused by uncertain regulatory constraints are evaluated. Three prominent forms of monopoly regulation are examined: constraints on rate of return, on price, and on competitive entry. The solution to the firm's profit maximization problem for the case when it must invest before the constraint is known is compared to the certainty case.

Under plausible demand and cost conditions, rate-of-return risk depresses investment and expands employment. In particular, it may reverse the over-capitalization that results from rate-base regulation. Presumably, by substituting variable inputs for irreversible capital the firm gains flexibility to respond to the policy uncertainty. Price and entry risk, however, are shown to lead to exactly the opposite conclusion when a few assumptions are added which, roughly speaking, imply that capital is used more intensively as output grows. As it happens, neither price nor entry risk has a definite effect on (expected) employment. Tests of these implications for investment behavior could be performed using a measure of regulatory risk extracted from market valuations of firms' securities.

In terms of welfare implications, the firm is found to be averse to all three types of regulatory risk. Incidentally, the firm in the Averch-Johnson model of regulation is also shown to prefer a nonrandom allowed rate of return when all factors can be adjusted in response to the constraint. Finally, it is demonstrated that both price and entry risk raise expected consumer surplus, but only at the expense of strong assumptions.

Glenn A. Woroch
Department of Economics
University of Rochester
Rochester, NY 14627
(716) 275-4239

1. REGULATORY RISK

Regulatory policy can amplify or mitigate the uncertainty present in a firm's environment. A policy may reduce financial risk by smoothing fluctuations in the levels of demand and cost. Adjustment clauses, for instance, dampen the earnings variability caused by fuel price shocks to electric power utilities. Alternatively, or in addition, the policy itself may introduce an element of uncertainty that is entirely unrelated to economic conditions. Regulatory decisions are directly affected by events such as turnover of agency staff, judicial rulings on procedural matters, and votes on budget appropriations that can be neither predicted nor controlled by the firm. Furthermore, investors might perceive the policy to be stochastic simply because the regulator's intentions are communicated with noise. Actually, a regulator may deliberately choose to add uncertainty to its policy, as in the case of a random inspection program. It is the consequences of this type of uncertainty -- which may be called "regulatory risk" -- that is the subject of this paper.

Policy uncertainty is not new to economic analysis. The political risk that surrounds the expropriation of direct foreign investment, debt repudiation, and tariff policy has long been considered an important factor in the operation of international capital markets. Outside the area of international finance, analysis of noneconomic risk has been scarce. In the field of regulation, there are numerous studies that treat demand or cost as uncertain, but rarely are the regulatory constraints themselves stochastic. One exception is Klevorick (1973) who allows the rate review to be a chance event. Another is due to Braeutigam (1979) in which the regulator is responsible for a stochastic delay before an innovation is introduced, a framework closer to our approach since the constraint is continuously valued.

Three prominent forms of monopoly regulation are analyzed in this paper: constraints on rate of return, on price, and on competitive entry. The constraints are taken to be exogenous random variables; the source of their randomness is not explicitly modelled. In order to study regulatory risk in isolation, cost and demand are assumed to be nonstochastic. The firm must invest in capital before the constraint is known.[1] Once the policy uncertainty is resolved, it adjusts variable factors to satisfy all realized demand. The solution to the firm's profit maximization problem is derived and compared to the certainty case to assess the effects of regulatory risk on investment, employment, profits, and consumer surplus.

Under plausible demand and cost conditions, rate-of-return risk depresses investment and expands employment. In particular, it may reverse the over-capitalization caused by rate-base regulation. This tendency should not be surprising since, by substituting the variable factor for irreversible capital, the firm gains flexibility to respond to policy uncertainty. This intuition is contradicted, however, when there is uncertainty in the price level or the extent of competitive entry. In these cases, risk leads to greater investment when a few reasonable assumptions are added which, roughly speaking, imply that capital is used more intensively as output grows. These very same conditions, however, are not sufficient to determine the effects of price and entry risk on employment.

