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THE U.S. VERSUS THE SOVIET INCENTIVE MODELS.(U)

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THE U.S. VERSUS THE SOVIET INCENTIVE MODELS

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The report is concerned with models of the use of performance incentives in the Soviet Union and United States. The principal analytical result is an extension of an analysis of the methods whereby Soviet planners make the decision about production targets a variable under control of the producer, who is the only one possessing a knowledge of the uncertain conditions of production. It is shown that this device can be viewed as a classical inventory problem. There is also an examination of the "U.S. incentive program" referring to multi-incentive contracts in which the profits received by the private producers are related to

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performance, outcome and cost. The analysis describes how this device can be extended to solve the target output selection problem of the Soviet planning system.

Introduction

The central planning organizations of both the Soviet Union and the United States have been concerned with influencing the behavior of enterprises in order to achieve improved allocation of resources. Although one is more likely to associate the central planning task with an economy such as the Soviet Union, the provision of many goods is centrally planned in the United States. For example, the Planning-Programming-Budgeting System of the United States government can be viewed as part of a central planning process. In the analysis I compare the incentive systems of the Soviet Union and the United States, thereby clarifying the similarities that exist between the two economic systems. A suggestion for improvement to the U.S. incentive system is also made.

The key similarity between planning in the Soviet Union and the United States is that the government does not know as much about individual values and technological opportunities as do the relevant producers or consumers. For example, in the United States, the Planning-Programming-Budgeting System frequently culminates in government acquisition of goods such as military hardware and space systems from private enterprises. The production technologies associated with many of these goods are not only highly uncertain, but are also more accurately known by the producers than by the government. Such goods as intercontinental ballistic missiles and manned space vehicles have embodied in them advanced technology and associated uncertainty about the conditions of production. This uncertainty is probably most pervasive during the engineering development phase of the "production" process when the performance characteristics of these goods are determined. The producers of these goods, however, will typically have a greater knowledge of this advanced technology and its impact on the conditions of production than does the government. Thus, the conditions of production are more uncertain for the government than for the producer at that time. The uneven impact of uncertainty implies that it is not possible for the government to specify the best output level.

A similar situation exists in the Soviet Union. The state enterprise may have better knowledge of its production technology than the planners, and the Soviet planners, therefore, may be unable to specify the optimal output level. Yet both the U.S. and Soviet decision makers attempt to provide appropriate incentives to motivate producers to select the "right" output level.

In the United States this system employs the so-called "contractual incentive function" which specifies a mutually acceptable rule connecting the monetary rewards of one decision maker to the subsequent performance of another. Numerous enterprises have devised profit-sharing formulae to motivate supervisory and managerial personnel, and the Department of Defense and NASA have relied on the use of performance incentives to monitor the work of major contractors. For example, performance incentives were included in contracts with a total value of several billion dollars during the U.S. moon program.[1] Recent innovations in the use of performance incentives have appeared in the new Amtrak contract which provides payments to the railroads according to the quality of services they provide (2:281-299). A similar contractual arrangement guarantees a one percent increase in the salaries of the policemen of Orange, California for every three percent decline in rape, robbery, burglary and auto theft (6:16).

Although the existing literature on economic planning does not specifically mention the use of contractual incentive functions, a related concept has arisen in discussions of "success indicators" in Soviet planning. The Soviet planning system often rewards enterprise agents according to the degree to which producers reach certain planned targets.[2] Thus, Soviet planners have implicitly defined a performance incentive system. In contrast to similar systems employed in the West, the Soviet system has not been "contractual" in the sense that it has been agreed upon by the planners and the enterprise managers. Instead, the state has unilaterally chosen the targets and rewards, and the enterprise managers have been expected to comply in order to attain their own maximum reward within the confines of the rules laid down by the planners. This "non-contractual" incentive system has clearly been an example of the use of performance incentives in the implementation of economic planning.

Recently, the Soviets have extended their incentive system to provide motivation for the state enterprises to select the optimal target output level before the determination of the actual output. The importance of this additional incentive stems from the fact that if the central planners have a good estimate of the amount of the good which <u>will be</u> produced before it is <u>actually</u> produced, then a better coordinated plan can be achieved. There is also a need for planners to coordinate outputs that are jointly used. For example, some intermediate goods are used jointly in the production of final goods, and final goods may be jointly consumed. The reason why an incentive is required to motivate the managers of the state enterprises to reveal the optimal target is that the enterprise may also receive a reward based on the actual output achieved in relation to the target output level. The existence of this reward may motivate the managers to understate the target output level if they are simply asked its value.

