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Rate of Return Regulation

Presiding: RICHARD S. BOWER†

Asymmetry of Information, Regulatory Lags and Optimal Incentive Contracts: Theory and Evidence

by
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and
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I. Introduction

The problems of cost overruns in both nuclear and non-nuclear power plant procurements have been well documented (see [5] [19]). For example, when the Shoreham 1 nuclear plant comes fully on line on Long Island it will have cost at least five times the amount first estimated [5]. This type of cost overrun causes acute problems for utilities since their ability to pass on costs to the consumer are subject to both a regulatory review and rate adjustment time-lag. The incentive effects of regulatory lag are well known. Specifically, by increasing the length of the lag regulators can create incentives for utilities to reduce their production costs (see Baumol [3] and Baumol and Klevorick [4]). In this paper we assume that regulatory lag is present, so that utilities have an incentive for cost efficiency, and concentrate on one very important area of cost control, namely, utility plant and equipment procurement. It is shown that cost efficiency can be directly related to the types of contract used by the utility in its procurements.

The procurement process and the equilibrium bidding behavior is modelled in sections II and III and the effect of contract parameters and other structural variables on expected procurement costs are explicitly derived. The existing models are enriched by incorporating a technology for cost reduction where the investment in cost reduction made by the contractor is unobservable to the utility. In the presence of such informational asymmetry, the optimal incentive parameter to be used is derived in terms of information available to the utility. In section IV the effects of changing contractual parameters and other structural variables (number of contractors bidding, the riskiness of the production process, etc.) on equilibrium bidding behavior and ex post cost reduction incentives are derived. In section V we relate some of the implications of our model to a sample

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of contracts used by New York State utilities in their plant and equipment procurements. In section VI we conclude with a discussion of the model's policy implications.

II. The General Model

It is assumed that utility procurements take place through competitive sealed bid auctions with the contract being awarded to the lowest bidder.[1,2] In general, competitive bidding requires that the contract specify the monetary reward to the winning bidder as a function of the bid price, fee and realized production costs of the project. Clearly the terms of the contract can directly affect the strategic relationship between a contractor's (bidder's) bid price, his estimates of production costs and his cost-reducing efforts. To capture these inter-relationships a game-theoretic approach is used in which all contractors for a given procurement are assumed to follow a Nash equilibrium bidding strategy (see Vickrey [26], Holt [12] [13] and Riley and Samuelson [21]). Hence the effects of contractual incentives on a contractor's bidding strategy is endogenized by requiring his expectations to satisfy an equilibrium or rationality condition. It is also assumed that there is *asymmetry of information* between the utility and the winning contractor.[3] In particular, the cost-reducing efforts of contractors are assumed to be unobservable to the utility so that production costs can only be controlled through the use of incentive features in the contract. The effect of such incentives on the equilibrium bid behavior is derived endogenously in our model. This makes it possible to compute the optimal contractual incentive parameters to be used by the utility in its procurement practices.

The contract is assumed to be linear in bids and actual costs.[4] Under this form of contract the winning contractor's revenue is given by:

$$\alpha b + \beta(b - c) + c \tag{1}$$

where b is the contractor's bid price, c is the realized cost, $0 \leqslant \alpha \leqslant 1$ and $0 \leqslant \beta \leqslant 1$ are contract parameters. Equation (1) includes both fixed-price and cost-plus contracts as special cases. A cost-plus contract results when $\beta = 0$ and the contractor receives the realized production cost (c) plus a fixed fee (αb). When $\alpha = 0$ and $\beta = 1$ a fixed price contract results, and the winning contractor's profit equals the difference between the bid price and the production cost. Hence, β, the sharing rate, specifies the portion of any *cost overrun* (i.e. $b - c$) borne by the contractor.[5]

[1] The majority of the contracts on file at the New York State Public Service Commission were the result of some type of competitive auction process.

[2] The circumstances under which a negotiated contract might be preferred to competitive bidding will be identified from the model developed below.

[3] An extensive literature on principal-agent problems based on informational asymmetries already exists (see Ross [20], Holmstrom [11], Harris and Raviv [10] and John and Majthay [16].

[4] This is the form most commonly found in private and public sector procurements (see [25]).

