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How DoD Policy Affects Private Expenditure on Independent Research and Development: A Comparison of Empirical Studies

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PREFACE

This Note originated in a presentation to the Conference on Defense Economics at the U.S. Air Force Academy on 29-30 August 1988. That presentation set several empirical studies of Independent Research and Development (IR&D) policy in a common context to compare their results, ask where a consensus might be developing on the effects of IR&D policy, and suggest what additional research could increase our understanding of these effects. This Note presents a formal statement of the arguments that the author made at the conference.

The Note uses economic models and concepts to analyze the incentive effects of IR&D policy. It explains relevant aspects of IR&D policy, but assumes that the reader has a working knowledge of basic price theory. Its conclusions and recommendations should interest policy analysts concerned with Department of Defense (DOD) acquisition and technology policies. Its formal arguments will be of greatest interest to economists concerned with explaining and measuring the effects of regulatory and public pricing policy.

The research reported in the Note was conducted within and paid for using Research Support funds of the Acquisition and Support Policy Program, a component of RAND's National Defense Research Institute, a Federally Funded Research and Development Center sponsored by the Office of the Secretary of Defense.

One of the studies discussed in this Note is a congressionally mandated RAND study of IR&D policy, also conducted under the Acquisition and Support Policy Program: A. J. Alexander, P. T. Hill, and S. J. Bodilly, *The Defense Department's Support of Industry's Independent Research and Development (IR&D): Analyses and Evaluation*, R-3649-ACQ, 1989. This report is an excellent source of institutional detail on IR&D not covered here.

SUMMARY

The Department of Defense (DOD) does not contract directly for independent research and development (IR&D); instead it encourages defense contractors to invest in IR&D by reimbursing them for a portion of their spending on it.[1] Recent policy concerns about IR&D have prompted a number of studies of its effects.

This Note compares the empirical results of three studies that ask how DOD policy affects the level of private spending on IR&D:

- Arthur J. Alexander, Paul T. Hill, and Susan J. Bodilly, *The Defense Department's Support of Industry's Independent Research and Development (IR&D): Analyses and Evaluation*, R-3649-ACQ, The RAND Corporation, 1989.
- John R. Brock, "Department of Defense Subsidization of Research and Development: Stimulus or Substitute?" unpublished draft, U.S. Air Force Academy, July 1988.
- Frank R. Lichtenberg, "Government Subsidies to Private Military R&D Investment: DOD's IR&D Policy," unpublished draft, Columbia University Graduate School of Business, June 1988.

In particular, the Note compares the varying methods, assumptions, and data sets used in these studies to determine how consistent their results are and, when taken together, what they can tell policymakers about the likely effects of changes in IR&D policy.

The principal conclusion of this Note is that *currently available empirical studies do not allow policymakers to predict how policy changes would affect private investment in IR&D*. The current studies provide useful guidance for further analysis that could improve policymakers' confidence in future changes that they might make, but the studies' current empirical results are not mutually consistent.

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[1]Although DOD oversees the IR&D reimbursement policy, other government agencies participate. This Note and the papers it reviews focus on the portion of the policy that DOD oversees *and implements*.

Table S.1 summarizes the studies' answers to two questions of particular importance to policymakers. First, how large is DOD's *behaviorally relevant* subsidy to private spending on IR&D?[2] Second, what effect does this subsidy have on private spending on IR&D?

On the size of subsidy, Brock does not distinguish short-term and long-term effects;[3] we can best interpret the effects he measures as short-term effects. The sample that Brock uses shows the range over time of measures for *central tendencies*. Values for individual contractors range from near zero to 100 percent in almost every year. Lichtenberg and Alexander et al. agree on a much smaller short-term subsidy of 10 percent; subsidies rise in a long-term perspective. These estimates differ primarily because Brock measures firm response to a different kind of incentive created by DOD's policy from that examined in the other studies; different numbers in the table do *not* point to an inconsistency. Alexander et al. offers the advantage over Lichtenberg of using a much longer time series and using a more widely accepted estimation technique; Lichtenberg's results, in contrast, come from the most current data available.

Table S.1

SUMMARY OF EMPIRICAL RESULTS

	Brock	Lichtenberg	Alexander et al.
Size of subsidy			
First year	50-80%	10%	10%
Long term	—	37%	23%
Effect of subsidy			
First year	$0.43-0.71	—	$0.70
Long term	—	—	$2.20

[2]Proponents of IR&D policy stress that DOD's program for promoting IR&D does not use direct subsidies. This Note uses the word "subsidy" in a traditional economic sense. A subsidy exists whenever policy reduces the effective private cost of an activity relative to its private value, thereby creating an incentive to increase the level of this activity.

[3]In this context, a short-term effect is the response to a change in the first year of the change. For the studies compared here, most of the long-term effect would be realized within five years.

On the effects of subsidies, the table displays the response of private spending on IR&D to a $1.00 increase in reimbursement. Alexander et al. estimates this directly; I infer values for Brock from its reported results. Lichtenberg does not address this question. Although one-year results look comparable for Brock and Alexander et al., they measure different quantities. Again, Brock and Alexander et al. focus on different incentives under DOD's policy. The Note uses a simple economic model to compare these results under a set of reasonable assumptions about firm behavior and finds that none of the incentives associated with DOD's policy could create responses that make the results for Brock and Alexander et al. comparable.

Although the studies reviewed here offer a useful start, then, additional analysis is needed to extract more sustainable answers from the available data. Such analysis should recognize that observed historical data can be explained in several ways and should develop tests explicitly designed to distinguish among these explanations. These tests in all likelihood could be developed in the context of a hybrid of the approaches that Brock and Alexander et al. use.

Future analysts should keep in mind that how DOD policy affects the level of private expenditure on IR&D is only one of several important empirical questions about IR&D policy. Others include the following:

- Does DOD policy encourage a form of private IR&D that broadens the defense technology base and reduces the social risk of relying solely on bureaucratically initiated contract research to allocate resources to defense research and development? If so, how and how much?
- Does DOD policy on IR&D encourage the transformation of new ideas from defense-oriented research and development into useful defense products and processes? How and how much?
- What is the value of DOD funds spent to encourage IR&D relative to their value in other defense uses?

ACKNOWLEDGMENTS

James Dertouzos of RAND arranged my participation in the Conference on Defense Economics for which I prepared this Note. Also at RAND, John Birkler supported the preparation of this Note financially; C. Robert Roll, Jr., stressed the importance of understanding the specific incentive structure underlying IR&D policy; and Kent Osband provided an especially helpful internal review. The following provided valuable information on IR&D policy and feedback on the discussion presented here: Arthur Alexander, Susan Bodilly, Paul Hill, James Hosek, and Milton Margolis of RAND; David Chu, Paris Genalis, David McNicol, and David Montgomery of the Office of the Secretary of Defense; John Brock, Air Force Academy; Ronald Culpepper, U.S. Navy; and Frank Lichtenberg, Columbia University. I thank them all and retain responsibility for any errors of fact or interpretation.

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I. INTRODUCTION

The Department of Defense (DOD) maintains a policy that is designed to reimburse defense contractors for a portion of their spending on Independent Research and Development (IR&D).[1] DOD pays for a great deal of research and development directly through contracts. IR&D is research and development that DOD does not contract for directly. IR&D policy is designed to encourage defense contractors to invest in this form of research and development despite the lack of direct contracts for research and development. It is often associated with Bid and Proposal (B&P) funds, which DOD provides to contractors in a similar way.

Those who support maintaining the independence of IR&D argue that it

- increases private spending on defense research and development,
- provides defense options that government officials may not think of, and
- enhances the transfer of technology from scientists to weapons developers by giving developers a direct stake in the scientists' work.[2]

Those who question the importance of IR&D argue that the policy is hard to understand and its effects are even harder to identify. Recent policy concerns about IR&D have prompted a number of studies of its effects.