Martin Weitzman (7:251-257) has analyzed this new incentive system using a model in which planners fix the resources or inputs available to the enterprise, but there is uncertainty associated with the output that can be produced with these fixed inputs. The uncertainty rests with the planners, thus justifying the selection of the target output level by the enterprise. Although the output actually achieved is not selected by the enterprise, Weitzman shows how the enterprise can use its knowledge of the uncertain conditions of production in conjunction with a specified performance incentive to select the best target output.

This report will first review the Weitzman analysis and then show that the new Soviet incentive program can be viewed as a classical inventory problem, which is a problem of determining how much of product to keep in storage. This interpretation of the incentive program is important because inventory theory is a well-developed analytical framework and general associations between inventory theory and planning may prove fruitful.

Recently, the state enterprises in the Soviet Union have been given greater flexibility in their use of inputs. In view of this change, I next show how the new Soviet incentive program can be extended to deal with a situation in which the inputs used by the enterprise are choice variables with associated cost.

An analysis of the U.S. incentive program will follow the discussion of the Soviet incentive system. To ease comparison between the two systems, a cost-effectiveness model will be used. Thus, I assume that the objective of the government is the achievement of some specified level of output or performance at minimum cost. The large degree of uncertainty which exists during engineering development prevents the government from knowing in advance what output level will be achieved for any level of expenditure. Furthermore, both the estimate of the actual output level, the target, and the output level actually achieved have associated costs which must be borne by the government rather than the producer. Therefore, the performance incentive can be viewed as a method of motivating the producer to take appropriate account of these costs during engineering development.

The existing incentive system motivates the producer to economize on the costs associated with the output level actually achieved. This system can be expanded to solve the target output selection problem. This expansion would lead to a greater compatibility of the various interrelated output decisions, thus making the target output itself a product worth paying for in the U.S.

I. <u>The New Soviet Incentive Model</u>

In analyzing the new Soviet incentive system, Weitzman uses a model in which the factors of production used by the enterprise to produce good y are set by the planners, an assumption which is realistic in the U.S.S.R. where inputs have typically been rationed by the state. A tentative target $\bar{y}$ and a tentative bonus fund $\bar{B}$ are assigned to the enterprise during the first or <u>preliminary</u> phase. The tentative target is the planner's best estimate of the target output level at that time. During the second, or <u>planning</u> phase, the enterprise has the option of revising the tentative target to $\hat{y}$ which has associated with it a revised bonus fund $\hat{B}$ computed in accordance with the formula,

$$\hat{B} = \bar{B} + \beta(\hat{y} - \bar{y}),$$

where the constant β is proportional to the "real social value of having an extra unit which has been pre-planned" (7:256).

In the third or <u>implementation</u> phase, when the enterprise ends up producing amount y, it actually receives the bonus fund

$$B = \begin{cases} \hat{B} + \alpha(y - \hat{y}) : y \geq \hat{y} & \text{(overfulfillment)} \\ \hat{B} - \gamma(\hat{y} - y) : y < \hat{y} & \text{(underfulfillment)} \end{cases}$$

where α is proportional to the "real social value of having an extra unit unexpectedly delivered," and γ is proportional to the "real social cost of being unexpectedly caught short by one unit" (7:256). Subsequent analysis reveals that correct decision making by the enterprise requires that the constants β, α, and γ be in the same proportion to their respective value coefficients. Under the "old" Soviet incentive system, $\hat{B}$ and $\hat{y}$ were fixed by the planners. Under the new system, they are set by the enterprise.

In the model developed by Weitzman, there is uncertainty during the planning phase as to the amount of output which will actually be produced with the fixed inputs. Only the producer knows the probability density function f(y). Thus, we have an example of the informational asymmetry which is so prevalent during the planning process and a justification for the producer to select the target output level. This uncertainty might in fact persist during the implementation phase, but with fixed inputs, actual output y is not a choice variable, and thus, the character of the uncertainty which applies then is not relevant to this analysis.