[5] The cost-reimbursable contract, e.g. labor hours, time and materials is also a "cost-plus type." In this case unit prices are usually pre-specified and contractor profit is directly proportional to total cost outcomes (see [25]). An alternative type of linear incentive contract is to make the contractor's fee proportional to $(b - c)$. This results in similar (albeit less strong) cost control incentives related to those implied by the contract specified in the text (see [25]).

It is assumed that there are m bidders for a particular procurement contract. Consider the bidding decision of a specific contractor where project production costs (c) are assumed to be random and represented by:

$$c = \bar{c} - f(I) + \tilde{\epsilon} \tag{2}$$

such that $\bar{c}$ is the expected value of production cost, $f(I)$ is the value of any internal cost reduction achieved by the contractor and $\tilde{\epsilon}$ is a normally distributed random variable with mean zero and variance σ^2. Specifically, $f(I)$ defines the extent of cost reduction achieved when the contractor invests I resources in cost-reducing activities (it is assumed that $f' \geq 0$ and $f'' < 0$). Since I is assumed to be unobserved by the utility, the procurement contract cannot be specified conditionally on values of I. Instead, the utility can use β, the sharing rate, to provide incentives for the contractor to undertake cost-reducing activities.

If the contractor fails to win in the bidding contest, he is assumed to invest his resources in an alternative investment opportunity, the profits from which are denoted by $\tilde{a}$, a normally distributed random variable with mean $\bar{a}$ and variance δ^2.

Consistent with previous literature in this area (e.g. McCall [18], Baron [2], Holt [12] [13], Gandhi and Saunders [8]) the contractor can be assumed to maximize the expectation of a concave utility function, $U(\tilde{w})$. Such an assumption may be appropriate if the shares of the contracting firm(s) are non-traded or are traded in an incomplete market without spanning. In this case firm value maximization is not the proper objective function for the contracting firm and managers may use some preference function judged to 'represent' shareholders' preferences (see Baron [1]). Such behavior by managers may also be consistent with agency theoretic views of the firm where less than perfect observability and enforceability of managerial decisions (and actions) can result in derived managerial objectives which are not in direct conformity with shareholder wealth-maximization (see Jensen and Meckling [14], John and Kalay [15], John and Williams [17]).

For analytical tractability it is assumed that:

$$U(\tilde{w}) = e^{-h\tilde{w}} \tag{3}$$

where h is the coefficient of absolute risk-aversion.[6] As has been noted by Hammond [9] the negative exponential provides a convenient and tractable framework within which to analyze risk-sharing problems. As is well known when $\tilde{w}$ is normally distributed, maximizing the expectation of (3) is the equivalent of maximizing:[7]

$$E(\tilde{w}) - \tfrac{1}{2}h \operatorname{Var}(\tilde{w}) \tag{4}$$

Now the ith contractor is assumed to know the distribution of profits from the alternative use of its resources ($\tilde{a}_i$) at the time he submits his bid b_i. Hence in

[6] There is some evidence of risk-averse behavior by contractors in a procurement context. On the bases of case studies Scherer [23] reports a prevalent concern that short-run contract losses might be interpreted as managerial failure requiring reorganization of the firm.

[7] Without evoking the above arguments, we could have just as well assumed that the firm will use (4) as a valuation rule for valuing its random prospects $\tilde{\pi}$ from its production under the contract or the profits $\tilde{a}$ from alternate investments.

the event the contractor fails to win the contract his objective value will be $\bar{a}_i - \frac{h}{2}\,\delta_i^2$. If ϕ_i is the probability of winning the contract the contractor's objective function can be written as:[8]

$$\phi_i\left(\bar{\pi}_i - \frac{h}{2}\sigma^2\right) + (1 - \phi_i)\left(\bar{a}_i - \frac{h}{2}\delta_i^2\right) \tag{5}$$

where $\bar{\pi}_i$ is the expected profit from winning the contract and, from (1) and (2), is equal to:

$$\bar{\pi}_i = (\alpha + \beta)b_i - \beta\bar{c} + \beta f(I) - I \tag{6}$$

Note that for any bid, b_i, by the contractor, once the contract is awarded the optimal level of cost-reducing investment (I) is given by the level of I which maximizes $\bar{\pi}_i - \frac{h}{2}\sigma^2$, i.e.,

$$f'(I) = \frac{1}{\beta} \tag{7}$$

Thus the amount of cost reducing investment made by the contractor will be a function of the cost-sharing parameter β. Given $f'' < 0$ it is easy to see that $I(\beta)$ is monotonically increasing in β, $0 < \beta \leq 1$. Incorporating this dependence of I on β we can rewrite $\bar{\pi}_i$ as

$$\bar{\pi}_i = (\alpha + \beta)b_i - \beta\bar{c} + \beta f(I(\beta)) - I(\beta) \tag{8}$$