This Note reviews three empirical studies that ask how IR&D policy affects the level of private spending on IR&D:

- Arthur J. Alexander, Paul T. Hill, and Susan J. Bodilly, *The Defense Department's Support of Industry's Independent Research and Development (IR&D): Analyses and Evaluation*, R-3649-ACQ, The RAND Corporation, 1989.

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[1] Although DOD oversees the policy, other government agencies participate. This Note and the papers it reviews focus on the portion of this policy that DOD not only oversees but also implements.

[2] For a discussion of these attributes, see Arthur J. Alexander et al., *The Defense Department's Support of Industry's Independent Research and Development (IR&D): Analyses and Evaluation*, R-3649-ACQ, The RAND Corporation, 1989.

- John R. Brock, "Department of Defense Subsidization of Research and Development: Stimulus or Substitute?" unpublished draft, U.S. Air Force Academy, July 1988.
- Frank R. Lichtenberg, "Government Subsidies to Private Military R&D Investment: DOD's IR&D Policy," unpublished draft, Columbia University Graduate School of Business, June 1988.

While these studies also address B&P policy, this review focuses on IR&D. It compares the results of these studies and asks what these results tell us about the policy itself and what they suggest for additional analysis of the policy.

Section II presents a simple economic model of IR&D. Section III uses this model to review the economic approach taken in each study. Section IV compares the studies' estimates of the size of subsidy created by IR&D policy and of the effects of IR&D policy on private spending on IR&D. Section V concludes the comparison and suggests directions for future research.

II. A SIMPLE ECONOMIC MODEL

Although DOD uses a complicated method to reimburse IR&D expenses, we can abstract details from this process to build a simple economic model. Because the three studies to be discussed focus on DOD's portion of the process, we ignore related activities outside DOD's purview.[1] This section summarizes how IR&D works and then explains why this process can induce three different kinds of behavioral responses. It treats each of these as a case and describes the effects of IR&D policy in each case.

THE BASICS OF IR&D

The extremely complex process used to implement IR&D policy boils down to the following basic factors. Each year, DOD negotiates with its major contractors to determine the maximum amount that it is willing to reimburse in that year.

- First, DOD negotiates a "ceiling" with each contractor, call it I_C.
- Second, DOD calculates the contractor's actual share of defense sales (D), multiplies this share by the ceiling, and uses the product (I_C*D) as the maximum amount of IR&D expense that it will reimburse.
- Third, DOD projects a level of defense sales for the contractor (S_P), divides the product above by these sales, and derives an overhead rate ($OH = I_C{*}D/S_P$).[2]

Table 2.1 presents a summary of the notation used.

The contractor is then allowed to recover IR&D expenses through this overhead rate, which is applied to defense contracts. The level of recovery is limited in two ways:

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[1]Because all of the studies use data maintained by the Defense Contract Audit Agency, they do not address directly portions of private IR&D spending reimbursed through nondefense federal contracts. Although such reimbursement is beyond the scope of this study, it deserves more attention in the future.

[2]In fact, an overhead rate is calculated and applied to direct costs. Because revenues are a simple markup over direct cost, the approach actually used is equivalent to that described here.

- The contractor cannot recover more than I_C*D.
- The contractor cannot recover more than the product of the overhead rate and *actual* defense sales (OH*S_A).

Within these limits, for every dollar the contractor *actually* spends on IR&D (I_A), the contractor can recover the product of its defense share and its actual expenditures (D*I_A).

BASIC CASES

From an economic point of view, the key question about this policy is what kind of incentives it creates and how contractors react to these incentives. The question essentially comes down to what the contractor can do to influence D*I_A. While IR&D policy might conceivably lead a contractor to expand its share of defense sales, it is more likely to react by trying to expand I_A. Two cases are potentially relevant:

Table 2.1

SUMMARY OF NOTATION

Symbol	Definition
D	Share of defense sales in contractor's total sales
F	Implicit fraction of projected private IR&D expenditures that DOD reimburses
I_A	Actual private IR&D expenditures
I_C	Negotiated ceiling for recovery of private IR&D expenditures
I_P	Projected private IR&D expenditures
OH	Overhead rate negotiated for recovery of private IR&D expenditures
OH_A	Arbitrary overhead rate
S_A	Actual level of contractor's defense sales
S_P	Projected (by DOD) level of contractor's defense sales
V	Direct value of an incremental IR&D expenditure to a contractor

1. The contractor wants to spend less than the ceiling ($D^*I_A < D^*I_C$), and it can recover all its allowable expenses through the overhead rate ($D^*I_A < OH^*S_A$). In this case, the contractor will focus on D^*I_A without regard to other policy constraints, and we need to know how the contractor chooses I_A.
2. The contractor wants to spend more than the ceiling ($D^*I_A > D^*I_C$), and it can recover all its allowable expenses through the overhead rate ($D^*I_A < OH^*S_A$). In this case, the ceiling limits the contractor's ability to affect D^*I_A. Hence, we need to know how the contractor can affect I_C.[3]

Other "noneconomic" explanations have been offered for contractor responses to IR&D policy when the ceiling is binding but defense sales are not. In one, R&D managers of defense contracting firms use DOD reimbursements to convince financial managers to allocate more corporate funds to IR&D even though these will not affect the firm's ceiling and hence the reimbursement it receives. In another, contractors may not expect DOD auditors to allow all private IR&D expenses when checking how much DOD will reimburse. Hence, even if a firm's private spending exceeds its ceiling, it may still be able to increase its reimbursement by expanding investment because not all of this spending will count against the ceiling.

Economic theory cannot easily explain such behavior without detailed data, and we do not address it here. The results reported in Section IV, however, suggest that such behavior may require closer attention. In this comparison, we focus on the two cases above.

Case 1—Simple Price Effect

The first case is the simplest to understand. In Fig. 2.1, dollars spent on IR&D are on the abscissa and marginal private costs and benefits per dollar spent on the ordinate. I is a schedule of returns expected from private investments in IR&D.[4] In a free market, the

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[3]In a third case, the contractor wants to spend less than the ceiling ($D^*I_A < D^*I_C$), but it cannot recover all its allowable expenses through the overhead rate ($D^*I_A > OH^*S_A$), presumably because defense sales fall short of expectations. In this case, defense sales limit the contractor's ability to affect D^*I_A. We need to ask how the contractor can expand sales. Historically, this has not been important. When inadequate defense sales seriously bind a firm's ability to recover IR&D costs, the firm can renegotiate its overhead rate to remove this constraint. Hence, we will not treat this case in detail.

[4]Using a stable investment schedule of this form implicitly assumes that each firm is a price taker *and* that one firm's investment behavior does not depend on the decisions of its competitors except when those decisions affect the output price that the firm faces and assumes is fixed. Oligopolistic behavior among firms could lead to conclusions that differ from those reported here and deserves analytic attention in the future. I thank Kent Osband of RAND for this insight.