During the planning phase, when $\hat{y}$ is selected, the problem faced by the enterprise (assumed risk neutral) is to choose $\hat{y}$ to maximize

$$\int_{-\infty}^{\hat{y}} [\bar{B} + \beta(\hat{y} - \bar{y}) + \gamma(y - \hat{y})] f(y)dy$$

$$+ \int_{\hat{y}}^{\infty} [\bar{B} + \beta(\hat{y} - \bar{y}) + \alpha(y - \hat{y})] f(y)dy \; . \qquad (1)$$

By differentiating with respect to $\hat{y}$, Weitzman shows that the optimal solution to this maximization problem is to select $\hat{y}$ such that

$$P(y \geq \hat{y}) = \frac{\gamma - \beta}{\gamma - \alpha} \; , \qquad (2)$$

where

$$P(y \geq \hat{y}) = \int_{\hat{y}}^{\infty} f(y)dy .$$

Because it is possible to multiply all of the coefficients by a constant without changing (2), only the relative magnitudes of the coefficients matter in determining the optimal $\hat{y}$. The appropriate relative magnitudes are achieved when these coefficients are in the same proportion to their respective value coefficients.[3] Furthermore, in view of the fact that (2) must be positive, this incentive system is meaningful only when the coefficients are set such that $\alpha < \beta < \gamma$.

An inventory theory interpretation

The fact that there are costs borne by the center when the actual outcome is both below and above target suggests that an inventory theoretic interpretation can be given to Weitzman's analysis. To see the classical inventory structure of this problem, rewrite (1) as

$$\bar{B} + \beta(\hat{y} - \bar{y}) + \int_{-\infty}^{\hat{y}} \gamma(y - \hat{y})f(y)dy + \int_{\hat{y}}^{\infty} \alpha(y - \hat{y})f(y)dy . \qquad (3)$$

The difference, $\bar{B} - \beta\bar{y}$, is fixed and therefore not relevant when choosing the target output level, but we must concern ourselves with the term $\beta\hat{y}$ which can be written as

$$\beta\hat{y} \equiv \beta \int_{-\infty}^{+\infty} yf(y)dy + \beta \int_{-\infty}^{\hat{y}} (\hat{y} - y)f(y)dy - \beta \int_{\hat{y}}^{\infty} (y - \hat{y})f(y)dy .$$

The expression,

$$-\beta\int_{\hat{y}}^{\infty}(y - \hat{y})f(y)dy \ , \tag{4}$$

is proportional to the benefits foregone, weighted by the probabilities, as a result of the economic system not being geared to a higher $\hat{y}$ when the actual output is larger than the target.

If the target is not achieved, the actual y is less than $\hat{y}$, and

$$\beta \int_{-\infty}^{\hat{y}}(\hat{y} - y)f(y)dy \tag{5}$$

is applicable. This expression can be viewed as (proportional to) the benefits still received (weighted by probabilities) from having the system geared to $\hat{y}$. Now insert (4) and (5) into the last two parts of (3), and obtain as the producer's problem the maximization of

$$(\beta - \gamma)\int_{-\infty}^{\hat{y}}(\hat{y} - y)f(y)dy + (\alpha - \beta)\int_{\hat{y}}^{\infty}(y - \hat{y})f(y)dy$$

which is equivalent to the minimization of

$$(\gamma - \beta) \int_{-\infty}^{\hat{y}}(\hat{y} - y)f(y)dy + (\beta - \alpha) \int_{\hat{y}}^{\infty}(y - \hat{y})f(y)dy \ .$$

The coefficient $\gamma - \beta$ can now be identified as (proportional to) the net social cost per unit of output actually achieved below the target and $\beta - \alpha$ as (proportional to) the net social cost per unit of output above the target.