In order to determine the effects of changes in structural variables on bidding behavior we need to derive the contractor's equilibrium bidding function. To make this derivation manageable it is assumed that all bidders have similar preferences as given by (4), similar technologies for cost reduction f, and common values for $\bar{c}$ and σ^2. Thus for all contractors, $i = 1, \cdots, m$, expected utility can be specified in terms of $\bar{\pi}_i$, ϕ_i, $\bar{a}_i$ and δ_i^2. That is, contractors differ only in their alternative investment opportunities ($\bar{a}_i$, δ_i^2) and therefore in their bids, b_i, and probabilities of winning, $\phi_i(b_i)$.

In the next section an equilibrium bidding strategy is derived which explicitly specifies a relationship between the bid price, b_i, and contractor-specific parameters $\bar{a}_i$ and δ_i^2. These relationships will be considered one at a time. If $\theta = (\bar{a}_i$ or $\delta_i)$ is the parameter under reference its values are assumed to be independent realizations of a continuous random variable with a probability density function $g(\theta)$ and probability distribution $G(\theta)$, respectively ($g(\theta)$ is assumed to be strictly positive for $\theta \epsilon [\underline{\theta}, \bar{\theta})$. Each contractor is assumed to know the realization of θ_i for himself and the distributions g_i, G_i which rule his rival's alternative investment opportunities.

III. Bidding Functions

The equilibrium bidding strategy for all contractors can be derived as the

[8] Note that $\phi_i(b_i)$ is a function of the bid submitted and will be endogenously derived as a part of the equilibrium bidding strategy.

common Nash strategy in a bidding competition modelled as a noncooperating game. The common Nash strategy will have the property that it maximizes the expected utility of each bidder when all rivals are known to be using the same strategy. If all contractors use the Nash strategy, each contractor's subjective probability distribution corresponds to the distribution of rival bids prior to the drawing of the profit alternative parameter θ.[9]

First assume that $\delta_i^2 = \delta^2$ for all firms $i = 1, \cdots, m$, and that $\bar{a}_i$ are independent realizations of a random variable uniformly distributed over $[\underline{\theta}, \bar{\theta}]$. Then the equilibrium bidding strategy can be derived as:

$$b(\bar{a}) = \frac{\beta\bar{c} + I(\beta) - \beta f(I(\beta)) + \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} + \dfrac{\bar{\theta} - \bar{a}}{m}}{(\alpha + \beta)} \tag{9}$$

This equation can be given a ready interpretation. The bid $b(\bar{a})$ is set such that the certainty equivalent of the profit from the contract is equal to the certainty equivalent of alternate investment profits plus a premium for bidding risk. Rearranging (9) we have:

$$(\alpha + \beta)b(\bar{a}) - \beta\bar{c} - I(\beta) + \beta f(I(\beta)) - \frac{h}{2}\beta^2\sigma^2 = \bar{a} - \frac{h}{2}\delta^2 + \frac{\bar{\theta} - \bar{a}}{m} \tag{10}$$

Detailed analysis of equations (9) and (10), and some of the comparative statics implications, are postponed until the next section.

Next, assume that $\bar{a}_i = \bar{a}$ for all m firms but that the standard deviations δ_i are independent realizations of a random variable uniformly distributed over $[\underline{\theta}, \bar{\theta}]$. In this case the equilibrium bidding strategy is:

$$b(\delta) = \frac{\beta\bar{c} + I(\beta) - \beta f(I(\beta)) - \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} - \dfrac{h(\bar{\theta} - \delta)}{m + 1}\left(\delta + \dfrac{\bar{\theta}}{m}\right)}{(\alpha + \beta)} \tag{11}$$

Equation (11) can be given a similar interpretation as (10). Note that the bidding premium, $\dfrac{-h(\bar{\theta} - \delta)}{(m + 1)}\left(\delta + \dfrac{\bar{\theta}}{m}\right)$, reduces to zero as $\delta \to \bar{\theta}$ or $m \to \infty$, and that bids are monotonically decreasing in the riskiness of the alternative investment opportunities.

