The Private R and D Investment Response to Federal Design and Technical Competitions

Frank R. Lichtenberg

The American Economic Review, Vol. 78, No. 3 (Jun., 1988), 550-559.

Stable URL:
http://links.jstor.org/sici?sici=0002-8282%28198806%2978%3A3%3C550%3ATPRADI%3E2.0.CO%3B2-K

The American Economic Review is currently published by American Economic Association.

The Private *R&D* Investment Response to Federal Design and Technical Competitions

By FRANK R. LICHTENBERG*

It is the federal government's role to promote investment in research and development (*R&D*) that yields innovations in the production of public goods, such as armaments for national defense and equipment for space exploration. At first blush, it might appear that the government can bring about such *R&D* investment by a combination of only two institutional arrangements: (1) performing *R&D* in government laboratories; and (2) contracting with private firms and nonprofit organizations (such as universities) to perform *R&D*. Indeed, official estimates of the distribution of U.S. *R&D* by mission (defense versus civilian) are based on the assumption that only *R&D* conducted under these two arrangements is directed toward federal missions.[1]

The major thesis to be developed in this paper, however, is that there is a third, and quantitatively important, method by which the government promotes *R&D* investment relevant to the provision of social goods: awarding major contracts by a method of acquisition known as "procurement by design and technical competition." In essence, this method consists in the government's simply revealing its demand for certain types of technological innovations, and encouraging private firms to sponsor the necessary *R&D*, the costs of which the sponsor will recover from profits on the sale of the product. Edwin Mansfield (1971) has observed that before World War II, the government tended to issue relatively few *R&D* contracts to industry or universities. If the government wanted private firms to perform defense-related *R&D*, it would encourage them to finance it on their own.[2] Since the beginning of World War II, the real value of government *R&D* contracts has increased very rapidly, and contracting has apparently become the most important of the three methods used by the government to promote *R&D* investment related to social goods. But we shall provide evidence that the government continues to induce a considerable amount of privately financed, federal mission-oriented *R&D* expenditure by sponsoring design competitions.

We develop this evidence by estimating regressions of company-sponsored (private) *R&D* expenditure on the value of competitive and noncompetitive government contracts and on other (nongovernment) revenue. These regressions are estimated using annual firm-level panel data for the years 1979–84 (which spanned a major defense buildup) for a sample of 169 industrial companies. The coefficients of these equations are estimates of the marginal response of private *R&D* to changes in the volume of competitive and noncompetitive procurement and in nongovernment demand. We also distinguish between the effects on private *R&D* of government procurement of *R&D* and of non-*R&D* services and products.

Previous studies have suggested that federal (contract) *R&D* has a smaller (often

*Columbia University Graduate School of Business, 726 Uris Hall, New York, NY, 10027, and National Bureau of Economic Research. Financial support from the National Science Foundation (via grant PRA 85-12979 to NBER), and from the MacArthur Foundation Faculty Research Program at Columbia University, is gratefully acknowledged. Two anonymous referees provided helpful comments on an earlier draft. Donald Siegel provided capable research assistance. I am responsible for any errors.

[1]See National Science Board, 1985, p. 6.

[2]"For example, in the procurement of military aircraft, an open competition was held; the winning firm recovered its development costs in the form of profits on the sale of the airplanes, and the losing firms did not recoup their *R&D* investment" (Mansfield, 1971, p. 122).

insignificant) effect on various measures of economic performance such as productivity and profitability than privately financed *R&D*.[3] Because the social returns to *R&D* done in pursuit of the federal government's objectives may differ from the social returns to other *R&D* investment, measuring the extent to which private *R&D* is dedicated toward federal missions may lead to a better understanding of the contribution of *R&D* to U.S. economic growth.

The remainder of this paper is organized as follows. In Section I we briefly describe the design and technical competition method of contracting, consider why the government chooses to employ this method (instead of or in addition to *R&D* contracting), and review previous evidence on private, federal mission-oriented *R&D*. In Section II we discuss the specification and estimation of an econometric model for determining the private *R&D* investment response to competitive procurement and to other components of demand. Empirical results are reported in Section III, and Section IV contains a summary and concluding remarks.