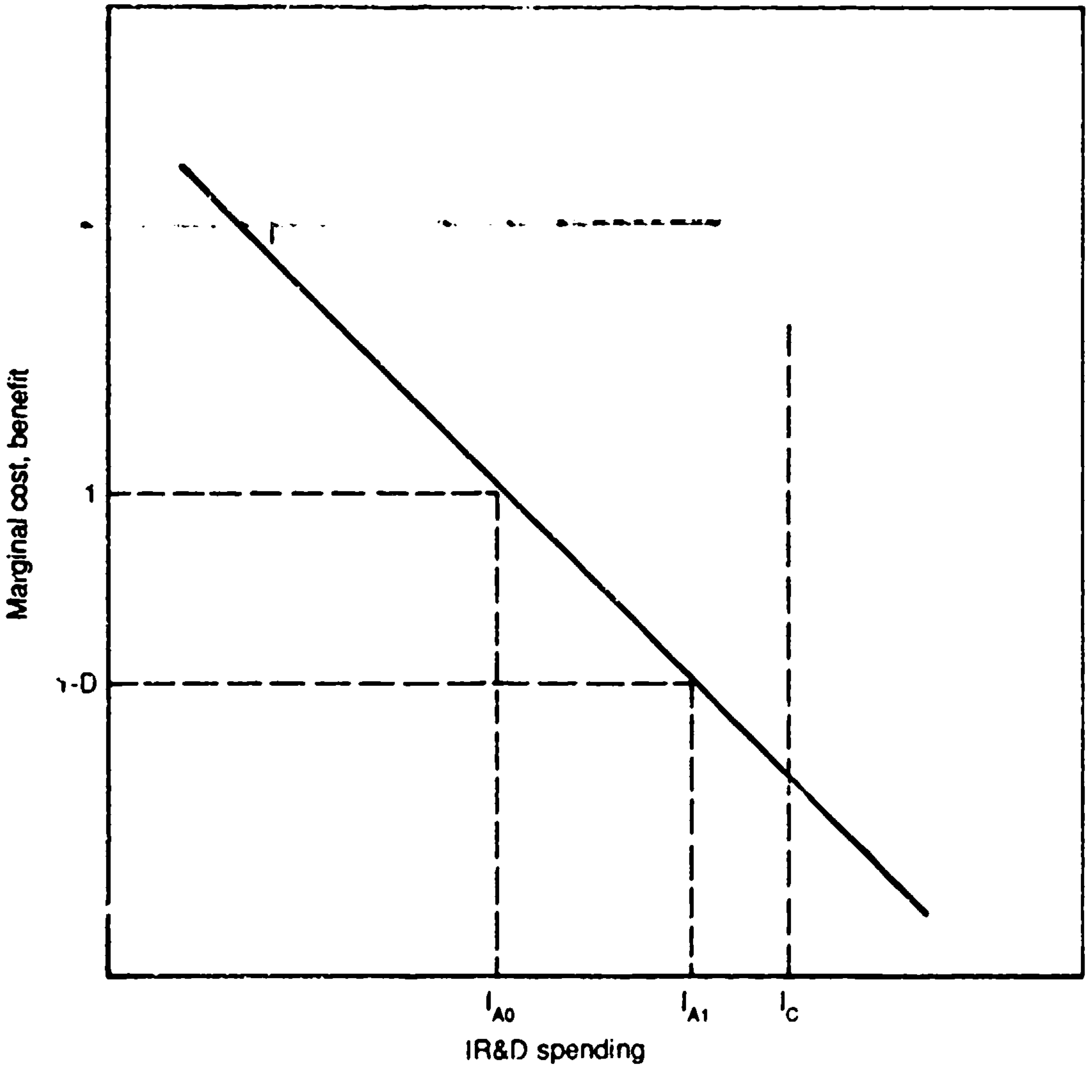

Fig. 2.1—No constraints: a simple price effect

contractor would spend I_{A0}, the amount at which the last invested dollar yields exactly one dollar (in net present value).

Under the conditions of the case, $I_{A0} < I_C$, shown as a simple vertical line. IR&D policy states that, under these circumstances, the contractor receives $D*I_A$ for every expenditure of I_A, implying that the effective cost of IR&D is (1 - D) for every dollar spent. In this case, then, we expect the contractor to expand its expenditure from I_{A0} to I_{A1}. To understand the magnitude of this effect, we need to know the size of D for the contractor in question and the elasticity of I in the relevant region.

Case 2—Endogenous Ceiling

In the second case, $I_C < I_{A0}$. In Fig. 2.2, IR&D drops the marginal cost of investment only up to I_{C0}; nothing changes beyond this level. Hence, the Case 1 argument would suggest that IR&D policy would not affect private expenditure. But suppose the contractor can do something to change the ceiling, I_C.

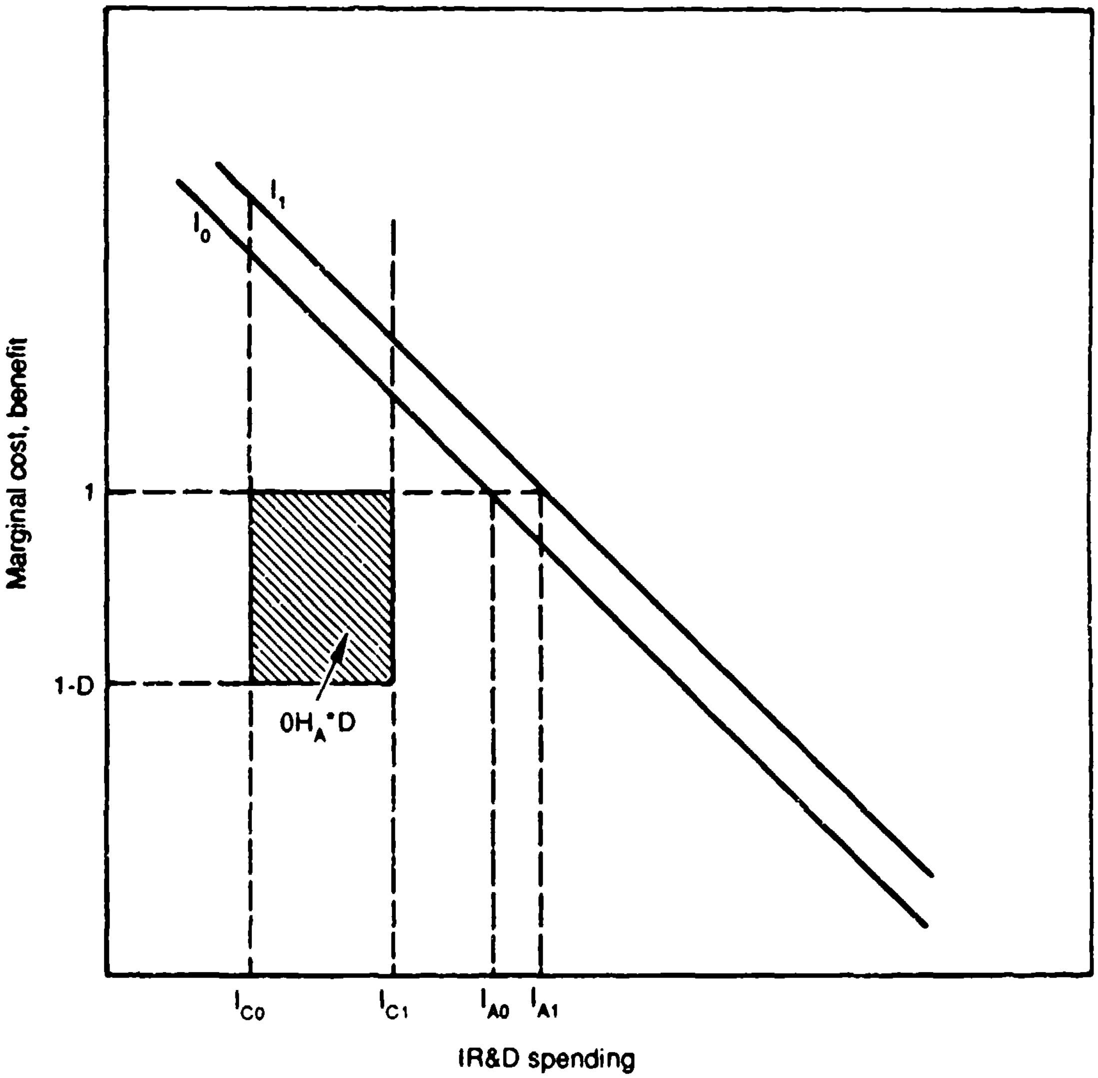

Fig. 2.2—Binding ceiling: effective subsidy of defense sales

Suppose, for example, that the negotiation process that yields the ceiling is designed to define it as the product of some arbitrary overhead rate (OH_A) and projected defense sales ($I_C = OH_A*Sp$).[5] DOD reimburses contractors for B&P in a manner something like this, and one might reasonably expect similar reimbursement for IR&D. To the extent that the contractor can influence Sp, it can increase its ceiling and its reimbursement. In this case, IR&D policy probably creates a direct incentive for the contractor to expand defense sales.