Several observable implications follow from the dependence of investment behavior on policy uncertainty. For example, capital intensity of utilities subject to rate-base regulation will be inversely related to the variability of allowed rates of return. Consequently, an agency's ratemaking process that is insulated from the petitions of interest

1 Spulber and Becker (1983) and Viscusi (1983) analyze **ex ante** investment when a regulatory constraint varies over time. In their models, however, the firm has perfect foreknowledge of the constraint.

groups, from budgetary control, and from legislative oversight will engender more investment by firms in its jurisdiction than one sensitive to these influences. Of course, regulatory risk must somehow be quantified before this relationship can be tested. Direct measures of the volatility of regulatory policy are unlikely to capture both subjective and objective risks. Alternatively, investors' beliefs about all types of risks are imbedded in the market prices of utilities' securities. In principle, the component of a firm's returns attributable to regulatory risk could be extracted from these data.

Regulatory risk affects the firm and its customers in different ways.[2] Peltzman (1976) has suggested that a regulator may serve a firm's interests by compensating it for cost and demand variability, presumably by shifting the risk to consumers.[3] Following this line of reasoning, a captured regulator would seek to completely eliminate its contribution to risk. The comparative statics results confirm this conjecture: regulatory risk lowers expected profit for a wide range of cases. Somewhat stronger assumptions on demand and cost are needed, however, to establish that price and entry risk raise expected consumer surplus; the effect of rate-of-return risk on consumers is indeterminate. Unlike Peltzman who sees the impact on risk as a byproduct of regulation, Owen and Braeutigam (1978) propose risk reduction as the principal motivation for regulation, whether it originates with firms or with consumers. The welfare implications are included here not so much to predict the incidence of regulation, or the form it may take, but rather to appraise the risk factor associated with different institutions for regulating -- or deregulating -- industry.

2 The consequences for factor owners and for total welfare are ignored.

3 Hogan, Sharpe and Volker (1980) find empirical support for the hypothesis that "more" regulation reduces the systematic part of financial risk.

The next section contains a description of the demand and cost conditions along with a sketch of the method used to evaluate the effects of regulatory risk. Each of the three constraints receives separate treatment in the subsequent sections. A final section sums up the results and suggests some extensions.

2. THE BASIC MODEL

The firm produces output q with capital k and labor ℓ according to the production function $q = F(k,\ell)$. Assume that $F(k,0) = F(0,\ell) = 0$, $F_k(k,\ell) > 0$, $F_\ell(k,\ell) > 0$ (where subscripts denote partial derivatives), and that F is strictly concave. On occasion, stronger assumptions on the technology are needed to obtain sharper results. Let r be the market cost of capital and w be the price of labor, both nonstochastic.

Demand for the product $D(p)$ is decreasing in p. The revenue function, given by $R(q) = P(q)q$ where $P(q)$ is the inverse demand function, is assumed to be strictly concave. Income effects are ignored so that an accurate measure of welfare is consumer surplus: $V(p) = \int_p^\infty D(v)dv$; the demand assumptions make it strictly decreasing and convex.

In what follows, the firm must invest in capital before, and hire labor after, the policy becomes known. Additional capital cannot be purchased nor can unneeded stocks be sold off. The objective of the firm is to maximize expected profit which can be interpreted in a number of ways depending on the nature of the asset markets. If the firm is able to issue claims contingent on each realization of the policy, then the proper objective is to maximize market value evaluated at contingent claims prices. Alternatively, if no such assets exist so that regulatory risk is not diversifiable, then expected net return is the appropriate criterion provided the firm is owned by risk-neutral investors.