I. Federal Design and Technical Competitions

A design and technical competition (henceforth abbreviated "design competition") begins "officially" when a federal agency (such as the Department of Defense) issues a formal Request for Proposals, which is often 1100 to 2500 pages long.[4] Three or four firms typically submit proposals (which may range from 23,000 to 38,000 pages in length) in response to requests issued by the Defense Department, which then begins an elaborate review process. The firm that submits the proposal receiving the highest "score" is generally selected as the contractor, and is essentially guaranteed (unless Congress decides to cancel the project) to be awarded a sequence of contracts for *R&D*, production, spare parts, maintenance, training, and so forth, over a number of years. The contracts that are initially awarded to the successful firm are officially designated as "competitive" contracts. But most of the revenue that the firm will receive by virtue of having won the competition will come from subsequent, "follow-on" contracts, which are officially designated as "noncompetitive" contracts. Table 1 indicates that in fiscal year 1984, the value of noncompetitive follow-on contracts after design competition was 2.72 times as large as the value of competitive contracts associated with these competitions. Because the winner of the design competition is virtually assured of eventually being awarded the relatively large follow-on contracts, it is often suggested that contractors are willing to incur losses (by "buying in," or submitting bids below anticipated costs) on the initial competitive contracts.

I think that it is natural to pose the question of *why* the government does promote mission-oriented *R&D* by sponsoring design competitions, in addition to doing so by directly contracting with firms to perform *R&D*. Perhaps the most compelling possible explanations are based on imperfect information considerations. A design competition appears to be an almost perfect example of a *contest*, in the sense defined by Barry Nalebuff and Joseph Stiglitz (1983) and others. In a contest, or competitive compensation scheme, the individual's reward or compensation (for example, whether he is awarded a contract) is determined only by his *rank* vis-à-vis his competitors, rather than by his "individualistic" output (or marginal product), as is the case in the classical model of pure price competition. These authors have shown that when the principal (in our case, the government) cannot directly and costlessly observe the level of input (effort) of the agents (contractors), rewards based on relative output are superior to payments based on individualistic output. They argue that competitive compensation schemes have "...greater flexibility and greater adaptabil-

[3] See, for example, Zvi Griliches and Frank Lichtenberg, 1984, and Griliches, 1986.

[4] Many analysts have noted, however, that potential contractors are aware of the government's interest in particular areas of technology, and attempt to influence the "shape" of government demand for innovations, long before the publication of Requests for Proposals. See, for example, Charles Danhof, 1968.

TABLE 1—DISTRIBUTION OF DEPARTMENT OF DEFENSE FISCAL YEAR 1984 NEGOTIATED COMPETITIVE AND NONCOMPETITIVE PROCUREMENT, BY METHOD

Method of Procurement	All contracts	*R&D* contracts[a]
Competitive		
Design and technical competition	11.6	4.4
Price competition	35.0	0.4
Noncompetitive		
Follow-on after design and technical competition	31.6	4.6
Follow-on after price competition	4.1	0.1
Catalog or market price	0.9	b
Other noncompetitive	34.3	3.9
Total, all methods	117.6	13.4

Source: Department of Defense (1985). All figures in billions of dollars.
[a]Contracts citing statutory authority 10 U.S.C. 2304(4)(11) ("experimental, developmental, test, or research") as their authorization for exception to the requirement for formal advertising.
[b]Less than $0.05 billion.

ity to change in the environment than do other forms of compensation" (p. 41), so that contests may be preferred when the risk associated with common environmental variables (for example, the difficulty of achieving technical progress in a given area) is large. Moreover, "the use of a contest as an incentive device can induce agents to abandon their natural risk aversion and adopt 'riskier' and more profitable production techniques" (p. 23).

Inability of the principal to monitor the (relative) ability, or productivity, of various agents, is a second type of imperfect information which may render competitive compensation schemes optimal. Suppose that both government contracts and potential contractors are heterogeneous, in the sense that one firm is more qualified to perform a given contract than other firms, but that the government is uncertain about the identity of the most qualified supplier. A number of theoretical models of markets characterized by this kind of imperfect information show that it is equilibrium behavior for sellers to invest in acquiring, and for buyers to rely on, *signals* of quality and ability.[5] It may be useful to interpret design competitions as signaling phenomena, in which the signal of contractor ability that the government relies on is the score on the technical proposal.

