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ABSTRACT

A relatively obscure defense procurement policy establishes a large subsidy to private military R&D investment. On the surface, it appears that the marginal subsidy to such investment is zero, but this is only true in the short run. Due to DOD's policy of allowable-cost determination, the long-run subsidy is substantial. It is much larger, in fact, than the subsidy provided by the R&D Tax Credit enacted in 1981. I calculate the subsidy by estimating an econometric model using contractor-level data from the Defense Contract Audit Agency. This subsidy may have an important influence on the amount and character of privately financed innovation in the U.S.

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In a previous paper (1988) I argued that the Department of Defense encourages its contractors to invest their own funds in defense-related research and development (R&D) by sponsoring design competitions for the award of major weapons contracts. I estimated the amount of private R&D investment devoted to winning the "prizes" offered by the Pentagon, and found it to be substantial.[1]

This paper seeks to show that the Defense Department encourages private military R&D not only by establishing prizes, but also by subsidizing expenditures dedicated towards winning the prizes. In other words, DOD promotes this contractor activity both by creating returns to it and by reducing the (private marginal) costs of it.

The Defense Department policy that provides a subsidy to private military R&D is its policy regarding so-called "Independent" R&D. Independent R&D is contractor-initiated and -directed technical effort that is not sponsored by, or required in performance of, a contract or grant. The contractor selects the projects that comprise its IR&D program. The Defense Department and its contractors consider independent, or non-contract, R&D to be "company-funded" R&D, and it is reported as such in financial statements and official government R&D statistics. But under the Defense Procurement Regulations, some of the costs of Independent R&D are "allowable," i.e. they can be included as indirect costs (overhead) in contractors' Defense Department contracts. Each year, ceilings on the amount of allowable Independent R&D costs are negotiated in advance by the Defense Department and each of its major

[1] In a recent paper, Rogerson (1988) has estimated the value of the prizes (economic profits) contained in aerospace contracts using an event-study methodology.

contractors. The existence of a subsidy to private military R&D is due to the way in which these ceilings are negotiated or determined.

In this paper I will formulate a simple model of allowable IR&D cost determination, and estimate the model using data for about 275 contractors compiled by the Defense Contract Audit Agency. These estimates enable me to calculate the (long-run) marginal rate of subsidy to contractor Independent R&D investment.

A major point of this paper is that, whereas the apparent marginal rate of subsidy to independent R&D is zero, the true (long-run) subsidy is positive and substantial. The apparent subsidy is zero because virtually all firms spend an amount in excess of the ceiling on allowable costs previously negotiated with the Defense Department.[2] Costs beyond the ceiling cannot be recovered from the Pentagon. But the true marginal subsidy is positive because the negotiated ceiling is an increasing function of lagged expenditures. Thus a contractor whose independent R&D costs already exceed his ceiling will not recover more funds from DOD this year by increasing his expenditure, but he will recover more in future years.

If IR&D policy does establish a subsidy for private military R&D investment, it may have an important effect on the amount and character of innovative activity in the U.S., and consequently on the nation's economic performance. Since IR&D policy does not subsidize private civilian R&D investment, it would lower the price to firms of sponsoring military R&D relative to that of sponsoring civilian R&D, and therefore

[2] In 1986 aggregate (across all contractors) independent R&D costs incurred was $5.0 billion, and aggregate allowable costs was $3.5 billion.

increase the relative quantity of military R&D. If, moreover, the aggregate supply of R&D inputs were sufficiently inelastic, the policy could reduce the absolute (as well as relative) amount of civilian R&D. There is abundant evidence that civilian R&D has a much larger impact on industrial productivity and other performance measures than military R&D.[3] The IR&D program may influence U.S. productivity growth by influencing the amount and composition (military versus civilian) of industrial R&D.

In Section I I describe DOD's IR&D policy and specify a model of allowable-cost determination, which enables me to compute the (long-run) marginal subsidy to private military R&D investment. In Section II I briefly describe the data set and present the empirical results. Section III contains concluding remarks.

I A MODEL OF DOD's POLICY OF ALLOWABLE-COST DETERMINATION

To develop a model of DOD's policy of allowable-cost determination, we adopt the following notation:

C = ceiling on allowable costs

X = total costs incurred

R = costs recovered from DOD

S = total sales of the contractor

D = DOD sales of the contractor

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[3]See, for example, Griliches and Lichtenberg (1984), and Griliches (1986).