The same technique is used to solve the firm's problem for all three policies. First, given installed capacity k, the employment level is chosen to maximize profit when the regulatory constraint takes the value $\tilde{x}$. It does so under a "common carrier obligation" that requires it to meet demand. Let the solution be $\ell(k,\tilde{x})$ which yields the "regulated quasi-rent" $\pi(k,\tilde{x})$. The outcome of an unspecified process, the constraint varies according to the distribution function $G(\tilde{x})$. Letting E represent the expectation with respect to G, the firm's investment problem is to choose k so as to:

(1) $$\text{Maximize } E\pi(k,\tilde{x}) - rk$$

provided, of course, that it breaks even. Sufficient conditions are sought to compare the solution of this problem with the one obtained when the constraint takes on its mean value $\bar{x} = E\tilde{x}$ and the optimal input levels are $\bar{\ell}$ and $\bar{k}$. Application of Jensen's Inequality to the first-order conditions will usually provide a comparison of the two cases. Some (but not all) of the results continue to hold when there is a general change in riskiness of the constraint.

3. RATE-OF-RETURN RISK

Consider first the standard formulation of rate-base regulation due to Averch and Johnson (1962), but now with an uncertain allowed rate of return: after the firm invests, an allowed rate of return on capital $\tilde{s}$ is drawn randomly from the interval (r_0,r_1). Let the allowed rate of return have mean $\bar{s} = E\tilde{s}$ which exceeds the competitive rate.

The subproblem of choosing employment amounts to maximizing the quasi-rent

$R(q) - w\ell$ subject to the rate-of-return constraint $R(q) - w\ell \leq \tilde{s}k$.[4] If the constraint is slack, then the firm behaves as a short-run monopolist equating the marginal revenue product of labor to the wage: $R'(q)F_\ell(k,\ell) = w$. Write the solution to this problem as $\hat{\ell}(k)$ and the corresponding unregulated quasi-rent as $\hat{\pi}(k) = R(F(k,\hat{\ell}(k))) - w\hat{\ell}(k) = \hat{s}(k)k$ where $\hat{s}(k)$ is the short-run monopoly rate of return. Let $\hat{r}$ be the long-run monopoly rate of return. A standard argument for concave programs verifies that $\hat{\pi}(k)$ is concave (see Dixit (1976, p. 70)). If, on the contrary, the constraint binds, then there is a continuum of outputs that attain the maximum. Assume that the firm selects the highest employment level (or equivalently, the lowest price) consistent with the upper bound on the rate of return: $\ell_0(k,s) = \max\{\ell: R(F(k,\ell)) - w\ell \leq sk\}$.[5] Employment is thus given by:

$$\text{(2)} \qquad \tilde{\ell}(k,s) = \begin{cases} \ell_0(k,s) & r_0 < s < \hat{s}(k) \\ \hat{\ell}(k) & \hat{s}(k) < s < r_1 \end{cases}$$

Profit is the difference between the regulated quasi-rent and the cost of capital:

$$\text{(3)} \qquad \pi(k,s) - rk = \begin{cases} (s - r)k & r_0 < s < \hat{s}(k) \\ \hat{\pi}(k) - rk & \hat{s}(k) < s < r_1 \end{cases}$$

so that expected profit is:

$$\text{(4)} \qquad E\pi(k,\tilde{s}) - rk = k\int_{r_0}^{\hat{s}(k)} s\,dG(s) + (1-G(\hat{s}(k)))\hat{\pi}(k) - rk$$

Differentiation by k yields a necessary condition for the optimal investment $\tilde{k}$:

$$\text{(5)} \qquad E\pi_k(k,\tilde{s}) = \int_{r_0}^{\hat{s}(k)} s\,dG(s) + (1-G(\hat{s}(k)))\hat{\pi}'(k) = r$$

[4] Notice that by design any investment that enters the rate base is sunk, and that all others are reversible.