Factors other than imperfect information about contractor effort and/or ability may account for the existence of design competitions. For example, judging from periodic congressional hearings and reports on the subject (see, for example, U.S. Congress, 1969), there is strong congressional demand for competition in procurement, perhaps because Congress believes that competitive procurement promotes economic efficiency or fairness. The recent passage of the Competition in Contracting Act also reflects this demand.

Existing evidence concerning private investment in federal mission-oriented *R&D* is limited and fragmentary; we are not aware of any previous *econometric* evidence. Aside from case studies and anecdotal evidence concerning company proposal efforts related to specific design competitions,[6] we are familiar with only two pieces of evidence. The first consists of financial data on Independent Research and Development published by the Defense Department.[7] Inde-

[5]See, for example, A. Michael Spence, 1984; and Richard Kihlstrom and Michael Riordan, 1984.

[6]See, for example, Edward Roberts, 1969.

[7]For a detailed discussion of Independent *R&D*, see my paper, 1986, and Judith Reppy, 1977.

pendent *R&D* is contractor-initiated and contractor-directed technical effort that is not sponsored by, or required in performance of, a contract or grant. The Defense Department recognizes independent *R&D* as a necessary cost of doing business and reimburses contractors for a fraction (on average, about 40 percent) of independent *R&D* costs. But the Defense Department and its contractors regard *all* independent *R&D* expense as "company-funded" *R&D*, and contractors generally report is as such in the *National Science Foundation Survey*, which is the basis for the official estimates of industrial *R&D*. The Defense Procurement Regulations specify that in order for the costs of a project to be eligible for reimbursement, the project must have a "potential military relationship" to Defense Department functions and operations. In 1983, major defense contractors reported having incurred $3.9 billion in independent *R&D* costs; this represents 9.2 percent of the National Science Foundation's estimate of $42.6 billion for "company-funded" *R&D* in that year.

The second piece of evidence is provided by F. M. Scherer's (1984) analysis of "linked" *R&D* and patent data of the largest *R&D*-performing companies. Scherer attempted to classify each of about 15,000 U.S. patents (obtained by 443 companies between June 1976 and March 1977) by "industry of use," that is, to identify the sector(s) of the economy in which (most intensive) use of the invention was anticipated. Two of the industries of use defined by Scherer were "defense and space operations" and "government, except postal and defense." He estimated the value of company-sponsored *R&D* "used" by these sectors to be $1206.3 million and $378.7 million, 11.3 and 3.6 percent, respectively, of the total amount of company-funded *R&D* ($10.64 billion) attributed to these companies.[8] Thus, according to Scherer's methodology, the federal government is the primary beneficiary of about 15 percent of company-sponsored industrial *R&D* expenditure.

II. Econometric Specification and Estimation Issues

Our research design for measuring the private *R&D* investment response to government procurement in general, and design competitions in particular, is to estimate, using longitudinal firm-level data, regressions of private *R&D* expenditure on three variables: the value of the firm's competitive contracts, of its noncompetitive contracts, and of its nongovernmental sales. (The sum of these three variables is total sales.) The coefficient of the first variable is our primary concern; we include the other two mainly to "control" for their influence and to provide benchmarks against which to measure the effect of competitive procurement.

As Table 1 reveals, there are two types of competitive procurement: design and technical competition, and price competition. Unfortunately, we cannot distinguish at the firm level between the two types of competitive contracts; we observe only the *sum* of the two.[9] Because price-competitive procurement is hypothesized to elicit less private *R&D* than design-competitive procurement, the coefficient on competitive contracts may perhaps be regarded as a lower-bound estimate of the effect of design-competitive procurement.