R, the amount of costs recovered from DOD, is determined by the following formula

$$R = \frac{D}{S} \cdot \min(X,C) \tag{1}$$

Cost recovered is the fraction of firm sales accounted for by sales to DOD times either costs incurred or the ceilings, whichever is lower.

As Table 1 indicates, in practice, $X \geq C$ in the case of all firms. The maximum value of the ratio C/X is 1; the mean and median values are .823 and .872, respectively. Hence $\min(X,C) = C$. Let us define $\theta = D/S$ as the DOD share of sales; we shall treat this fraction as a parameter. Then equation (1) reduces to

$$R = \theta \cdot C \tag{2}$$

The private cost to the firm P of conducting a level of investment X is

$$\begin{aligned} P &= X - R \\ &= X - \theta C \end{aligned} \tag{3}$$

The marginal rate of subsidy to contractor IR&D expenditure is

$$MRS = \frac{dR}{dX} = \theta \cdot \frac{dC}{dX}. \tag{4}$$

The marginal private cost of investment, which is generally hypothesized to determine the equilibrium rate of investment, is 1 - MRS. The marginal rate of subsidy, hence marginal private cost, depends on the derivative dC/dX. A primary objective of my empirical work is to determine the value of this derivative.

Table 1

Statistics Characterizing Distribution of C/X,
Ratio of Negotiated Ceiling to
IR&D Costs Incurred

Maximum	1.00
.75 Quantile	1.00
Median	.872
Minimum	0
Mean	.823

Note: These statistics are based on pooled data for 1985 and 1986. The total number of observations is 598.

The ceiling C is set in an agreement negotiated by the firm and DOD prior to the investment of funds. One might, therefore, regard C as predetermined, i.e. independent of the realized expenditure X. In this case, $dC/dX = 0$ and IR&D reimbursement has no effect on the marginal private cost of investment; it reduces only total costs, like a lump-sum payment. But the proposition that C does not depend on X, if it is true at all, is probably only true in the short run. Winston (1985, p. 22) maintained that "the accepted ceilings are set at a fraction of the contractor's anticipated IR&D expenditures that are deemed to meet the PMR criterion and to be of value of DOD." This hypothesis can be represented as follows:

$$C_t = \gamma X_t^A \tag{5}$$

where C_t denotes the ceiling negotiated for period t and X_t^A denotes anticipated expenditure during the period. Suppose X_t^A is forecast by a distributed lag function of past actual expenditures, with geometrically declining lag coefficients:

$$X_t^A = \delta(X_{t-1} + \lambda X_{t-2} + \lambda^2 X_{t-3} + \ldots) \tag{6}$$

Substituting (6) into (5),

$$C_t = \gamma\delta(X_{t-1} + \lambda X_{t-2} + \lambda^2 X_{t-3} + \ldots) \tag{7}$$

It is well known (see, e.g., Pindyck and Rubinfeld (1981, pp. 232-3)) that eq. (7) can be rewritten in the more empirically tractable autoregressive form

$$C_t = \beta X_{t-1} + \lambda C_{t-1} \tag{8}$$

where $\beta \equiv \gamma \cdot \delta$.[4] In this model there is a distinction between the short-run and long-run derivatives of C with respect to X; these are β and $\beta/(1 - \lambda)$, respectively.

It is interesting to note that an alternative "structural" model for determining C can generate a similar (although restricted) reduced-form equation. Suppose that the change in a firm's negotiated ceiling is proportional to the degree of "excess demand" for IR&D funds, as measured by the difference between lagged costs incurred and the lagged ceiling:

$$C_t - C_{t-1} = \beta(X_{t-1} - C_{t-1}) \tag{9}$$

Adding C_{t-1} to both sides,

$$C_t = \beta X_{t-1} + (1 - \beta)C_{t-1} \tag{10}$$

In eq. (10) the coefficients on X_{t-1} and C_{t-1} sum to 1, whereas this is not the case in eq. (8). This restriction can be tested by estimating both equations.

Below I report estimates of these equations based on cross-sectional data for about 275 IR&D sponsoring organizations. To attenuate heteroskedasticity and for other reasons, I estimate logarithmic versions of the equations, i.e., C and X are defined as logarithms of the respective variables. In this case β and $\beta/(1 - \lambda)$ are respectively the short- and long-run elasticities of C with respect to X. The long-run derivative of C with respect to X is

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[4] Reppy (1977, p. 399) noted that "the size of the negotiated ceiling is in general a function of the previous year's ceiling, modified by any changes in expected sales base or sales mix."

$$\left.\frac{dC}{dX}\right|_{LR} = \frac{\beta}{1 - \lambda} \cdot \frac{C}{X} \tag{11}$$

and the long-run marginal rate of subsidy is (from eq. (4))

$$MRS_{LR} = \frac{D}{S} \cdot \frac{\beta}{1 - \lambda} \cdot \frac{C}{X} \tag{12}$$

This expression is evaluated at the sample aggregate values of D, S, C, and X to obtain an "average" estimate of the long-run marginal rate of subsidy.