[5] A policy that made allowable quasi-rent increasing in employment, however slight, would induce this choice.

where use was made of the fact that $\hat{\pi}(k) = \hat{s}(k)k$. Unfortunately, since $\pi_k(k,s)$ is neither concave nor convex in s, Jensen's Inequality is not of any use here. Instead, integrate by parts and rearrange to get:

$$(6) \qquad E\pi_k(k,\tilde{s}) = [\hat{s}(k)-\hat{\pi}'(k)]G(\hat{s}(k)) - \int_{r_0}^{\hat{s}(k)} G(s)ds + \hat{\pi}'(k)$$

Replacing G with another distribution function H yields the inequality:

$$(7) \qquad E\pi_k(k,\tilde{s}) \leq [\hat{s}(k)-\hat{\pi}'(k)]H(\hat{s}(k)) - \int_{r_0}^{\hat{s}(k)} H(s)ds + \hat{\pi}'(k)$$

whenever: (i) H is a mean-preserving contraction of G; (ii) $H(\hat{s}(k)) \geq G(\hat{s}(k))$; and (iii) $\hat{s}(k) \geq \hat{\pi}'(k)$. All three conditions are satisfied as H approaches the degenerate distribution corresponding to the mean rate of return, and as k approaches $\bar{k}$. In that case, $H(\hat{s}(\bar{k})) = 1$ and $\hat{s}(\bar{k}) = \bar{s} > \hat{\pi}'(\bar{k})$, so that the right hand side of (7) is bounded above by r. Since $\pi_k(k,s)$ is decreasing in k by the second-order conditions, k must be raised to restore the equality in (5).

Inspection of (2) shows that $\tilde{\ell}(\tilde{k},\tilde{s})$ is bounded below by $\hat{\ell}(\tilde{k})$. Also, $\hat{\ell}(k)$ is decreasing provided:

$$(8) \qquad \hat{\ell}' = - \frac{R'' F_k F_\ell + R' F_{k\ell}}{R'' F_\ell^2 + R' F_{\ell\ell}} < 0$$

The denominator in (8) is negative by the second-order condition for short-run profit maximization; the numerator is negative if, in the words of Baumol and Klevorick (1970, p. 179), "capital and labor are substitutes in the production of revenue." Then,

$$(9) \qquad \tilde{\ell}(\tilde{k},\tilde{s}) \geq \hat{\ell}(\tilde{k}) > \hat{\ell}(\bar{k}) = \bar{\ell}$$

for all $\tilde{s}$ in $[r_0,r_1]$ since $\tilde{k} < \bar{k}$. These results are summarized in:

Proposition 1: Rate-of-return risk (i) decreases investment, and (ii) provided the factors are substitutes in the production of revenue, increases employment.

Thus, the addition of uncertainty to rate-base regulation works in the opposite direction to the famous Averch-Johnson results. Risk reduces total investment and, since it also raises employment, it lowers the capital-labor ratio, driving it "closer" to cost-efficiency. In fact, it is possible that **undercapitalization** occurs for low rates of return. Moreover, production may occur even when allowed rates fall **below** the competitive level (i.e., $\tilde{s} < r$) in contrast to the case of certainty where the firm simply shuts down. Of course, the losses that result must be balanced against profits earned when allowed rates of return exceed the competitive level.

Reverse Averch-Johnson effects have also been detected in models with demand uncertainty (e.g., Peles and Stein (1976)) and with random rate review (Klevorick (1973) and later Bawa and Sibley (1981)). In part, these theoretical studies have been motivated by the fact that the statistical tests of the overcapitalization hypothesis have been rejected as often as they have been accepted. Explanations for this lack of empirical support range from misspecification of parametric forms, to improper characterization of regulatory behavior, to errors in measurement of the price and quantity of capital. At the very least, the above proposition suggests that the omission of regulatory risk should be added to this list.

Turning to distributional issues, it can be shown that owners of the regulated firm are harmed by rate-of-return risk. To see this, note that, from (3), $\pi(k,s)$ is concave in s, so that:

$$E\pi(\tilde{k},\tilde{s}) - rk < \pi(\tilde{k},\bar{s}) - rk \tag{10}$$

Now observe that $\hat{s}(\tilde{k}) > \hat{s}(\bar{k}) = \bar{s}$ since $\hat{s}(k)$ is decreasing and since $\tilde{k} < \bar{k}$. Again using (3), we have:

$$\pi(\tilde{k},\bar{s}) - r\tilde{k} = (\bar{s} - r)\tilde{k} < (\bar{s} - r)\bar{k} \tag{11}$$

the right hand side of (11) being the level of profit under certainty.