IV. Optimal Contract Parameters

Equations (9) and (11) specify explicit forms of bidding behavior for all potential bidders. Using (9) and (11) we can examine the equilibrium effect of structural variables (e.g., σ^2, $\bar{a}$, δ, m) and contractual parameters, α and β, on contractor bid behavior. Consider (9) which is the equilibrium bidding function derived under the assumption that a_i, mean alternate investment profits, differ across firms. The optimal bid b for a firm with mean profit $\bar{a}$ is given by:

[9] The details of the derivation are available from the authors upon request. Our approach is similar to that in Holt [12, 13] and Riley and Samuelson [21].

$$b(\bar{a}) = \frac{\beta\bar{c} + I(\beta) - \beta f(I(\beta)) + \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} + \frac{\bar{\theta} - \bar{a}}{m}}{(\alpha + \beta)} \tag{9}$$

We first consider the case where there are no opportunities available to the contracting firm to invest (I) in cost reducing activities.

(i) No Cost Reduction Opportunities

By setting $f(I) \equiv 0$ in (9) we obtain:

$$b(\bar{a}) = \frac{\beta\bar{c} + \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} + \frac{\bar{\theta} - \bar{a}}{m}}{(\alpha + \beta)} \tag{12}$$

It is easy to see from (12) that bids are monotonic in $\bar{a}$. The expected profit from the bid $(\alpha + \beta)b(\bar{a}) - \beta\bar{c}$ is set such that over and above $\bar{a}$ the expected profit from the alternative investment, two kinds of premiums are demanded. The first term $\frac{h}{2}(\beta^2\sigma^2 - \delta^2)$ is a risk premium required by the contractor to take this project rather than the alternative project. Clearly if $\beta\sigma = \delta$ this risk premium will be zero. The second term $\frac{\bar{\theta} - \bar{a}}{m}$ can be considered a premium for the bidding risk involved.

It will be useful to characterize the expected procurement cost, E, in terms of the winning bid, $b(\bar{a})$.

$$E = (\alpha + \beta)b(\bar{a}) - \beta\bar{c} + \bar{c} = \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} + \frac{\bar{\theta} + \bar{a}}{m} + \bar{c} \tag{13}$$

It is clear from (12) and (13) that the equilibrium bids, $b(\bar{a})$, and expected procurement costs are increasing functions of the project's production cost risk, σ^2.[10] Moreover, the effect of changing the contract parameters, α and β, on the equilibrium bidding behavior can also be studied using (12) and (13). Specifically

$$\frac{\partial b(\bar{a})}{\partial \alpha} = \frac{-b(\bar{a})}{(\alpha + \beta)} \tag{14}$$

is negative. Hence an increase in α will decrease the equilibrium bid $b(\bar{a})$. But, examining (13) it is also clear that expected procurement cost is independent of α. Thus the increased probability of cost overruns, due to reduced bids, does not result in higher expected procurement costs to the utility.

Looking next at the cost incentive parameter, β, it is clear that expected procurement costs are monotonically increasing in β. The relationship between the bid price $b(\bar{a})$ and β is derived in (15):

[10] In this setting the entire effects of increasing risk is captured by increasing σ^2 (see Rothschild and Stiglitz [22]).

$$\frac{\partial b(\bar{a})}{\partial \beta} = \frac{(\alpha + \beta)[\bar{c} + h\beta\sigma^2] - (\alpha + \beta)b(\bar{a})}{(\alpha + \beta)^2} \tag{15}$$

which is positive when $\bar{c} + h\beta\sigma^2 > b(\bar{a})$. Consequently, the behavior of bids with respect to increases in β is ambiguous even when cost reducing technology is absent, that is, bids which are smaller (larger) than $\bar{c} + \beta h\sigma^2$ will increase (decrease) with β.[11] These results can be collected as a proposition.

Proposition 1: Equilibrium contract bids are increasing in production cost risk (σ^2) and decreasing in α. Expected procurement costs are increasing in both σ^2 and β and are independent of α.