II. DATA AND EMPIRICAL RESULTS

The data for this investigation are derived from *Detailed Statistical Reports on IR&D/B&P Costs Incurred by Major Contractors for 1985-86* compiled by the Defense Contract Audit Agency (DCAA).[5] The DCAA report contains data on expenditures, ceilings, and reimbursements pertaining to another type of technical effort related to IR&D: the preparation of bids and proposals (B&P). Because the reasoning which led to the specification of eqs. (8) and (13) applies as well to B&P as it does to IR&D expenditure, these equations are estimated for both IR&D and B&P expenditure. The disturbances of the IR&D and B&P equations are likely to be correlated, in part because there is some fungibility of expenditures between the two categories. We can therefore obtain more efficient parameter estimates by estimating the IR&D and B&P equations jointly, using Zellner's seemingly unrelated regressions (joint generalized least

[5] I am grateful to Colonel Robert Gustin of the Defense Contract Audit Agency for providing me with these data.

squares) technique. In this context we can also test the hypothesis that the parameters of equation (8), hence MRS_{LR}, are the same for B&P as they are for IR&D.

Joint generalized least squares estimates for IR&D and B&P of equation (8) are presented in the first two columns of Table 2. I also report point estimates and standard errors of the nonlinear function of the parameters $\beta/(1 - \lambda)$, since this expression is needed to compute the long-run marginal subsidy. (The standard errors were computed by estimating the model using a nonlinear regression procedure.) In both equations, the parameter β (the coefficient on X_{t-1}) is positive and significantly different from zero. The hypothesis that $\beta + \lambda = 1$, which is implied by the model (9), is decisively rejected in the case of IR&D but is not rejected (at the .10 level) in the case of B&P. The cross-model residual correlation is -.093, suggesting that there is some substitution between IR&D and B&P ceilings and/or expenditure. In the third column of Table 2 I report estimates of the model on which the restriction is imposed that the parameters β and λ are identical across equations. The F-statistic (prob. value) for testing this restriction is 1.68 (.187), so I am unable to reject this restriction.

Table 3 presents calculations of the average and (long-run) marginal rates of subsidy separately for IR&D and B&P and for the two categories pooled. The long-run marginal subsidy to IR&D alone is 36.9 percent, slightly less than (but not significantly different from) the average subsidy of 43.4 percent. The marginal and average subsidies to B&P expense are somewhat higher: 45.7 and 55.6 percent, respectively.

Table 2

Joint GLS Estimates of eq. (8) for
IR&D and B&P expenditures

Parameter or function (standard error)	(1) IR&D	(2) B&P	(3) Restricted
β	.202	.297	.246
	(.096)	(.078)	(.059)
λ	.731	.675	.706
	(.100)	(.078)	(.060)
$\frac{\beta}{1 - \lambda}$	.750	.909	.834
	(.093)	(.052)	(.047)
intercept	.500	.184	
	(.135)	(.135)	
F-statistic (prob. value) for testing $H_0 : \beta + \lambda = 1$	17.1	2.65	18.8
	(.000)	(.104)	(.000)
weighted R^2	.9289		.9284
weighted MSE	1.000		1.002
degrees of freedom	552		554

In the case of B&P, the difference between the estimated marginal and average subsidy rates is significant. Since we were unable to reject the hypothesis of equality of the IR&D and B&P coefficients, the pooled results perhaps deserve the greatest emphasis. These imply that the government pays 41.3 percent of the marginal cost of IR&D and B&P expense. This is slightly (although significantly) less than the average subsidy rate of 47.4 percent.

The rates of subsidy were computed using data for 1985-86; it is natural to ask whether similar rates applied in the past. Data presented by Winston (1985, p. 67) reveal that the average subsidy for IR&D and B&P combined during the period 1974-84 ranged between 41.4 and 48.0 percent, with little discernible trend. But Hill and Bodilly (1988) assert that IR&D cost "recovery is now less tightly tied to the firm's expenditure" than it was in the past, implying that the marginal subsidy rate has declined.