The effect on consumers, on the other hand, is ambiguous. The ambiguity arises because less capital but more labor is employed under risk making an assessment of the output effect impossible without an exact specification of the production function. Therefore, price, and hence, consumer surplus under the two regimes cannot be compared. This verifies:

Proposition 2: Rate-of-return risk (i) reduces expected profit, and (ii) has an indeterminate effect on expected consumer surplus.

This last proposition relates to the literature on the desirability of price instability. Oi (1961) and others found that a competitive firm prefers variable prices when it can adjust all factors ex post. The opposite is true with regard to the regulated firm that enjoys such full flexibility: it is averse to rate-of-return risk. To establish this result, which is of independent interest, it is necessary to assume that $r < s < \hat{r}$ in order to draw upon properties of the solution to the certainty case.

Proposition 3: Regulated profit is concave in the allowed rate of return.

Proof: For each s, the regulated firm maximizes $\hat{\pi}(k) - rk$ subject to $\hat{\pi}(k) \le sk$. Let $k(s)$ be the solution and $\lambda(s)$ the associated multiplier satisfying the usual first-order conditions at an interior optimum:

(12) $$(1 - \lambda)\hat{\pi}'(k) - r + \lambda s = 0$$

(13) $$-\hat{\pi}(k) + s = 0$$

They exist and are continuously differentiable by the Implicit Function Theorem. Takayama (1969) has shown that the multiplier takes values between 0 and 1 and is decreasing. An easy comparative statics exercise demonstrates that $dk/ds = k/(\hat{\pi}' - s) < 0$. Let $\bar{\pi}$ denote the value of the program. Routine application of the Envelope Theorem yields $d\bar{\pi}/ds = (\hat{\pi}' - r)dk/ds = \lambda k$ for all s, and serves to establish $d^2\bar{\pi}/ds^2 = \lambda' k + \lambda k' < 0$. ∎

Thus, Proposition 2 verifies that the firm's risk aversion persists even when not all factors can be adjusted in response to the constraint. Incidentally, it is not possible to also show that investment is concave in the allowed rate of return causing it to decrease with risk, a result that would parallel Proposition 1.

4. PRICE RISK

The behavior of the competitive firm under price uncertainty has been the subject of intensive study. The case of partial flexibility in which the firm invests before the price is known was first treated by Hartman (1976).[6] In contrast to the competitive model, however, a regulated firm usually does not enjoy the luxury of setting any quantity it chooses, but instead, operates under a "common carrier obligation." The analysis of this demand-constrained case provides results that complement those of Hartman.

[6] In the same year and in the same journal, Peles and Stein (1976) employed this setup in their analysis of rate-of-return regulation with demand uncertainty.

Let $\tilde{p}$ be the random price having mean $\bar{p} = E\tilde{p}$. Since revenue is completely determined once the regulated price is realized, the firm simply employs the least amount of labor necessary to meet demand. Let $L(q,k)$ be the labor requirement satisfying $F(k,L(q,k)) = q$. The properties of L that are needed below include:

(14) $$L_q = 1/F_\ell > 0$$

(15) $$L_k = -F_k/F_\ell < 0$$

(16) $$L_{qq} = -F_{\ell\ell}/F_\ell^3 > 0$$

(17) $$L_{kk} = -(F_\ell{}^2 F_{kk} - 2F_k F_\ell F_{k\ell} + F_k{}^2 F_{\ell\ell})/F_\ell{}^3 > 0$$

where the last inequality is due to the fact that the term in parentheses is just a quadratic form of the Hessian of F, a negative definite matrix.