The above analysis has interesting implications, both normative and positive. Since expected procurement costs are monotonically increasing in $\beta^2\sigma^2$ (when $f \equiv 0$), a risk-neutral utility minimizes its expected procurement costs by setting $\beta = 0$, i.e., by using a cost-plus contract. This is a well known result in optimal risk-sharing which will be qualified when cost-reducing opportunities for the contractor are introduced in Section IV (ii).[12] High variance in production costs (σ^2) is most likely in initial production of tailor made projects in new and/or developing (high technology) areas such as large hydro or nuclear power projects (see Cross [6]). For example, it seems reasonable to assume that nuclear power projects have much greater production cost risks (risk of cost overruns) than conventional coal fired plants. Furthermore, the technology for contractor cost reducing investment might be viewed as less effective or even non-existent in these areas (i.e. $f(I) \approx 0$). Consequently, when σ^2 is large and $f(I)$ is small, expected costs of procurement tend to be minimized with low values for β, i.e., contracts approximating the cost-plus type may be optimal. Furthermore, if over time, with increased experience from repeated procurements and availability of additional information, σ^2 should decrease and effective cost reducing technologies evolve, then a transition might be observed from low β(cost-plus type) contracts to high β(incentive type) contracts.

It is also possible to examine the effects of increasing the number of bidders (m) on the bid price $b(\bar{a})$. By examining (12) it is clear that the last term (bidding risk premium) is decreasing in m. Hence increasing the number of competing contractors (m) decreases the equilibrium bid price $b(\bar{a})$. In the limit, as $m \rightarrow \infty$ this term disappears altogether and the equilibrium bid is such that the certainty equivalent of the contract profit equals the certainty equivalent of the profits from alternative investments. Similarly, equilibrium bids $b(\bar{a})$ are increasing in $\bar{\theta} - \underline{\theta}$, the dispersion of contractor types with respect to mean profits from alternate investments. The range $\bar{\theta} - \underline{\theta}$ of the distribution of $g(\cdot)$ could be viewed as a proxy for the utility's uncertainty regarding the exact characteristics of the bidding firms. These conclusions can be stated as a proposition.

Proposition 2: The equilibrium bids and expected procurement costs are decreasing in the number of bidding firms (m) and increasing in the range of firm type ($\bar{\theta} - \underline{\theta}$).

[11] This contrasts with Holt [13] who, based on an intuitive argument, suggested that this relationship is always positive when cost reducing technology is absent.

[12] See, for example, Cummins [7] and Holt [13].

These last results have some other interesting implications. In a bidding environment where the number of prospective bidders are very small and the contractor's alternative profit opportunities are widely dispersed, the bidding premium term $\frac{\bar{\theta} - \bar{a}}{m}$, and hence $b(\bar{a})$, could be very large. In such an environment a negotiated contract may be an optimal strategy for the utility. In fact for initial procurement of new types of plant and equipment the utility is likely to be highly uncertain regarding the relative efficiency of prospective contractors (i.e. $\bar{\theta} - \underline{\theta}$ will be large), given a small m as well, this could result in an extremely large premium being impounded in a bid price $b(\bar{a})$. Of course as m increases and $\bar{\theta} - \underline{\theta}$ narrows competitive bidding will eventually come to dominate a negotiated procurement.

(ii) The Effects of a Cost Reduction Technology

Consider the general model specified in Section II where a cost reducing technology is assumed to exist for the contractor. By making an investment I in cost reducing effort the contractor's expected costs of production can be reduced by $f(I)$. In this case the contractor's bid price $b(\bar{a})$ is given by equation (9), i.e.,

$$b(\bar{a}) = \frac{\beta\bar{c} + I(\beta) - \beta f(I(\beta)) + \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} + \frac{\bar{\theta} - \bar{a}}{m}}{(\alpha + \beta)}$$

where

$$I(\beta) \text{ solves } f'(I(\beta)) = \frac{1}{\beta} \tag{16}$$

Since $f' \geq 0$ and $f'' < 0$, it is clear that $I(\beta)$, and therefore $f(I(\beta))$ (the cost-reduction) is increasing in β. Thus changing the contract parameter β will also affect $b(\bar{a})$ *via* the cost-reducing investment function. We denote by $\partial b(\bar{a})/\partial\beta_f$ the value of the partial derivative in the presence of cost reducing opportunities to the contractor. Differentiating (9) and collecting terms, and using (16), we have

$$\frac{\partial b(\bar{a})}{\partial\beta_f} = \frac{\partial b(\bar{a})}{\partial\beta} - \frac{\alpha f + I}{(\alpha + \beta)^2} \tag{17}$$

where $\frac{\partial b(\bar{a})}{\partial\beta}$ is given by (15).