If a dollar of extra actual sales tends to raise projected sales by a dollar over time, it then increases the ceiling by $OH_A =$ [illegible] I_{C0}. It increases reimbursement by OH_A*D. As long as the ceiling remains below I_{A0}, this change can only affect private spending on IR&D through a scale effect that increases the value of IR&D as firm sales grow. That is, over time, it would tend to shift the investment schedule from I_0 to I_1, inducing a shift from I_{A0} to I_{A1} in Fig. 2.2. To understand the magnitude of this long-run effect, we need to know OH_A, the elasticity of the contractor's supply and demand schedules for defense sales, and the scale elasticity of the firm's demand for IR&D.

Alternatively, suppose the negotiation process that yields the ceiling makes the ceiling responsive to actual private spending on IR&D. For example, suppose the negotiation process that yields the ceiling defined it as a fraction (F) of projected private expenditures on IR&D (I_P). To the extent that the contractor can influence I_P, it can increase its ceiling and its reimbursement. In this case, IR&D policy probably creates a direct incentive for the contractor to expand its IR&D expenditures.

If a dollar of extra IR&D expenditures tends over time to raise projected expenditures by a dollar, then it increases the ceiling by $F = I_{C1} - I_{C0}$ in Fig. 2.3 and reimbursement by $F*D$. The contractor must spend its own money to support such an expansion. It will be willing to spend an extra dollar as long as it expects this to yield at least $V = 1 - F*D$ on returns from the investment in IR&D. This points to a marginal subsidy of IR&D that would induce an expansion from I_{A0} to I_{A1}.[6] To understand the magnitude of this long-run effect, we need to know F, D, and the elasticity of I in the relevant region.

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[5]C. Robert Roll, Jr., of RAND suggested this mechanism and the accompanying analysis.

[6]Proponents of IR&D policy stress that DOD's program for promoting IR&D does not use direct subsidies. This Note uses the word "subsidy" in a traditional economic sense. A subsidy exists whenever policy reduces the effective private cost of an activity relative to its private value, thereby creating an incentive to increase the level of this activity.

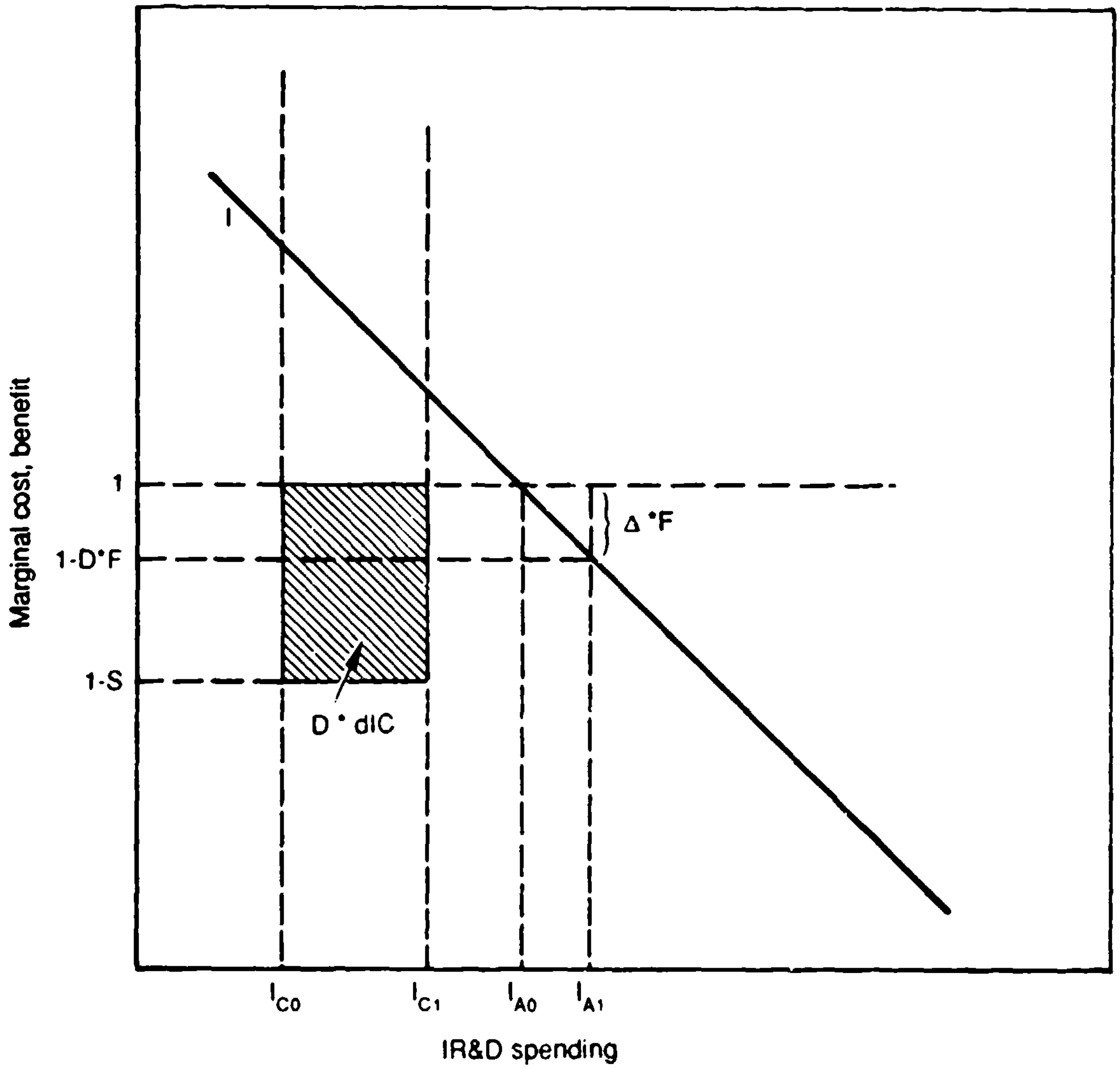

Fig. 2.3—Binding ceiling: effective direct subsidy of IR&D

The negotiation process can take many forms. When the ceiling binds, this discussion tells us that the way IR&D policy affects private spending on IR&D depends heavily on the nature of the negotiation process. The examples offered here are only two among many possibilities.

DISCUSSION

Each of these cases differs from the others. In fact, the studies to date of IR&D have not attempted to parse and quantify all of these effects. Either they have been selective in which effects they addressed or they have approached the problem at a much higher level of aggregation. We can use the analysis in this section to place the studies reviewed in perspective. Let us turn to those studies now.

III. THREE EMPIRICAL STUDIES OF IR&D

Three recent empirical studies examine how IR&D policy affects the level of private IR&D spending. Each views IR&D in a very different way. This section compares the three papers, using the simple economic model in Section II to suggest how to interpret the empirical results that each presents.

BROCK: NEOCLASSICAL STATIC APPROACH

Brock essentially posits that contractors cannot affect the ceilings that they face, and it focuses on an environment like that in Case 1, above, to explain the way in which IR&D policy affects contractor behavior. It uses IR&D data on 37 firms over the 19-year period from 1963 to 1981. During this period, 55 percent of the firms spent more on IR&D than their negotiated ceilings. That is, 45 percent of the firms operate in an environment like that in Case 1, and the study effectively concentrates on them to detect an effect.