The investment problem (1) boils down to choosing capital so as to minimize $E[wL(D(\tilde{p}),k) + rk]$ which requires that $EwL_k(D(\tilde{p}),k) + r = 0$ at $\tilde{k}$. Assume that L_k is decreasing and concave in q, and also that D is convex in p. Repeated application of Jensen's Inequality then gives:

(18) $$\begin{aligned} 0 &= EwL_k(D(\tilde{p}),\tilde{k}) + r \\ &\le wL_k(ED(\tilde{p}),\tilde{k}) + r \\ &\le wL_k(D(\bar{p}),\tilde{k}) + r \end{aligned}$$

Thus, using the fact that L_k is increasing in k from (17), $\tilde{k} > \bar{k}$ where $\bar{k}$ minimizes cost of producing $D(\bar{p})$.

The assumptions needed to obtain this result have natural economic interpretations. First of all, the convexity of demand allows price elasticity to be both increasing and decreasing and includes the popular linear and exponential forms. Next, a tedious but straightforward derivation yields:

(19) $$L_{qk} = [\partial(-F_k/F_\ell)/\partial\ell]/F_\ell$$

(20) $$L_{qqk} = [F_\ell\partial^2(-F_k/F_\ell)/\partial\ell^2 - F_{\ell\ell}\partial(-F_k/F_\ell)/\partial\ell]/F_\ell^3$$

Thus, L_k is decreasing in q provided the marginal rate of substitution decreases with labor for given capital (i.e., $\partial(-F_k/F_\ell)/\partial\ell < 0$) which, in turn, implies that capital is a "normal" input in the sense that more be used as output expands. Somewhat stronger is the additional condition that the marginal rate of substitution decreases at a decreasing rate for fixed investment (i.e., $\partial^2(-F_k/F_\ell)/\partial\ell^2 < 0$), making L_k concave in q. In that case, production becomes more capital-intensive as the scale grows. It is common belief that traditional public utilities exhibit such capital-using, labor-saving properties.[7]

Notwithstanding these extra restrictions, the consequences for expected employment remain indeterminate. Using the fact that L is increasing and convex in q from (14) and (16), and the assumption that D is convex in p:

(21) $$EL(D(\tilde{p}),\tilde{k}) > L(ED(\tilde{p}),\tilde{k}) > L(D(\bar{p}),\tilde{k})$$

But it was shown that under the maintained assumptions $\tilde{k} > \bar{k}$, and so $L(D(\bar{p}),\tilde{k}) < L(D(\bar{p}),\bar{k})$ since L is decreasing in k by (15), thereby ruling out the possibility of an unambiguous comparison.

Proposition 4: **Under the additional demand and cost assumptions, price risk (i) increases investment, but (ii) has an indeterminate effect on expected employment.**

7 If, instead, L_k was decreasing but convex in q and D was concave in p, then price risk would reduce investment as in the case of rate-of-return risk. These conditions lead to unrealistic implications for capital usage, however.

While entry risk reverses the conclusions for investment obtained for rate-of-return risk, it has similar distributional effects. As usual, provided they are not rationed, consumers prefer price risk because consumer surplus is convex in price. It is possible to establish that price risk decreases expected profit in the special case where revenue is concave in price:

$$\text{(22)} \qquad E[R(\tilde{p}) - wL(D(\tilde{p}),\tilde{K}) - r\tilde{K}] \le R(\bar{p}) - wL(D(\bar{p}),\tilde{K}) - r\tilde{K}$$
$$\le R(\bar{p}) - wL(D(\bar{p}),\bar{k}) - r\bar{k}$$

where the first inequality follows from (21) and the second from the fact that $\bar{k}$ minimizes the cost of meeting demand when price is fixed at $\bar{p}$. Notice that the concavity of revenue does not contradict the convexity of demand since $d^2R/dp^2 = 2D' + pD'' < 0$ does not imply $D'' < 0$.

Proposition 5: Price risk (i) raises expected consumer surplus, and (ii) reduces expected profit when revenue is concave in price.