Let us use the notational convention

$$c_1 = \gamma - \beta ,$$

$$c_2 = \beta - \alpha .$$

The problem facing the enterprise can therefore be written

$$\min_{\hat{y}} c_1 \int_{-\infty}^{\hat{y}} (\hat{y} - y) f(y) dy + c_2 \int_{\hat{y}}^{\infty} (y - \hat{y}) f(y) dy . \quad (6)$$

When the producer's maximization problem (1) is rewritten as the minimization problem (6), it is possible to view the selection of $\hat{y}$ as the selection of the amount of a good (the target) to be placed in inventory. The coefficient c_1 can be viewed as the carrying cost per unit of unsold inventory and c_2 the per unit shortage cost. Taking the derivative of (6) with respect to $\hat{y}$ (and equating it to zero) we see that for the optimal solution value $\hat{y}$,

$$P(y < \hat{y}) = \frac{c_2}{c_1 + c_2} = \frac{\beta - \alpha}{\gamma - \alpha} . \quad (7)$$

Equation (7) is a well-known formula from inventory theory (5:136). Therefore,

$$P(y \geq \hat{y}) = \frac{c_1}{c_1 + c_2} = \frac{\gamma - \beta}{\gamma - \alpha} ,$$

which is the solution obtained by Weitzman. .

The inventory formula (7) has a simple economic interpretation. Letting $P = P(y < \hat{y})$, this formula can be rewritten as

$$Pc_1 = (1 - P) c_2 \quad (8)$$

and indicates that P should be selected through the selection of $\hat{y}$, so that the expected net social cost of the output produced less than the target and the output produced at least as great as the target are equal. The reason an inventory theoretical interpretation is interesting is that inventory theory is a well-developed framework and analogies that can be found with the planning process might prove fruitful in the development of a theory of economic planning.

Production inputs variable

Although Weitzman has chosen to view production inputs as fixed, largely because this assumption reflects the Soviet planning environment, it is possible to extend his analysis by allowing the production inputs used during the implementation phase to be choice variables of the enterprise. This extension may have relevance to the Soviet planning problem now that the managers of state enterprises are being given greater flexibility in the use of inputs. In order to simplify the analysis, I assume that there is the same degree of uncertainty about the conditions of production during the planning phase when the enterprise selects the target output level and during the implementation phase when a level of cost expenditure is selected. In the view of the enterprise, the conditions of production during both phases can be represented by

$$y = h(c, \theta),$$

where θ is a random variable with density function $f(\theta)$ applicable for both the planning phase and the implementation phase, and c represents production costs. Although identical uncertainty permits one to view the enterprise as selecting $\hat{y}$ and c simultaneously, a meaningful economic interpretation can still be given for the need to select $\hat{y}$ beforehand by assuming that the actual output y is not revealed at the time c is selected but rather at some later time which can be called the implementation phase. It will also be assumed in this extension that the share of cost expenditure borne by the enterprise is equal to s.

Assuming that the coefficients β, γ, and α continue to apply, and the profits are determined by $T(\hat{y},c)$, the producer must solve

$$\max_{\hat{y},c} T(\hat{y},c) = \int_{-\infty}^{\theta^{-1}(\hat{y},c)} [\overline{B} + \beta(\hat{y} - \overline{y}) + \gamma(h(c,\theta) - \hat{y}) - sc]f(\theta)d\theta + \int_{\theta^{-1}(\hat{y},c)}^{\infty} [\overline{B} + \beta(\hat{y} - \overline{y}) + \alpha(h(c,\theta) - \hat{y}) - sc]f(\theta)d\theta \quad (9)$$

where the inverse function $\theta^{-1}(\hat{y},c)$ determines the value of θ which achieves $y = \hat{y}$ when the production costs are c. The enterprise must set the derivative of this with respect to $\hat{y}$ equal to zero obtaining

$$\partial T/\partial \hat{y} = \int_{-\infty}^{\theta^{-1}(\hat{y},c)} (\beta - \gamma)f(\theta)d\theta + \int_{\theta^{-1}(\hat{y},c)}^{\infty} (\beta - \alpha)f(\theta)d\theta = 0.$$

It is easy to verify that this equality implies that

$$P(\theta \geq \theta^{-1}(\hat{y},c)) = \frac{\gamma - \beta}{\gamma - \alpha}. \quad (10)$$

Similarly, the derivative of (9) with respect to c set equal to zero yields

$$\frac{\partial T}{\partial c} = \int_{-\infty}^{\theta^{-1}(\hat{y},c)} [\gamma h_c(c,\theta) - s]f(\theta)d\theta + \int_{\theta^{-1}(\hat{y},c)}^{\infty} [\alpha h_c(c,\theta) - s]f(\theta)d\theta = 0. \tag{11}$$

[4]