Brock uses a neoclassical production model to establish the specification for its econometric work. It posits that a firm's real private spending on IR&D is a function of:

- Output factors, including the firm's real defense (+) and nondefense sales (+) and the proportion of *all* defense contracts let as fixed-price contracts (+)[1]
- Input price factors, including the interest rate (-) and the firm's share of defense sales in total sales (+), which indicates the level of IR&D subsidy in a Case 1 environment
- Other factors, including a dummy indicating whether the firm's IR&D spending exceeds its ceiling (-), industry dummies, and the total value of R&D contracts awarded to the firm (+).[2]

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[1]Signs in parentheses indicate the expected direction of effect for each independent variable. Brock argues that contractors can more easily recover their investments in IR&D through fixed-price contracts than through alternative forms of contracts. Only DOD-wide data are available for this variable.

[2]IR&D and other research are often thought to be complementary.

In its econometric work, Brock uses all of these variables, including real private spending on IR&D, in logarithmic form.

Significantly, Brock makes actual investment in a year--not desired capital stock—the dependent variable in its analysis, as we might expect in a neoclassical setting. As a result, the Brock model has no dynamic elements in it. It seeks short-run effects that occur within a year. Brock also uses defense sales as a share of total firm sales to define the subsidy that it analyzes. In fact, DOD negotiates with divisions of firms, suggesting that defense shares within these divisions—and hence subsidies—could be much larger than Brock's approach would suggest. To the extent that using an inappropriate defense share leads to measurement error, the study will yield low estimates of this effect.[3]

Brock uses this model to specify a variety of econometric models. In general, its models have high explanatory power ($R^2 > .9$), and Brock finds that defense and nondefense sales and the IR&D "subsidy rate" have highly significant positive effects. Results on the other variables are mixed. The results for the "ceiling" dummy are disappointing. Given its emphasis on Case 1 and the absence of any contractor control over the ceiling, we would expect Brock to interact the subsidy and ceiling dummy to eliminate this "price" effect when a firm exceeds its ceiling. Perhaps if Brock had tested this form, its results for the ceiling dummy would be more nearly consistent with its expectations. Its estimate of the subsidy effect would also probably be higher, since the current specification averages the responses of firms technically with and without a marginal incentive to react to the subsidy.

LICHTENBERG: DYNAMIC MODEL OF GOVERNMENT BEHAVIOR

Lichtenberg approaches IR&D policy quite differently from Brock. It uses data on 275 negotiating units during the period 1985-1986, when most units spent more on IR&D than their ceilings. If Lichtenberg used a model like Brock's, we would expect little private response to IR&D policy. Instead, Lichtenberg posits a model based on Case 2, in which the ceiling binds for a firm, but the firm can influence the level of its ceiling. The study focuses on the extent of this influence.

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[3]It might be argued that, to the extent that the relevant defense shares are systematically higher than those Brock reports, Brock will yield high estimates of the effect of the DOD subsidy on private IR&D spending. Brock's log-log specification eliminates this effect on the coefficient of defense sales. This effect will bias the constant in the equation estimated. This effect need not concern us.

Lichtenberg posits two models. In the first, the ceiling negotiated in any period is a fraction of the amount the government expects the firm to spend on IR&D in that period. This model is consistent with our second example in Case 2. The use of a model of expectation formation based on distributed lags of past expenditures and the implementation of a Koyck transform yields a simple dynamic model. The negotiated ceiling this period is a function of:

- The negotiated ceiling last period (+)
- Private spending on IR&D last period (+).

In the second model, the government adjusts the ceiling up from one year to the next by an amount equal to a fraction of the difference between private spending in the first year and the ceiling in the first year. This yields the same dynamic econometric model as the first model, but imposes a constraint on its coefficients that can be tested. Lichtenberg does not employ company or industry dummies; the other two papers do. Hence, Lichtenberg attempts to explain variation across industries and firms, while the other papers tend to limit their examination to variation within industries or firms.

Lichtenberg estimates these models for IR&D and B&P separately and together. The study yields highly significant results with great explanatory power. A test of the constrained coefficients leads Lichtenberg to prefer its first model to its second. As we shall see in a moment, a more complete model would ask how private firms react to such government behavior. The private reaction is likely to involve a dynamic process that should be considered simultaneously with the process that Lichtenberg focuses on. This raises the possibility that its simple econometric models may not be properly identified.

ALEXANDER ET AL.: DYNAMIC MODEL OF GOVERNMENT AND PRIVATE BEHAVIOR

Alexander et al. examines a wide range of policy issues relevant to IR&D. I will focus on the results relevant to the comparison at hand—how DOD policy affects private spending or IR&D. Alexander et al. uses data on about 70 firms for the period 1969-1985. This period overlaps the periods studied in the first two papers and, in a sense, we can think of the Alexander et al. paper as a kind of hybrid of the first two.

Like Lichtenberg, Alexander et al. accepts the notion that private firms can influence their ceilings and models this similarly to Lichtenberg. Alexander et al. states that the maximum amount that DOD *wants* to pay a "business unit"—the product of its negotiated ceiling and the share of defense sales in its total sales—in a given year is a function of the unit's actual IR&D expenditures in that period, as well as other factors. Alexander et al. then posits that the ratio of this maximum between two years is positively related to the ratio of the desired maximum in the second year to the actual maximum in the first. This yields an econometric specification similar to Lichtenberg's. The maximum in a year is a function of:

- The actual expenditure on IR&D in that year (+)
- The maximum in the previous year (+)
- Other factors.

Again, this formulation posits a behavioral response like the second example in Case 2, above.

Unlike Lichtenberg, Alexander et al. also recognizes a parallel behavioral relationship through which business units adjust their actual spending on IR&D in response to changes in the DOD maximum. In fact, it posits a wholly analogous specification in which private expenditure on IR&D in a year is a function of:

- The DOD maximum payment for that year (+)
- The private expenditure on IR&D in the previous year (+)
- Other factors.

Alexander et al. does not explain the basis for this behavioral response in any detail. Discussion in the paper strongly suggests the second example in Case 2. But the econometric approach Alexander et al. takes could capture the behavioral effects for business units in any or all the cases posed in Sec. II. This makes it extremely difficult to interpret the results of this paper in terms of specific behavioral responses and to compare them with the results of alternative approaches.

Alexander et al. uses a wide range of specifications, modeling IR&D and B&P together and separately, using business unit and aggregated firm data, using alternative time periods, and experimenting with time and firm dummies and a range of "other variables." It estimates these fully identified models with 3-stage least squares. The models consistently explain a high proportion of variance and yield highly significant coefficient estimates for DOD maximum, private expenditure, and the other variables most often included, defense sales and defense sales as a fraction of total sales.

DISCUSSION

The most striking thing about this simple comparison is how the three studies differ in their assumptions, approaches, and data sets. Table 3.1 summarizes these differences. Given the differences, we should not be surprised to see significant differences in their results. And we should not necessarily believe that differences in the results of the studies suggest that one study has better—more useful—answers than another. Rather, by attempting to understand the basis for their differences, we may be able to determine to what extent the studies yield mutually compatible results and what those results might mean.

Table 3.1

COMPARISON OF STUDIES

	Brock	Lichtenberg	Alexander et al.
IR&D or B&P	IR&D	Both	Both
Years of data	1963-1981	1985-1986	1969-1985
Number of firms in data	37	c. 100	70
Firms with binding ceilings	55%	Most	?
Behavioral relationships examined	Private	Government	Both
Relevant cases from Sec. II	Case 1	Case 2, Example2	Case 2, Example 2 for Govt; unclear for private

IV. A COMPARISON OF EMPIRICALLY MEASURED EFFECTS

The studies compared here yield two kinds of results pertaining to IR&D policy. First, they provide estimates of the extent of the *behaviorally relevant* subsidy that DOD provides for private IR&D spending. Second, they provide estimates of how much IR&D policy affects actual private spending on IR&D. Let us consider each in turn.