Directly comparing the no-cost and cost reducing technology cases we find the response of $b(\bar{a})$ to an increase in β has decreased by $(\alpha f + I)/(\alpha + \beta)^2$.

It is also of interest to examine the effects of increasing β on expected procurement costs when cost-reducing technology is present. In this case expected procurement cost (E) is given by:

$$E = \bar{c} - f(I(\beta)) + I(\beta) + \frac{h}{2}(\beta^2\sigma^2 - \delta^2) + \bar{a} + \frac{\bar{\theta} - \bar{a}}{m} \tag{18}$$

Clearly E is not only influenced by β through the risk premium term $\frac{h}{2}\beta^2\sigma^2$ but also through the cost reduction term $f(I(\beta)) - I(\beta)$. The optimal β is given by $\partial E/\partial\beta = 0$, i.e. β which solves $-f'(I(\beta))I'(\beta) + I'(\beta) + \frac{h}{2}(2\beta)\sigma^2 = 0$. Simplifying,

$$I'(\beta)[1 - f'(I(\beta))] + h\sigma^2\beta = 0 \tag{19}$$

From (19) it is clear that $I'(\beta) > 0$ and $f'(I(\beta)) > 1$. Therefore the first term in (19) is negative indicating the cost reducing investment incentives provided by β; the second term is positive indicating the effect due to the cost risk premium. Thus, for a given cost reduction technology f and parameters h and σ^2, the optimal contractual sharing rate β^* can be computed by the utility (note that this is independent of the contractor specific parameters $\bar{a}_i$ and $\bar{\delta}_i$). Formulating these results as a proposition we have:

Proposition 3: The optimal sharing rate, β^*, from a risk-neutral (cost minimizing) utility's point of view, is given by (19).

Two immediate corollaries follow:

Corollary 1: If contractors use a risk neutral valuation rule, i.e. $h = 0$, or if the variance of production costs are zero ($\sigma^2 = 0$) then a fixed price contract is optimal.

Proof: Since $h\sigma^2\beta = 0$ in (19) the optimal β satisfies $1 - f'(I(\beta)) = 0$, which is true when $\beta = 1$ i.e., the contract is fixed-price.

Corollary 2: If cost reduction technology is ineffective or absent then a (risk-neutral) utility will always find it optimal to use a cost-plus contract.

Proof: Again, since the first term in (19) is zero, the equation is satisfied when $\beta = 0$.

It is useful to study an illustrative example where the technology for cost reduction is given as $f(I) = k\sqrt{I}$ and k is a positive constant.

Illustrative Example:

It is specified that $f(I) = k\sqrt{I}$ and $I(\beta)$ is given by (16), that is:

$$f'(I(\beta)) = \frac{k}{2\sqrt{I(\beta)}} = \frac{1}{\beta}; \quad \text{i.e.,} \quad I(\beta) = \frac{k^2\beta^2}{4} \tag{20}$$

Substituting into equation (19) we find $\frac{k^2\beta}{2}\left[1 - \frac{1}{\beta}\right] + h\sigma^2\beta = 0$, such that

$$\beta^* = \frac{k^2}{k^2 + 2h\sigma^2} \tag{21}$$

The optimal value of the sharing rate, β^*, can be specified in terms of k (the characteristics of the cost-reducing technology), h, the contractor's risk aversion parameter and σ^2, the variance of the production costs of the procurement project. Note that as $\sigma^2 \to 0$ then $\beta^* \to 1$ (the fixed-price contract) and as $\sigma^2 \to \infty$ then $\beta^* \to 0$ (the cost plus contract). Hence if a certain type of plant or equipment has, initially, a very high σ^2, e.g. nuclear power projects, and this cost-variance reduces with experimentation and replication over time, equation (21) suggests that incentive type contracts (high β^*) will eventually replace cost-plus contracts (low β^*) as the optimal contractual form for the procurement. Similary, as the effectiveness of a cost-reducing technology increases from zero (low) levels to high levels, i.e., as k goes from 0 to $\bar{k}$ (say), low β^*(cost plus type) contracts will be replaced by high β^*(incentive type) contracts.[13]

V. Some Empirical Evidence

The model developed in sections II–IV implied that for any given regulatory lag and degree of bidding competition incentive procurement contracts are most likely to be used for projects with low σ^2 (see propositions 1 and 3). Given this prediction it is of interest to examine the *actual* types of contracts used by a sample of public utilities and how their incentive (non-incentive) nature has changed over time.