For several reasons—omitted variables, simultaneity, and errors in variables—the right-hand side variables may be correlated with the disturbance of the regression described above, so that ordinary least squares estimates may not be consistent. If omitted variables were the only problem, *and* if those variables were constant over t for a given i, then we could obtain consistent estimates by including a dummy variable for each firm,

[8] These estimates were obtained using what Scherer termed the "private goods" assumption, according to which a patent (and its associated *R&D* expenditure) benefited (was assigned to) only one, rather than several, industries of use.

[9] We can and do distinguish, however, between *R&D* and non*R&D* competitive contracts. This is helpful because most competitive *R&D* contracts are awarded by design competition, whereas most competitive non-*R&D* contracts are awarded by price competition.

TABLE 2—SAMPLE AGGREGATES AND COMPARISON NATIONAL DATA

	Aggregates for Sample of 169 Firms			
Year	Company-Sponsored *R&D* Expenditure	Sales	Value of Federal Contracts	Value of Federal *R&D* Contracts
1979	17.4	732.8	38.3	7.0
1980	20.1	807.3	43.0	7.8
1981	23.0	887.5	52.6	8.3
1982	25.6	877.6	66.6	12.1
1983	28.0	908.6	72.7	13.5
1984	33.3	968.7	78.9	14.8
	U.S. National Data			
Year[a]	"Company and Other Funds for *R&D*"[b]	Sales[c]	DoD Prime Contract Awards[d]	"Federal Funds for *R&D*"[b]
1979	25.7	1215.0	58.5	12.5
1980	30.5	1427.6	66.7	14.0
1981	35.4	1589.2	87.2	16.4
1982	39.5	1479.3	102.5	18.5
1983	42.6	1596.5	121.1	20.2
1984	47.3[e]	[f]	124.9	22.0[e]

[a] All data except Defense Department contracts on calendar-year basis; contract awards on a fiscal-year basis. All amounts in billions of dollars.
[b] *Source:* National Science Board, 1985, Appendix Table 4-4.
[c] Net sales of *R&D*-performing manufacturing companies. (*Source*: National Science Board, 1985, Appendix Table 4-7.)
[d] Department of Defense Prime Contract Awards to Businesses for Work in the U.S. (Source: Department of Defense, 1985, Table 3).
[e] Estimated.
[f] Not available.

that is, by using a fixed-effects or "within" estimator. But the omitted variables may not be time-invariant, the within estimator does not eliminate possible simultaneous-equations bias, and it is likely to exacerbate biases due to errors in variables.[10] Fortunately, however, under reasonable assumptions we can address all three of these potential specification errors by estimating the model using instrumental variables. Below we report both ordinary least squares and instrumental variables estimates of "total" (excluding fixed-firm effects) and "within" versions of the model. We should perhaps pay the most attention to the instrumental variables total estimates; using instrumental variables with fixed effects is superior only if the instruments are endogenous with respect to the omitted time-invariant characteristics, a possibility which seems unlikely to pose a serious problem.[11]

Because the model we estimate is a relationship among *levels* (rather than logarithms or ratios) of variables, the disturbances are likely to be heteroskedastic. In order to eliminate the heteroskedasticity we performed *weighted* least squares and instrumental variables estimation, using the reciprocal of total sales as the weight. We tested for homoskedasticity using the statistic proposed by Halbert White (1980); in all

[10] See Zvi Griliches and Jerry Hausman, 1986.

[11] The instruments used for the regressors of the model are described in the Data Appendix.

cases the χ^2 statistic was much lower than the critical value for rejecting homoskedasticity.

III. Empirical Results

Variants of the model were estimated on annual 1979–84 panel data for 169 industrial firms. The construction of the data base is described in the Data Appendix. Sample aggregate values of selected variables and comparison national data are presented in Table 2. The data reflect the major defense buildup which occurred during this period: the value of federal contracts more than doubled, whereas total sales increased by only about 35 percent.