BEHAVIORALLY RELEVANT SUBSIDIES

Over the period covered jointly by the three studies, DOD has reimbursed 34 to 53 percent of contractors' private expenditures on IR&D; the rate is currently in the low 40s. But this average subsidy rate is not the key to understanding the behavioral effects that these studies address. The subsidy rate relevant to Brock is a negotiating unit's share of defense business in total sales. That relevant to Lichtenberg and Alexander et al. is the amount by which government reimbursements increase in response to a one dollar increase in private spending on IR&D.

Brock

Brock does not report the values of the defense share that it used to measure the behaviorally relevant subsidy rate. For the period 1969-1981, in which its data overlap with Brock's, Alexander et al. reports the following shares for business units. Recall that these will tend to exceed Brock's figures, because the Brock figures presumably include all nondefense sales, not just those associated with a relevant business unit. The ratio of total defense sales to total sales for the whole sample varies from 49 to 64 percent over time; the mean share in the sample varies from 66 to 74 percent; the median share varies from 71 to 83 percent. Values for more recent years are comparable to these. While these values substantially exceed the average subsidy, they apply only to the 45 percent of Brock's sample that has not exceeded its ceiling.[1] The remainder receive no subsidy at the margin.

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[1]None of the studies offers evidence that would tell us whether firms with higher shares of defense sales are more or less likely to exceed their ceilings.

Lichtenberg

Lichtenberg seeks an entirely different number. It wants to know how much DOD will adjust a firm's ceiling in response to private spending on IR&D. It finds that DOD reimburses about 10 percent of private expenditures in the first year and about 37 percent over the long run. These numbers are much smaller than Brock's, but closer to the average, at least in the long run. With the significant discounting we would expect for risky investments, the effective subsidy could be significantly less than 37 percent.

Alexander et al.

Alexander et al. seeks essentially the same number that Lichtenberg seeks. While it does not report the estimated subsidy in the same form that Lichtenberg uses, we can easily calculate it. For IR&D alone, Alexander et al. finds that, at the margin, DOD reimburses about 10 percent of private expenditures in the first year and about 23 percent over the long run.[2] These are lower than Lichtenberg's and the average size of the subsidy. A simultaneous equations specification in Alexander et al. might have helped to isolate the effects sought here.

Results in Alexander et al. point to another potential subsidy. They show consistently, across all models, that an increase in defense sales increases DOD's reimbursement. This effect is consistent with the behavioral response posited in the first example of Case 2 in Sec. II. Recall that this creates an effective subsidy to defense sales only when a firm exceeds its ceiling. When this occurs, the subsidy to sales is 1.7 to 2 percent, the overhead rate used to recover IR&D over the period studied in Alexander et al.

Discussion

These estimates represent three very different concepts. The high subsidies to IR&D of 50 to 80 percent apply only to firms that have not exceeded their ceilings. These are not statistically based estimates; they reflect the structure of a neoclassical model of production and are based on directly observed shares of defense sales. The lower subsidies to IR&D of 10 to 40 percent apply only to firms that have exceeded their ceilings and seek to increase their ceilings by increasing their spending on IR&D.

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[2]To achieve this result, I calculated the short- and long-run elasticities from Eq. (3) in Table C.5; the short-run elasticity differs from that reported in the table. And I used the share of DOD reimbursement in total private IR&D spending for the Alexander et al. sample in 1985. For comparison with Lichtenberg, note that because of a difference in specification, we need not adjust the Alexander et al. elasticities for the share of defense sales in total sales.

The subsidy to defense sales also applies only to firms that have exceeded their ceilings. To the extent that different firms face different circumstances, presumably all types of subsidies could be operative at the same time. The main point here, however, is to understand that the principal differences in these estimates reflect differences in concept, not differences in data or estimation technique.

HOW IR&D POLICY AFFECTS PRIVATE SPENDING ON IR&D

Brock and Alexander et al. provide results that we can use to estimate the effects of IR&D policy on private IR&D spending. It is easiest to make the results comparable by approaching these results in the context that Alexander et al. uses and ask what effect we can expect from a one dollar increase in DOD reimbursement of private expenditure on IR&D.

Alexander et al.

Alexander et al. estimates this effect more or less directly. It estimates a relationship between total private spending on IR&D and DOD reimbursement which indicates that an additional dollar of DOD reimbursement will yield $0.70 of private spending in the first year and $2.20 over the long run.[3] We cannot identify the contributions of the individual channels that transmit this effect. But the analysis in Section II and the discussion of subsidies above suggests that government willingness to adjust the ceiling in response to increases in private spending on IR&D and defense sales plays a part. More direct reaction to the DOD treatment of the share of defense sales when a firm does not exceed its ceiling probably also plays a part. Brock measures this last effect; let us examine its results on this one effect.

Brock

Brock estimates an elasticity that we can use to estimate the effect of an additional DOD dollar on private IR&D spending. Let us examine first how to use this elasticity and then turn to Brock's estimates. Fig. 4.1 shows private IR&D spending on the abscissa and private costs and benefits on the ordinate. I is an investment schedule for IR&D. A firm chooses to invest up to I_{AO}, where the marginal value of investment just equals the private

[3]To achieve this result, I calculated the short- and long-run elasticities from Eq. (4) in Table C.5; the short-run elasticity differs from that reported in the table. And I used the total levels of private IR&D spending and DOD reimbursement for the Alexander et al. sample in 1985. The use of other equations in Alexander et al. yields similar results.