To obtain qualitative results we require knowledge of the function $h(c,\theta)$. Assume that the uncertainty is additive and that h_c depends only on $c(h_{c\theta} = 0)$.[5] Then it can be shown that (11) implies that

$$P(\theta \geq \theta^{-1}(\hat{y},c)) = \frac{\gamma h_c - s}{(\gamma - \alpha)h_c} . \tag{12}$$

For both (10) and (12) to be satisfied simultaneously, it must be true that

$$\frac{\gamma - \beta}{\gamma - \alpha} = \frac{\gamma h_c - s}{(\gamma - \alpha)h_c}$$

which implies that the producer must set

$$\beta h_c(c) = s . \tag{13}$$

This condition implies that when $\hat{y}$ is optimal, the selection of the level of cost by the enterprise can be determined by evaluating the profit from a small adjustment in $\hat{y}$. The effect on the profit obtained from y is captured when the optimal value of $\hat{y}$ is selected. Thus, the producer should vary c until the extra profit associated with a small increase in target output (βh_c) just equals the reduced profits from increasing c by one unit (s).

One can rewrite (13) as

$$c = h_c^{-1}(s/\beta),$$

thereby permitting (10) to be written as

$$P(\theta \geq \theta^{-1}(\hat{y}, h_c^{-1}(s/\beta)) = \frac{\gamma - \beta}{\gamma - \alpha}. \quad (14)$$

The enterprise must satisfy this condition during the planning phase when selecting $\hat{y}$. This condition recognizes that during the implementation phase the producer selects the optimal cost expenditure. Comparing (14) with (2) shows that the producer must simply account for the impact of the additional choice variable (cost) on the likelihood of being over target. However, once this adjustment is made, the economic interpretation described by (8) continues to apply.

II. The U.S. Incentive Model

The purpose of the U.S. incentive model is to motivate producers to select an output level which is socially optimal. The DOD and NASA Guide states that

> the concept of multiple incentive contracting must quantitatively relate profit motivation directly and in accordance with the Government's objectives. . . . it establishes the contractor's profit in direct relationship to the value of the combined level of performance in all areas (3:107).

Furthermore,

> the process of including performance in an incentive structure must logically begin with the determination of the "value" of the characteristics which will be incentivized. The multiple incentive contract should reflect the importance to the government of various cost, schedule, and performance outcomes, through the profits assigned to each part of the multiple incentive structure (3:117).

Cost-effectiveness analysis

One method of describing the U.S. incentive model is to use a cost-effectiveness analysis approach.[6] This approach applies when the government's objective is the achievement of some specified level of system performance at minimum cost and it simplifies comparison of the U.S. incentive model with the Soviet model. It is assumed that increasing individual performance level p of some component of the system during the engineering developing phase of procurement leads to future, or "downstream" cost savings for the government because of reduced acquisition costs, maintenance costs, etc. The basic structure of the U.S. incentive model can be most easily illustrated if it is assumed that the producer is given a performance reward based on the level of p actually achieved and on development costs. Later, a more complicated model will show how the U.S. incentive program can be expanded to incorporate the target selection features of the new Soviet incentive program.

I assume that the cost of development function, C(p), is deterministic during the implementation phase when the producer actually selects p. This function may, however, be known only to the producer. Indeed, in order to justify using a performance incentive in the first place, there must be some uncertainty in the government's mind about the cost of development at the time the incentive is specified. Otherwise, the government would simply specify p. The downstream cost function, D(p), determines the costs borne by the government through the dependence on the output level selected by the producer. This function is assumed to be known by the government. Total cost is the sum of the development cost and the downstream cost and the downstream cost and is designated T(p). At the time of producer decision making, the objective of the government is to solve

$$\min_{p} T(p) = C(p) + D(p) .$$

The first order condition for this problem is

$$C' = -D' , \tag{15}$$

which simply says that the performance level should be increased until the producer's marginal development cost expenditure just equals the government's marginal downstream cost reduction.

The profit,or performance incentive function given to the producer under the U.S. incentive system is typically of the form

$$\pi = G(p) - sC \tag{16}$$

where G(p) represents dollars of profit earned as a function of the performance level p, and s equals the share of the development cost borne by the producer. The relevant first order,or profit maximizing condition for the producer is

$$G'(p) = sC'(p) .$$

In view of the government's optimization condition (15), the optimal incentive structure is obtained when -D' is substituted for C', and the government constructs the performance incentive function such that

$$G'(p) = -sD'(p)$$

Therefore, with the inclusion of a constant A, a performance incentive function of the form

$$\pi = -sD(p) - sC + A$$

will motivate the producer to satisfy (15), thereby satisfying the objectives of the government.