The estimates are presented in Table 3. Panel A of the table displays estimates of the model in which the coefficients on competitive and noncompetitive procurement are constrained to be equal. This model is useful for developing an estimate of the fraction of the total "induced" increase in private *R&D* accounted for by the increase in government procurement. Because the instrumental variable total estimates are most likely to be consistent and efficient, we focus mainly on these estimates. These imply that a $1 increase in government sales tends to induce a 9.3-cent increase in private *R&D* while a $1 increase in nongovernment sales induces only a 1.7-cent private *R&D* increase. The difference between these two coefficients is highly significant: $F_{1,1006} = 31.6$ (P-value = .0001).[12]

These estimates enable us to compute the fraction π of the total induced increase in private *R&D*-induced by the increase in government procurement.[13] The point estimate (standard error) of π is .528 (.050). The point estimate implies that slightly over half of the total induced increase in private *R&D* between 1979 and 1984 was induced by the increase in government sales; the limits of the .95 confidence interval on this share are .430 and .626.

Panel B of Table 3 presents unconstrained estimates of the model. The difference between the coefficients on competitive and noncompetitive contracts is positive and highly significantly different from zero for all estimation techniques except ordinary least squares total, in which case it is negative and insignificant. The magnitude of the difference increases as we move across the columns from left to right. The total instrumental variables estimates suggest that a $1 increase in competitive procurement induces a 54-cent increase in private *R&D* expenditure. As noted earlier, the prospect of substantial future noncompetitive follow-on contracts awarded to the winner of the design competition makes firms willing to make *R&D* investments which are large, relative to the value of the initial competitive contracts. The coefficient on noncompetitive contracts is negative but insignificant, suggesting that the entire stimulus to private *R&D* from government procurement comes from competitive acquisition.

The remainder of the empirical analysis is devoted to extending and amplifying the major finding that a considerable quantity (and share) of private *R&D* investment is induced by competitive procurement. The *timing* of private *R&D* investment, relative to the award of contracts, is the issue we address first. The regressions reported above are of company-funded *R&D* on *contemporaneous* sales classified by type. It is natural to hypothesize, however, that some private *R&D* expenditure is made by firms in years prior to the year in which competitive contracts are awarded. To investigate this hypothesis, we estimated the model including also values of the regressors in year $t+1$; these estimates are shown in panel C. In all four columns, the coefficient on future competitive contracts is almost as large as or larger than the coefficient on current competitive contracts; the future coefficient is always more significant. The instrumental variables total estimates imply that most of the long-run response of private *R&D* to

[12] In the case of the instrumental variable within estimates, the difference is not significant: $F = 0.3$.

[13] $\pi \equiv \gamma_1 \Delta G/(\gamma_1 \Delta G + \gamma_2 \Delta N)$, where ΔG denotes the change in government sales, ΔN denotes the change in nongovernment sales, and γ_1 and γ_2 are the coefficients on G and N, respectively. As shown in Table 2, the sample aggregate values of ΔG and ΔN over the period 1979–84 were $40.6 and $195.3 billion, respectively.

TABLE 3—ORDINARY LEAST SQUARES AND INSTRUMENTAL VARIABLES ESTIMATES OF WEIGHTED TOTAL AND WITHIN REGRESSIONS OF COMPANY-FUNDED *R&D* ON SALES CLASSIFIED BY TYPE
(*t*-Statistics in Parentheses)