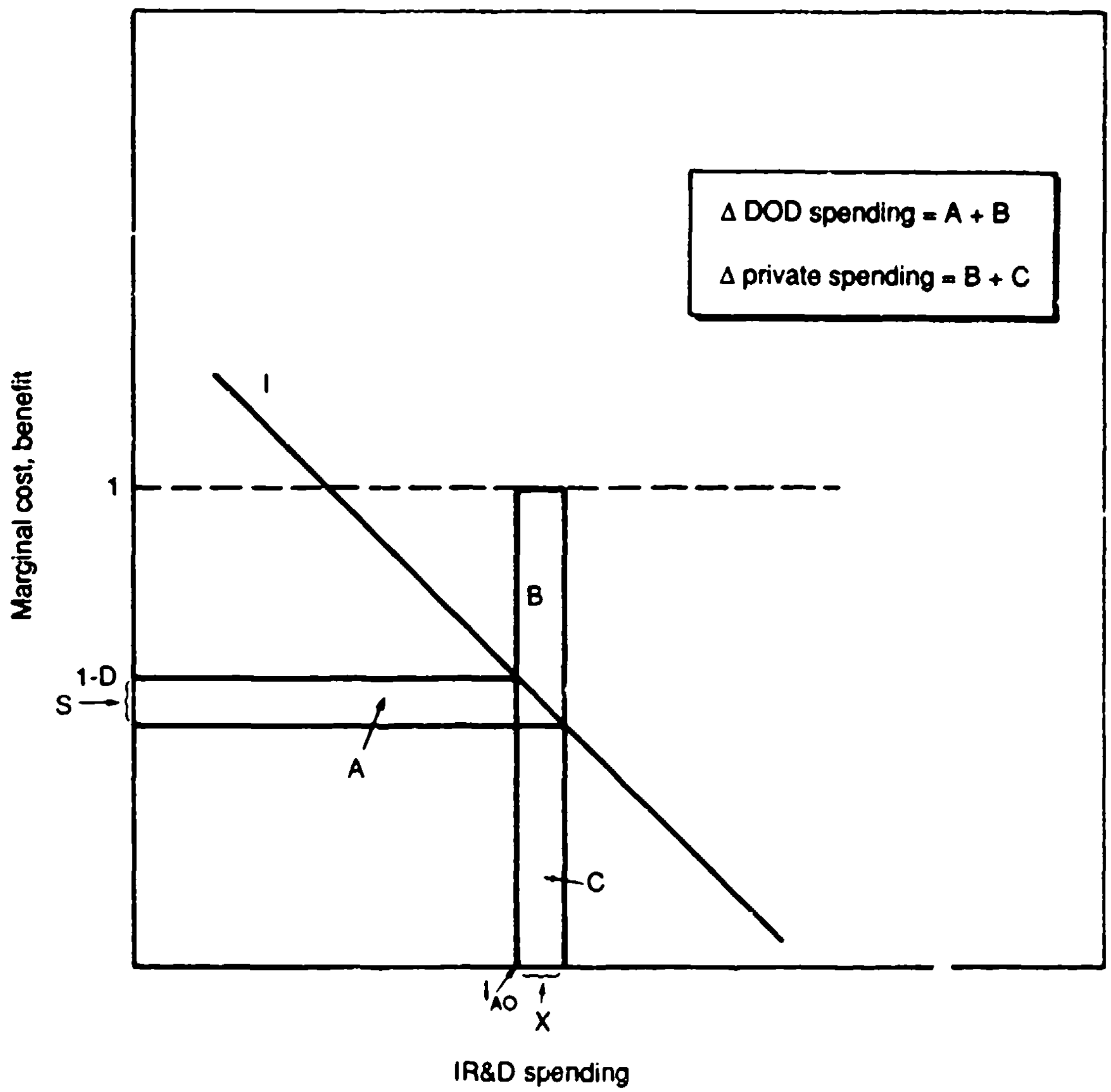

Fig. 4.1—How additional DOD reimbursement affects private spending on IR&D

cost of investing, one minus the share of defense sales in total sales. Call the elasticity of I at this point E and the level of investment I_{A0}. Now ask how much money DOD would have to spend to induce additional private spending. DOD would increase the subsidy by s, inducing an increase in private spending of $x = - E*I_{A0}*s/(1 - D)$. Fig. 4.1 identifies this quantity as the area B + C. To increase the subsidy by s, DOD must increase its outlay by $s*I_{A0} + x*D = s*I_{A0}*[1 - E/(1 - D)]$. In Fig. 4.1, this corresponds to area A + B. The marginal effect of an additional dollar of reimbursement, then, is the ratio of the private response to the marginal government outlay, $- E/(1 - D - D*E)$.

We can estimate the relevant effect by using Brock's estimates of E and appropriate values of D. For 1985, D falls in the range of .67 to .79. Brock reports short-run values of E in the range of -0.35 to -0.20. These imply that an extra dollar of DOD reimbursement generates $0.43 to $0.71.[4]

Discussion

The short-run estimate of $0.70 in Alexander et al. lies at the upper end of the range suggested by Brock's estimates. Brock's results, however, apply to only some of the firms relevant to the results reported in Alexander et al. Brock's results apply only to firms that have not exceeded their ceilings; the behavior of all contractors contributes to the results in Alexander et al. Hence, simple consistency in their results should not be expected and is not in itself informative. If the portion of the effect in Alexander et al. explained by Case 1 in Sec. II—the case of the unconstraining ceiling—is consistent with Brock's results, what magnitudes of other effects—for example, effects explained by Case 2—would be required to achieve Alexander's results? The simple answer is that, in the short run, they would have to be somewhat larger than the effect explained by Brock. That is, if firms whose IR&D expenditures exceed their ceiling respond more to government spending than the firms that Brock studies, then an effect for the firms Brock studies that falls in the center of its range would be consistent with the results of Alexander et al. What can we say about other effects that might be reflected in Alexander's results?

We want to consider effects that come from government decisions to change a firm's ceiling in response to its actions, effects addressed in Case 2 in Sec. II. The first example is unlikely to create a large effect. A change in the overhead rate of 1 percent might induce a 0.5 percent increase in output. Linear homogeneity of production would induce a 0.5 percent increase in IR&D. Because sales are 50 times the size of IR&D, the firm would spend only one extra cent on IR&D for every dollar that DOD reimbursed in this way.[5]

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[4]Keep in mind that this range takes Brock's results at face value. It does not reflect concerns about Brock's definition of share of defense sales or its specification of the relationship between the subsidy effect and the effect of a constraining ceiling. If these problems were properly addressed, the range shown here could easily shift. We cannot predict the direction of such a shift.

[5]If the elasticity of demand for defense sales is E_D and the elasticity of supply is E_S, a one percentage point change in the overhead rate will change output by approximately $- E_D * E_S/(E_S - E_D)$. Hence if both elasticities are (in absolute value) unity, a one percentage point change shifts output 0.5 percent and, with linear homogeneity, shifts IR&D 0.5 percent. If defense sales is S_A, then IR&D is $.02 * S_A$, a one percentage point change costs DOD $.01 * S_A$, and the effect on IR&D is $.0001 * S_A$. The result in the text follows. It is obviously sensitive to the choice of E_D and E_S. But the effect will be small no matter what reasonable choice is made.

The second example in Case 2 may appear more promising, but it is not. The size of effect depends on whether DOD can treat portions of a business unit's activity differently. Let us start by assuming that it cannot. In this case, DOD implicitly agrees to increase a contractor's ceiling if it increases its total spending on IR&D. Recall from Sec. II that DOD's agreement to increase the ceiling by F for every extra dollar of private spending on IR&D leads the contractor to expand investment to the point where the last dollar invested yields V = 1 - D*F.

Now suppose the government changes its policy by increasing F and signals this change by increasing its reimbursement for earlier investments. If I_{CE} is the ceiling that a contractor expected for a given year, the cost to DOD of changing policy this way in this year is $D*I_{CE}*(\Delta F/F)$. The policy changes the value that contractors use as a hurdle rate by $- D*\Delta F$; this change, in turn, implies a change in private spending of $- E*(I_A/V)*D*\Delta F$. The ratio of private to government spending changes associated with this policy is then $- E*(I_A/I_CE)*F/V$.

This change will tend to be small for the following reason: Any change in F will have much larger effects on the cost to DOD, where the change in F must be applied to all previous private investment than on the contractor's expenditure, where a change in F has a small effect on V and hence a small effect on the contractor's incentives.

To see this, let us consider the effects of a hypothetical 1 percentage point change in F. To do so, assume the following parameter values: Let E = -0.3, in the middle of Brock's range. Use 1985 values of I_A and I_C in Alexander et al.'s sample to calculate I_A/I_{CE}. Use 0.1, the one-year subsidy estimated by both Lichtenberg and Alexander et al., to value F. Use a central value of D for 1985 of 0.7 from Alexander et al.'s sample. These imply a value of .93 for V. The effect on DOD cost is $246 million; the effect on contractor expenditure is $11 million. The one-year "multiplier" of DOD policy is 0.05; an extra dollar of DOD funds yields an extra 5 cents of private expenditure in the first year. The general magnitude of this outcome is not particularly sensitive to the parameter values used.