Extending the U.S. incentive model

For selected U.S. procurements in which the producer is the only supplier of a good whose performance is rewarded in relation to some target (thereby creating an incentive for the producer to understate the target if simply asked its level), there is value in extending the U.S. incentive program to include producer target specification. In addition to depending on the actual performance level, downstream costs also depend on the target performance level because of the time needed to prepare the operational environment (e.g., train maintenance people, etc.) for the actual performance level.

In extending the U.S. incentive model, I assume, for the purpose of comparison with the Soviet incentive model, that during the planning phase an incentive function is specified and the producer selects a target performance level $\hat{p}$. The actual performance level p is not achieved until an implementation phase.

During the planning phase, the downstream cost function will be of the form $D(\hat{p},p)$. Although all costs are variable at that time, certain downstream costs are fixed at the time the actual performance is achieved. During the planning phase the dependence of these costs on the target performance level can be represented by $F(\hat{p})$. Those costs which remain variable when the actual performance level is determined can be represented by $Dv(\hat{p},p)$.

In order to parallel the extension of the new Soviet incentive model to the situation where inputs are variable, I now assume that the choice variable of the producer is a level of development cost expenditure c. In the cost-effectiveness analysis section above, the performance level p was selected as the producer's choice variable. At both the time the producer selects the target performance level and the time that a cost expenditure level is selected, the producer's view of the conditions of production is represented by

$$p = g(c,\theta),$$

where θ is a random variable which has the same density function at both of the times of producer decision making. It is assumed that the government does not know g during the planning phase, thus justifying the selection of $\hat{p}$ by the producer. As we shall see, the government's information about downstream cost is transmitted to the producer in the incentive function. This information combined with the producer's information about the conditions of production yields, via profit maximization, the best solution to the target selection problem.

The government is interested in the minimization of

$$E(c + Dv(\hat{p},p) + F(p)) .$$

The first order conditions associated with this minimization are

$$1 + E(\partial Dv/\partial p)(\partial p/\partial c) = 0 \qquad (17)$$

$$E(\partial Dv/\partial \hat{p}) + \partial F(\hat{p})/\partial \hat{p} = 0 . \qquad (18)$$

The profit function given to the producer is of the form

$$\pi = G(\hat{p},p) - sc , \qquad (19)$$

where s again represents the share of the development cost borne by the producer. This function has the same basic form as (16) to retain compatibility with what has typically been used for the existing U.S. incentive system. The first order conditions which apply for the <u>producer</u> are

$$E(\partial G/\partial \hat{p}) = 0 , \qquad (20)$$

$$E(\partial G/\partial p)(\partial p/\partial c) = s . \qquad (21)$$

Comparing (17) and (18) with (19) and (20) shows that the government can achieve its objective if it constructs an incentive function such that

$$G_{\hat{p}} = -s(Dv_{\hat{p}} + F_{\hat{p}}) , \qquad (22)$$

$$G_p = -s(D_p). \qquad (23)$$

When condition (22) is satisfied, the incentive profit received by the producer from a change in the target performance level is just equated to a proportion of the incremental downstream cost savings. A similar interpretation applies to (23).

Thus,

$$G(\hat{p},p) = -sD(\hat{p},p) + A ,$$

where A is a constant.

By linearizing the function $Dv(\hat{p},p)$ about $\hat{p}$, and $F(\hat{p})$ about $\overline{p}$, where $\overline{p}$ is some specified performance level, e.g., a government estimate of the target performance level, one can obtain a formal equivalence of the U.S. and the Soviet incentive models. Thus, if one approximates $Dv(\hat{p},p)$ by

$$K/s + \alpha/s(\hat{p} - p) \quad \text{when} \quad p \geq \hat{p}$$

$$K/s + \gamma/s(\hat{p} - p) \quad \text{when} \quad p < \hat{p} \,,$$

and $F(\hat{p})$ by

$$M/s + \beta/s(\overline{p} - \hat{p}) \,,$$

then

$$-sD(\hat{p},p) = \begin{cases} -(K + M) + \alpha(p - \hat{p}) + \beta(\hat{p} - \overline{p}) : p \geq \hat{p}) \\ -(K + M) + \gamma(p - \hat{p}) + \beta(\hat{p} - \overline{p}) : p < \hat{p}) \,. \end{cases}$$