	Ordinary Least Squares		Instrumental Variables	
Independent Variables	Total	Within	Total	Within
	A			
Government Contracts	0.046	0.050	0.093	0.027
	(10.3)	(9.95)	(7.12)	(1.08)
Nongovernment Sales	0.027	0.034	0.017	0.041
	(33.4)	(20.4)	(7.46)	(6.38)
	B			
Competitive Contracts	0.039	0.105	0.544	0.694
	(1.79)	(6.38)	(4.85)	(2.57)
Noncompetitive Contracts	0.048	0.041	−0.040	−0.153
	(6.53)	(7.12)	(1.06)	(1.74)
Nongovernment Sales	0.027	0.034	0.017	0.038
	(33.4)	(20.2)	(6.35)	(3.31)
	C			
Competitive Contracts (t)	−0.044	0.062	0.085	0.300
	(0.96)	(3.23)	(0.35)	(1.05)
Competitive Contracts ($t+1$)	0.072	0.056	0.400	0.498
	(1.77)	(3.56)	(1.85)	(1.55)
Noncompetitive Contracts (t)	0.033	0.031	0.097	−0.012
	(1.42)	(3.79)	(0.84)	(0.11)
Noncompetitive Contracts ($t+1$)	0.015	0.007	−0.116	−0.193
	(0.73)	(0.93)	(1.13)	(1.14)
Nongovernment Sales (t)	0.002	0.022	−0.026	−0.001
	(0.35)	(11.0)	(0.87)	(0.03)
Nongovernment Sales ($t+1$)	0.022	0.009	0.040	0.044
	(4.33)	(4.67)	(1.43)	(1.82)
	D			
Competitive *R&D*	−0.048	0.085	0.857	0.174
	(1.29)	(1.87)	(1.01)	(0.08)
Noncompetitive *R&D*	0.156	0.005	−2.113	−1.683
	(3.09)	(0.17)	(2.18)	(1.24)
Competitive non-*R&D*	0.072	0.123	1.212	1.077
	(2.07)	(6.05)	(3.89)	(1.80)
Noncompetitive non-*R&D*	0.036	0.046	−0.074	−0.050
	(4.05)	(6.42)	(0.96)	(0.32)
Nongovernment Sales	0.027	0.034	0.016	0.037
	(33.5)	(20.2)	(3.53)	(2.03)
	E			
R&D Contracts	0.039	0.047	−0.476	−0.930
	(1.98)	(2.56)	(2.63)	(2.05)
Non-*R&D* Contracts	0.048	0.051	0.151	0.134
	(7.09)	(7.92)	(7.14)	(1.94)
Nongovernment Sales	0.027	0.034	0.017	0.040
	(33.4)	(20.4)	(5.73)	(3.04)

Note: All regressions include year dummies. The within regressions also include firm dummies; the total regressions do not. The weight used is the reciprocal of sales.

competitive procurement is a response to future procurement. The fact that the sum of the t and $(t+1)$ coefficients in panel C is close to the corresponding t coefficient in panel B suggests that the purely contemporaneous version of the model provides reasonable estimates of the long-run responses. Since the coefficient standard errors are much lower in this version, we henceforth exclude leading values of the regressors.

The second extension we consider concerns the distinction between *R&D* and non-*R&D* government contracts. Previous econometric studies of the effect of government procurement on private *R&D* investment have examined the effect only of *R&D* contracting, and not of contracting for non-*R&D* services and products.[14] Moreover, these studies have not distinguished between competitive and noncompetitive procurement of *R&D*. For both reasons, the models upon which these studies were based may have been misspecified and the empirical results, misinterpreted. In panel D we present estimates of the model in which both competitive and noncompetitive contracts are disaggregated into *R&D* and non-*R&D* contracts. Focusing again on the instrumental variable total estimates, we find that both *R&D* and non-*R&D* competitive contracts have a large positive effect on private *R&D*. It is somewhat surprising that the coefficient on the latter is larger (since most of these are price-competitive contracts), but the difference is far from significant: $F_{1,1003} = 0.14$ (p − value = .712). The point estimates of the coefficients on both *R&D* and non-*R&D* *non*competitive contracts are negative, but the non-*R&D* coefficient is small and insignificant, whereas the *R&D* coefficient is very large and significantly different from zero. The latter is also significantly different from both the competitive *R&D* coefficient (P − value = .084) and from the noncompetitive non-*R&D* coefficient (P − value = .040). To summarize the implications of this model: competitive contracts (whether or not for *R&D*) have a large positive effect on private *R&D*, noncompetitive *R&D* contracts have an even larger negative ("crowding-out") effect, and other noncompetitive procurement has essentially no effect.

Although the hypotheses that competitive and noncompetitive non-*R&D* have equal effects on private *R&D*, and that competitive and noncompetitive non-*R&D* have equal effects, are rejected by the data, to achieve comparability with previous studies it is useful to impose these restrictions; we do so in panel E. The instrumental variable total estimates suggest that the net effect of government *R&D* contracting on private *R&D* investment is negative: the negative effect of noncompetitive *R&D* contracting outweighs the positive effect of competitive *R&D* contracting. A *ceteris paribus* increase of $1 in the value of *R&D* contracts would evidently result in a 48-cent reduction in private *R&D* expenditure. In contrast, the positive effect of competitive non-*R&D* procurement outweighs the negative effect of noncompetitive non-*R&D* contracts, so that the net impact of non-*R&D* procurement is positive. Because *R&D* accounts for only about one-sixth of the total value of contracts, government procurement as a whole has a positive and substantial effect on private *R&D* investment.