5. ENTRY RISK

Control of competitive entry is the final type of monopoly regulation examined. Despite the prevalence of its use, there is no standard formulation of entry restriction comparable to, say, rate-base regulation. In its stead, a dominant-firm model is proposed in which the regulator adjusts the size of the competitive fringe facing the firm.

Let $S(p)$ be the competitive supply curve of a single entrant; it is assumed to be increasing and concave. The regulator permits n such firms to enter the market leaving the dominant firm with residual demand: $Q(p,n) = D(p) - nS(p)$. Investment occurs before the extent of competitive entry is known. For simplicity, it is assumed that $\tilde{n}$ is a continuous-valued nonnegative random variable drawn from a distribution having mean $\bar{n} = E\tilde{n}$. Once again, labor is hired so as to meet demand given installed capacity k. For a fixed size of the fringe $\tilde{n}$, price is set at $\hat{p}(\tilde{n})$ so as to equate marginal revenue and cost:

$$p[1 - 1/\epsilon(p,n)] = wL_q(Q(p,n),k) \tag{23}$$

where $\epsilon(p,n)$ is the price elasticity of (residual) demand. Differentiate this condition with respect to n and rearrange to get:

$$\hat{p}' = -[2Q_p + (\hat{p}-wL_q)Q_{pp} - wL_{qq}Q_p^2]/[(1-wL_{qq}Q_p)Q_n + (\hat{p}-wL_q)Q_{pn}] \tag{24}$$

The numerator is nonpositive by the second-order condition; the denominator is negative since $L_{qq} > 0$, $Q_p < 0$, $Q_n = -S < 0$, $Q_{pn} = -S' < 0$ and $\hat{p} > wL_q$. Therefore, as expected, price falls with a rise in the number of entrants. It will also be assumed that $\hat{p}$ is concave in n. While this is a strong assumption, the results will often hold under weaker conditions. Characteristic of comparative statics under uncertainty, this assumption depends on the sign of third derivatives which are difficult to interpret.

The solution to the firm's problem (1) requires that $E\pi_k(k,\tilde{n}) = r$ at $\tilde{k}$ where $\pi(k,\tilde{n})$ is the regulated quasi-rent. Successive differentiation yields:

$$\pi_{knn} = -w[L_{qqk}(dQ/dn)^2 - L_{qk}\, d^2Q/dn^2] \tag{25}$$

where

$$d^2Q(\hat{p}(n),n)/dn^2 = Q_{pp}(\hat{p}')^2 + 2Q_{pn}\hat{p}' + Q_p\hat{p}'' + Q_{nn} > 0 \tag{26}$$

provided that $\hat{p}'' < 0$ since, in addition to the other properties of Q, $Q_{pp} = D'' - nS'' > 0$ and $Q_{nn} = 0$. Under the assumptions added in the last section (i.e., $L_{qk} < 0$, $L_{qqk} < 0$ and $D'' > 0$) plus the assumption that $\hat{p}$ is concave in n, π_k is convex in n. As a result,

(27) $$r = E\pi_k(\tilde{k},\tilde{n}) > \pi_k(\tilde{k},\bar{n})$$

Therefore, $\bar{k} \geq \tilde{k}$ since $\pi_{kk} = -wL_{kk} < 0$.

Now, since L is increasing and convex in q, and since Q(p(n),n) is assumed to be convex in n, it follows that:

(28) $$EL(Q(\hat{p}(\tilde{n}),\tilde{n}),\tilde{k}) > L(Q(\bar{p},\bar{n}),\tilde{k})$$

But when $\tilde{k} > \bar{k}$, $L(Q(\bar{p},\bar{n}),\tilde{k}) < L(Q(\bar{p},\bar{n}),\bar{k})$ since $L_k < 0$. Thus, specific knowledge of the demand function and the production function is required to determine the effect on expected employment.

Proposition 6: Under the additional assumptions, entry risk (i) raises investment, but (ii) has an indeterminate effect on expected employment.