As might be expected obtaining such information is difficult given the confidentiality surrounding such contracts. Fortunately, however, New York State Public Service laws require all electric, gas and steam utilities with gross operating revenues in excess of $5M to file with the Public Service Commission a copy of each cost-plus type contract over $100,000 and, each quarter, a copy of every fixed price type contract over $1 million that the utility has made with a contractor for the purpose of improvement, extension or maintenance of utility plants. These contracts are reviewed and commented on by the staff of the Public Service Commission who can make recommendations as to their acceptability. However, these recommendations are not binding on the Commission in its rate proceedings.

The gas and electric utilities that have filed contracts in New York State are Brooklyn Union Gas, Central Hudson Gas and Electric, Consolidated Edison, Long Island Lighting Co., New York State Electric and Gas Corp., Niagara Mohawk Power Corp., Orange and Rockland Utilities and Rochester Gas and Electric. The contracts made by these utilities with outside contractors for the period 1976–81 and filed with the Commission were reviewed and classified into six types: fixed price, fixed-price incentive, cost-plus incentive fee, fixed price redetermination (automatic adjustment), cost-plus fixed fee and cost-reimbursable. The first three types of contracts specified above may be viewed as basically "incentive" type contracts while the latter three are basically "non-incentive" types.

The time series behavior of each of the six types of contract for reporting New York State Electric and Gas Utilities are shown in Table I, where information on both the number of contracts and aggregate value of the contracts is shown. Information on the frequency of incentive versus non-incentive type contracts can be summarized by adding rows 1 through 3 and categorizing them as incentive

[13] In section IV we have analyzed the case where the bidding function takes the form of $b(\bar{a})$, i.e., equation (9). Due to space limitations it was not possible to consider the case when $b(\delta)$ is the appropriate bidding function (equation (11)).

Table I

Types of Contract Reported by New York State Electric and Gas Utilities 1976–81

Type of Contract	1976 No. of Contracts	1976 % of all Contracts	1976 Aggregate Value ($M)	1977 No. of Contracts	1977 % of all Contracts	1977 Aggregate Value ($M)	1978 No. of Contracts	1978 % of all Contracts	1978 Aggregate Value ($M)	1979 No. of Contracts	1979 % of all Contracts	1979 Aggregate Value ($M)	1980 No. of Contracts	1980 % of all Contracts	1980 Aggregate Value ($M)	1981 No. of Contracts	1981 % of all Contracts	1981 Aggregate Value ($M)
Incentive Type																		
1.Fixed price	13	41.9	32.953	14	36.8	76.789	17	48.6	50.8	31	72.1	61.88	26	56.6	102.719	41	60.3	194.56
2.Fixed price incentive	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3.Cost plus incentive fee	–	–	–	3	7.9	376.017	1	2.9	.417	–	–	–	2	4.3	1.375	4	5.9	499.08
Non-Incentive Type																		
4.Fixed price re-determination	3	9.7	3.179	4	10.5	11.92	12	34.2	169.75	–	–	–	1	2.2	6.139	–	–	–
5.Cost plus fixed fee	7	22.6	139.38	2	5.3	1.536	1	2.9	.656	3	7.0	12.078	2	4.3	1.422	4	5.9	28.17
6.Cost reimbursable[a]	8	25.8	6.435	15	39.5	32.953	4	11.4	4.046	9	20.9	7.288	15	32.6	12.746	19	27.9	67.158
Total	31	100	181.947	38	100	499.215	35	100	255.669	43	100	81.046	46	100	124.401	68	100	788.98

[a] Includes Time and Materials and Labor Hour Contracts.

type contracts and adding rows 4 through 6 and categorizing them as non-incentive types.