The parameters α, γ, and β have the same interpretation as in the new Soviet incentive model. For example, in that $\hat{p}$ is a preplanned performance outcome, β is simply proportional to the social value of having an extra unit which has been preplanned and can be identified as a proportion of the cost savings achieved when $\hat{p}$ is varied during the planning phase.

If inputs are fixed as assumed by Weitzman, the term sc vanishes from the profit function (19), and one obtains an equivalence to the new Soviet incentive model. If the inputs are variable and $g(c,\theta)$ applies, then one obtains an equivalence to the extended Soviet incentive model developed above. The relevant maximization problem that must be solved by the producer is analogous to (9).

Note that the cost share s is the factor of proportionality that applies to the parameters α, γ, and β. If the cost share changes, then so too will the parameters. Thus, there appears to be a degree of freedom in the selection of these parameters. However, this factor of proportionality has distributional significance and, in fact, is related to the distribution of societal profits between the center and the enterprise. It is subject to optimization in an analysis of risk sharing between the center and the producer, and has been discussed by Hildebrandt and Tyson (4:1-29).

Conclusions

Decision makers in both the United States and the Soviet Union face similar problems of correctly guiding production at the enterprise level. To achieve certain social objectives, the United States government has employed the contractual incentive function whereas the Soviet planners have used the non-contractual, or unilateral incentive function.

The new Soviet incentive system provides an incentive for the enterprise to reveal the socially optimal target output level. My analysis has shown that this system can be expanded to deal with the situation when the enterprise controls the amount of resources utilized, a situation which is becoming increasingly typical in the Soviet Union and which continues to be the norm in the United States. Although the option of placing an incentive on the target output level has not yet been used in the United States, the existing U.S. incentive system can be expanded to permit that possibility.

Footnotes

1. Using z, x, and y to represent measures of relative profit, cost, and performance, the functional form which applied to several of the large dollar value incentive contracts used during the U.S. moon program is

$$z = f(x) + g(y) + \alpha f(x)g(y) + \beta$$

where

$$f(x) = a_1 x e^{a_2 x^{a_3}} \qquad g(y) = b_1 y e^{b_2 y^{b_3}}$$

and a_1, a_2, a_3, b_1, b_2, b_3, α, and β are constants. In addition. between 1967 and 1970, there were approximately $27 billion of multiple incentive contracts evaluated by a Department of Defense analysis group.

2. It is widely accepted that this is the Soviets' most famous planning problem. In addition to monetary incentives, the Soviets have also tried to solve this problem using informational exchange during bargaining with the enterprise.

3. Each coefficient of the right hand side of (2) can be multiplied by a constant k yielding

$$\frac{k\gamma - k\beta}{k\gamma - k\alpha} = \frac{k(\gamma - \beta)}{k(\gamma - \alpha)} = \frac{\gamma - \beta}{\gamma - \alpha}$$

In that the value coefficients are measured in rubles per extra output, multiplying each coefficient by a constant can be viewed as a change in the monetary unit which could never affect the selection of $\hat{y}$. Also note that the units associated with each coefficient of the right hand side of (2) cancel. As the left hand side of (2) is a probability (a pure number), such a cancellation is required to equate both sides of (2).

4. Notation such as h_c represents the partial derivative of the function h with respect to the variable c.

5. Although this assumption is strong, it is frequently interesting to know what assumptions are required to obtain a sharp characterization of an optimal policy. It is not difficult, however, to imagine an interaction between the level of cost expenditure and the random variable θ. For example, high levels of cost expenditure might be associated with greater uncertainty. Such interactions have been excluded from the analysis.

6. As far as I am aware, the first mathematical treatment of multiple incentive contracting using a cost-effectiveness approach similar to the one presented here was by Ackerman and Krutz (1:1-64).

7. The expectation operators are not required in (22) or (23) because the terms inside the expectation operators of (20) and (21) are substituted for the terms of (17) and (18) inside these operators.

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