Just as for the other two types of regulatory risk, expected profit falls. Unfortunately, very strong assumptions that have little economic content are needed to obtain this result. Nonetheless, these conditions are included for the sake of completeness:

Proposition 7: Entry risk (i) raises expected consumer surplus, and (ii) reduces expected profit when π is concave in n.

Proof: First of all, provided that $\hat{p}'' < 0$, $d^2V(\hat{p}(n))/dn^2 = V''(\hat{p}')^2 + V'\hat{p}'' > 0$ since $V' < 0$ and $V'' > 0$.

Now, by the fact that $\bar{k}$ is the maximizer, if π is concave in n, then:

$$E\pi(\tilde{k},\tilde{n}) - r\tilde{k} < \pi(\tilde{k},\bar{n}) - r\tilde{k} \tag{29}$$
$$< \pi(\bar{k},\bar{n}) - r\bar{k}$$

The concavity of π depends on the magnitudes of the various derivatives:

$$\pi_{nn} = (\hat{p} - wL_q)(Q_{pn}\hat{p}' + Q_{nn}) + \hat{p}'(1 - wL_{qq}Q_p) - L_{qq}Q_n \tag{30}$$

since the first term is positive and the remaining two are negative. ■

6. SUMMARY AND EXTENSIONS

The allocative and distributional effects of three popular polices toward monopoly have been evaluated when they are implemented in a stochastic fashion. The intuition that the firm will ration sunk investment in response to the uncertainty is verified for rate-base regulation but not for either price or entry control. In general, investors gain from the elimination of regulatory risk; consumers benefit from price and entry risk but only under additional restrictions on tastes and technology.

Several restrictions have been imposed on the model that, once relaxed, should open promising avenues for future research. To begin with, uncertainty of the regulatory constraint was treated as exogenous. One way to make it endogenous is to allow the firm itself to have some influence over the policy. This is not an unrealistic situation in the context of monopoly regulation given the intimacy of firm-regulator interaction. Bawa and Sibley (1981) have taken a step in this direction using a version of Klevorick's (1973) model of stochastic regulatory review. They make the probability of rate review increasing in the firm's excess profit in the previous period. Since the firm has discretion over the level of profits if it is not reviewed at that time, it gains some control over the probability that it will be reviewed in the future. Incidentally, the rate hearing may serve to reduce the firm's uncertainty as it learns more about the regulator's intentions. It is customary to view this institution solely as a means for the regulator to gather information about the firm.

It was also assumed throughout the analysis that the firm operated under a single regulatory constraint. In reality, a variety of agencies control a vast array of the firm's activities, each one subject to regulatory risk. Consider the choice among different investment projects of an electric power utility. State authorities not only set the level and structure of electricity rates but also monitor compliance with safety and emissions standards. Federal regulators become directly involved if electricity is produced for interstate transmission or if nuclear generation is the chosen technology. Furthermore, the size, the location, and the generating technology of a powerplant are critical to the approval of a construction permit. In fact, a utility will typically own plants of various types in several states, and sell electricity within and across state lines, and very often distribute natural gas as well. Presumably, after assessing the regulatory risk associated with each project (in addition to other sources of uncertainty), the firm selects a portfolio of projects based on their profitability relative to capital market opportunities. In this way, project selection reveals the implicit risks that utilities attach to different regulatory agencies which could be used to produce a risk-return ranking of their policies.

Finally, the discussion has been narrowly confined to direct regulation of market power to the exclusion of the many other forms of government intervention. The results call for a re-consideration of the standard implications of any policy whose final form is not known before an irreversible investment must be undertaken. Fiscal programs represent a case in point which undoubtably have far-reaching consequences. Each stage in the design and implementation of virtually every tax plan is replete with uncertainty. An analysis of tax risk should produce some important results for personal savings and business investment. To my knowledge, Ekern's (1971) investigation of the portfolio effects of uncertain capital gains taxation is the only study of this sort. Clearly, more needs to be done.

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