The analysis above assumes that DOD treats a negotiating unit in a unitary way. In fact, DOD negotiates separate IR&D overhead rates for each contract within a business unit and could potentially change its policy only for new contracts, leaving older contracts undisturbed. This reduces the cost to the government of changing policy by allowing DOD to focus its attention on only a fraction of a unit's IR&D activity. Unfortunately, this also reduces the effectiveness of DOD policy. In fact, focusing on individual contracts reduces the costs and effects of DOD policy proportionately, leaving the results above unaffected.[6]

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[6]To see this, let α_i be the share of a business unit's defense sales associated with the ith contract. Then a DOD decision to increase its reimbursement for IR&D within the

Only if DOD can reduce its own costs without reducing the effects of policy on private spending can it hope to increase this ratio. It could do this, for example, by disproportionately rewarding changes in private spending on IR&D and using a much higher value of F_i for changes in private spending than for the initial level of spending. Such "price discrimination" could induce much higher multipliers, but it is not sustainable over time.

If a high value of F_i applies only to annual increments, it provides no sustained incentive to new investment. If it applies permanently to any additions to investment beyond some point, government costs rise as private investment in IR&D rises over time, progressively eroding the multiplier. Either way, such policy would be hard to implement in a clear enough way in induce a response and could not sustain the incentive effect implied by a one-year analysis.

These calculations raise a serious question about the model specified by Alexander et al. The model posits a simple relationship in which an extra dollar of DOD expenditure today yields a significant private expansion of investment today and in the future. But the subsidy that IR&D policy creates when contractors spend more than their ceilings looks forward: DOD creates a subsidy by implicitly promising to increase government payments in the future if contractors act today. Such a subsidy cannot account for the result in Alexander et al. that DOD payments today yield private responses over time unless, as suggested above, DOD must signal changes in its policy by changing its treatment of past private expenditures. And the calculations above illustrate why such signaling cannot create a large private response relative to DOD spending. In fairness, Alexander et al. does not specify the channels through which government policy has its effect. Simply note that the possible channels explored here cannot explain it.

SUMMARY

The studies compared here estimate subsidy rates and the effects of these subsidies on how much private contractors spend on IR&D. They identify one subsidy rate relevant to firms that have not exceeded their ceilings. This rate differs dramatically by firm; its central tendency lies in the range of 50 to 80 percent of private IR&D spending. Another subsidy rate applies to private spending when contractors have exceeded their ceilings. The papers

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context of one contract ($\Delta F_i > 0$) increases DOD costs by $D*I_{CE}*\alpha_i*(\Delta F_i/F_i)$. But, in equilibrium, the unit will carry IR&D expenditures to the point where $V = 1 - \Sigma D*\alpha_i*F_i$. Hence, a change in F_i induces a change in private spending of $- E*(I_A/V)*D*\alpha_i*\Delta F_i$. Effects on DOD and private flows net out, leaving the ratio of these effects unchanged.

agree that this subsidy rate is about 10 percent if viewed with a one-year horizon and rises to the range of 20 to 40 percent over the long run. A third subsidy to defense sales may also be important when a contractor's ceiling binds. This is on the order of 2 percent.

Levels of effects are harder to pin down. Brock's results suggest that an extra dollar of DOD spending on firms that have not exceeded their ceilings will increase private spending on IR&D by 40 to 70 cents in the first year. Alexander et al. estimates that an extra DOD dollar spent on *all* contractors will expand private spending by 70 cents in the first year. For this result to be consistent with Brock's, we need to find a response by firms that have exceeded their ceilings equal to or slightly higher than Brock's results. The current studies do not allow us to find such a response, and basic economic models of firm behavior cannot deduce one from the available results. In sum, while a reasonable level of agreement exists about the levels of DOD-induced subsidies, significant questions remain about the effects of these subsidies.

V. CONCLUSIONS

DOD policy on IR&D is subtle and complex. Each of the papers compared here approaches it from a different perspective to keep this complexity manageable; when we view the papers together, we can appreciate the complexity of the policy they examine and conclude that a good deal remains to be done to understand its effects.

First, we need to understand better the channels through which IR&D policy acts on the level of private spending on IR&D. Brock's neoclassical approach offers enough structure to understand one particular aspect of IR&D policy—its effects on firms that do not spend more on IR&D than their ceilings; adjustments in the econometric specification of this model and perhaps in the data used to represent the IR&D subsidy could improve our understanding here. In recent years, more and more contractors appear to have spent more on IR&D than their ceilings, raising basic questions about how the Brock approach can inform current policy.

Alexander et al. focuses more on how policy affects contractors that spend more than their ceilings on IR&D, the contractors most relevant to current policy. The aggregate level of this analysis, however, severely constrains our ability to understand the results in Alexander et al. and put them in perspective relative to the results of other studies.

A model that reflects the dynamic approach of Alexander et al., but gives more attention to the structure on which Brock focuses, would add to our understanding. In particular, we would want a composite model that could explicitly test alternative hypotheses about the effects of IR&D policy, based on the following key hypotheses:

- For the most part, IR&D policy involves lump-sum grants that create few if any incentives for private contractors to expand investment in IR&D. The results reported to date reflect either spurious correlations or incentives that affect a minor proportion of total private spending.
- For the most part, IR&D policy creates lump-sum grants that empower R&D managers employed by private contractors to expand corporate IR&D funding. That is, the grants are essentially lump sums, but institutional arrangements within firms transform these lump sums into effective incentives.

- For the most part, IR&D policy creates effective marginal incentives to invest but does so only for contractors that spend less on IR&D than their ceilings.
- For the most part, IR&D policy does in fact raise ceilings in response to increased private spending on IR&D and this incentive has a large effect on even those contractors that spend more on IR&D than their ceilings.

Testing these hypotheses is important in and of itself to ensure that we understand the effects of this subtle policy; the current studies still leave us a good distance from this understanding. Testing them is also important because IR&D is under close scrutiny now and likely to remain so for the foreseeable future. We can expect repeated efforts to change IR&D policy; understanding more about its subtleties will allow policymakers to make changes that achieve goals important to them.

A basic difficulty of the current studies is that they do not start from an understanding that alternative hypotheses are viable *and they do not then design models explicitly to compare these hypotheses.* Properly approached, such comparisons could well involve variables not even mentioned here or in any of the studies reviewed. The key to this approach is analysis sensitive to behavioral alternatives and to the structure that must be understood to detect these alternatives. Such an approach will benefit from the studies reviewed here, but will probably have to step well beyond them.

The effect of IR&D policy on the level of private spending is not the only relevant object of policy analytic interest. While this comparison focuses on this aspect of IR&D policy, Alexander et al. points out that two other issues are at least as important: IR&D policy can potentially

- Help DOD hedge against the risk of relying too much on government officials to determine where R&D resources should go
- Help contractors transfer the products of their R&D from scientists to the engineers who will use these products to design weapons and other final products that contribute to the national defense.

Measuring how well IR&D pursues these goals is challenging, but it is important because IR&D potentially can contribute uniquely to these goals. Independent research inherently escapes the direct control of government officials and hence may help broaden the range of research that DOD can draw on; any other type of research faces the liability of government influence. And by encouraging the firms that intend to use IR&D to produce weapons actually to produce that IR&D, the policy facilitates the best known method of transforming science into concrete designs—getting the people who know the science to take it into the design process.

While IR&D is not the only approach to R&D funding that facilitates this transformation, we need to understand how unique aspects of IR&D contribute to this goal. It is particularly important to understand these effects—as well as how IR&D policy affects the level of private spending on IR&D—because ultimately DOD must consider how IR&D policy fits into its total plan to build the defense technology base and the products it generates.

In the end, the most difficult aspect of IR&D is how much its product is worth. Even if IR&D policy allows an extra dollar to generate significant new private expenditure on IR&D, the products of that expenditure need not be worth their cost. This is the ultimate problem addressed by defense resource allocation and getting answers relevant to IR&D policy is no easier than getting them for other issues of defense resource allocation. But in the end, it is a problem that all IR&D policy hangs on. Moreover, it will require a form of analysis very different from that presented in the papers compared here or suggested with regard to IR&D's effects on hedging and technology transfer.