When such aggregation is undertaken a clear trend emerges toward greater use of incentive contracts over time. For example, in 1976 41.9% of these contracts can be classified as incentive and 58.1% non-incentive, compared to 66.2% incentive and 33.8% non-incentive in 1981. The major changes underlying these trends appears to be a shift away from cost reimbursable contracts (type 6) in favor of firm fixed price contracts (type 1). Moreover, since 1979 there appears to have been considerable reluctance on the part of utilities to use escalator or readjustment clauses in fixed price contracts possibly because of adverse cost experience with such contracts in earlier years. Where partial incentives have been built into contracts incentive fees have been used rather than the more straightforward cost-sharing found under the fixed price incentive contract. In practice most of the cost-plus incentive fee contracts have been agreed with Architect-Engineers for construction and management services at nuclear and hydro-electricity plants and usually related to target work hours or labor costs.

An interesting approach to analyze trends in utility contractual arrangements is to divide the sample into nuclear and non-nuclear related procurements. In particular, it might be argued that because of the uniqueness and specialized nature of many of the projects related to nuclear plant construction and maintenance many of the problems of production cost risk (σ^2) are particularly acute. Under such circumstances we might expect contractors to be extremely reluctant to take on contracts of the fixed price type for nuclear power related procurements,[14] unless (i) through experimentation and replication contractors find that the σ^2 for the whole project diminishes, or (ii) utilities through experience and information sharing are able to break nuclear project procurements into smaller parts *for procurement purposes*, thereby giving each individual procurement much greater project (and therefore cost) definition.

In Table II above, the sample of reported contracts has been divided into nuclear and non-nuclear power related procurements and then into incentive types (1 through 3) and non-incentive types (4 through 6). As can be seen incentive type contracts are more frequently used in non-nuclear procurements. Indeed the proportion of incentive contracts in the non-nuclear area appears to have been growing (52% of all contracts in 1976 to 73.1% in 1981). As implied by our model, in the nuclear power procurement field (high σ^2) non-incentive cost-plus type contracts tend to predominate. Nevertheless even in this area some trend appears to be emerging towards greater use of contractual incentives. For example in 1976 only 14.3% of contracts were of the incentive type, in 1981 this had increased to 40%. In a recent report TBA [24], using survey data, suggested three possible reasons for these contractual trends. The first was a movement toward internal reorganization by utilities to provide better information and monitoring of project costs. The second was the increasing tendency of utilities to break large nuclear projects into smaller procurements so that likely cost outcomes could be more easily estimated. Third, some learning by experience appeared to occur as utilities and contractors became more familiar with the

[14] As implied by very high equilibrium values of bid prices ($b(\bar{a})$).

Table II

Percent of Incentive and Non-Incentive Contracts in Nuclear and Non-Nuclear Power Activities New York State Power Utilities 1976–81.

	1976	1977	1978	1979	1980	1981
Nuclear Power Related						
Incentive	14.3	29.4	37.5	35.7	50.0	40.0
Non-Incentive	85.7	70.6	62.5	64.3	50.0	60.0
Non-Nuclear Power Related						
Incentive	52.0	58.3	58.8	90.0	78.6	73.1
Non-Incentive	48.0	41.7	41.2	10.0	21.4	26.9

specialized technical nature of many nuclear procurements. All these reasons are directly related to control over the size of σ^2, and the effectiveness of cost reducing technology and are consistent with Propositions 1 and 3.

VI. Conclusion

The results of the model and the contractual trends identified above have some interesting policy implications. First, they suggest that the length of the regulatory lag can be used by rate commissions to induce utilities to make more effort to reduce costs and therefore become more cost efficient by using optimal contracts for each type of procurement.[15] Second, to the extent that utilities or regulatory commissions disseminate cost information regarding specialized procurements (especially in nuclear related activities), asymmetries of cost information existing between utilities and contractors will diminish over time allowing utilities to exercise far better cost control through fixed price and other incentive type contracts, to the long run benefit of the consumer. Thirdly, as more contractors with specialized technology enter the nuclear power procurement industry, bidding will be more competitive and fixed price and incentive contracts will become more optimal. Hence utilities should encourage as wide and extensive a bidding arrangement as possible.

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[15] This does not imply that regulatory lag is the optimal method of generating incentives. In particular, an "incentive rate of return" as used on the Alaskan pipeline may be superior for utility cost control.

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