The marginal rates of subsidy to IR&D and B&P appear to be quite high. The R&D Tax Credit created by the 1981 Economic Recovery Tax Act provides a benchmark against which we can compare this subsidy. The provisions of the credit allowed firms to deduct from their tax liability an amount equal to 25 percent of their R&D spending above a certain base-period amount. But due to certain technical features of the credit -- particularly the way in which the base-period amount was calculated -- the effective rate of subsidy it provided was much lower than 25 percent; Baily and Chakrabarti (1988, p. 119) estimate that the effective rate of subsidy was 7 to 8 percent. Moreover, the credit was only temporary -- it was originally due to expire at the end of 1985 after 4-½ years. In contrast, DOD's IR&D policy has remained essentially unchanged since 1970, and predecessor policies can be traced back to the 1930s.

Table 3

Calculation of Marginal and Average Subsidies
to IR&D and B&P Expenditure

	1986 Sample aggregate values[a] ΣX	ΣC	ΣR	$\frac{\beta}{1-\lambda}$	marginal subsidy[b] $\frac{\Sigma D}{\Sigma S} \cdot \frac{\beta}{1-\lambda} \cdot \frac{\Sigma C}{\Sigma X}$	average subsidy $\Sigma R/\Sigma X$	t-statistic to test H_0: marginal = average
IR&D	4971	3515	2159	.750	.369 (.046)	.434	1.41
B&P	2415	1749	1343	.909	.457 (.026)	.556	3.81
pooled	7386	5264	3502	.834	.413 (.023)	.474	2.65

Notes: a. millions of dollars
b. standard error in parentheses.
$\Sigma D/\Sigma S$ = 113.8 b./163.8 b. = .695

III. CONCLUDING REMARKS

The evidence presented in this paper is consistent with the hypothesis that the Defense Department, via its independent R&D policy, provides a substantial implicit subsidy -- on the order of 40 percent -- to private military R&D investment. Contractors spend above their ceilings on allowable costs, so it appears on the surface that the marginal subsidy is zero. This appearance is misleading because in the long run, negotiated ceilings respond positively to lagged expenditures.

While our estimates reveal the magnitude of the subsidy to private military R&D, they do not reveal how much (additional) R&D is undertaken due to the existence of the subsidy. To determine this with any precision, we would need to know the price-elasticity of supply of R&D, a parameter about which little is known. But the existence of the subsidy is no doubt partly responsible for the fact (established in my earlier paper) that the marginal private R&D intensity of government (primarily defense) sales is much higher than the R&D intensity of nongovernment sales -- 9.3 percent as opposed to 1.7 percent.

The main point of this paper is that the government encourages private defense-related R&D investment by providing an implicit subsidy to this activity as well as by establishing rewards or prizes for performing it. We conclude by briefly considering two questions about the "logic" of this policy.

First, why does the government provide a subsidy for private military R&D, in addition to establishing prizes for innovation? Presumably if the subsidy were abolished the government could continue to induce the same amount of private R&D investment by increasing the value of the prizes. The answer may be that the cost to the government of promoting a given level of investment may be lower with a combination of prizes and subsidies than it would be with prizes alone. By providing a subsidy the government in effect shares with the contractor the risk of investment; the agency theory literature suggests that such risk-sharing is often optimal from the principal's (government's) point of view.

The second question is, given that the government wants to provide a subsidy, why doesn't it do so explicitly by announcing "we'll pay 40 percent of your independent R&D expense, with no ceiling," rather than by imposing ceilings that are in reality influenced by past expenditures? It is not possible to offer a definitive answer to this question, but two factors may account for the institutional arrangements we have described. First, while the major objective of independent R&D policy is to strengthen the defense technology base by promoting private military R&D investment, for political reasons the Defense Department may need to at least appear to be "controlling costs" by imposing ceilings.[6] Second, the government is interested not only in encouraging private innovation but also in transferring technologies and knowledge developed in the course of independent R&D to government officials. The negotiation of ceilings provides the government with the opportunity to monitor contractor activity, thereby facilitating technology transfer.

[6] Alexander (1988, p. 35) notes that there are two offices within the office of the Secretary of Defense involved with independent R&D policy: The Deputy Undersecretary for Research and Advanced Technology, whose primary concern is the promotion of technology and the encouragement of industry R&D, and the Deputy Assistant Secretary for Procurement, whose primary concern is reducing the cost of acquisition.

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