IV. Summary and Conclusions

Competitive procurement, of both *R&D* and other services and products, stimulates considerable private *R&D* investment. Because the firm that is awarded the initial competitive contracts for a weapons system is virtually guaranteed to receive a stream of noncompetitive follow-on contracts, the amount of private *R&D* investment associated with competitive procurement is large relative to the value of competitive contracts. A $1 increase in competitive procurement is estimated to induce 54 cents of additional private *R&D* investment.

Noncompetitive *R&D* procurement tends to crowd out private *R&D* investment. The award of noncompetitive *R&D* contracts signals the end of the design and technical competition. At this stage of the procurement cycle, there are incentives for firms to

[14]See, for example, David Levy and Nestor Terleckyj, 1983, and John Scott, 1984.

reduce private *R&D*. Losers of the competition reduce spending because the prize is no longer at stake; the winner reduces spending because the government is now willing to directly sponsor the *R&D* via contracting. A \$1 increase in noncompetitive *R&D* procurement tends to reduce private *R&D* by more than \$2. Noncompetitive non-*R&D* has essentially no effect on private *R&D* investment.

In contrast to previous studies of the effect of government *R&D* on private *R&D*, which have not controlled for non-*R&D* procurement and which have not distinguished competitive from noncompetitive procurement, we find that the net effect of *R&D* procurement on private *R&D* is negative. But non-*R&D* procurement, which is about five times as large, has a stimulatory effect, so the net effect of procurement in general is positive and quantitatively important. Over the course of the defense buildup that occurred during the period 1979–84, the increase in government sales accounted for about one-sixth of the total increase in demand. (The government's share in (the level of) sales tends to be lower, about 5 to 8 percent.) Our estimates imply that slightly over half of the total induced increase in private *R&D* was induced by the increase in government demand. The government therefore appears to play a larger role in determining the allocation of the nation's scientific and technical resources, hence the rate and direction of technical progress, than is perhaps generally recognized.

DATA APPENDIX

The data used in the econometric analysis were derived from two sources: a computer tape prepared for the author by the Federal Procurement Data Center, and the widely available *Compustat General Annual Industrial File* distributed by Standard & Poor's.

The Federal Procurement Data Center, which is part of the General Services Administration, has since 1978 administered the Federal Procurement Data System, a uniform system for reporting data on procurement by federal agencies.[15] The computer tape provided by the Federal Procurement Data Center contained a putatively complete enumeration of every contract action during 1979–85 corresponding to the top 1500 (ranked by value of contract actions) contractors; the tape contained records of about 1.3 million contract actions. Each record included the following data on the attributes of the contract action:

1) The calendar year in which the action occurred (*YEAR*),

2) A numerical code assigned by Dun and Bradstreet to identify the "ultimate parent corporation" of the contractor (*DUNS*)

3) the number of dollars obligated or deobligated by the action (*VALUE*)

4) The method of procurement associated with the action (*METHOD*)

5) A four-character product or service code (*PSC*).

The rules for determining whether a contract action is (a) competitive and (b) for *R&D* were as follows:

if $METHOD = 3$ ("negotiated competitive"), then the action is competitive ($COMPET = 1$); otherwise it is noncompetitive ($COMPET = 0$)

if the first character of *PSC* was an "*A*," then the contract is for *R&D* ($RD = 1$); otherwise it is not for *R&D* ($RD = 0$).

We computed the total value of each firm's contract actions, by method (competitive versus noncompetitive) and product (*R&D* versus non-*R&D*) in each year by aggregating *VALUE* by *YEAR*, *DUNS*, *COMPET*, and *RD*.

The following were the data items obtained from the *Compustat* file:

1) Data (fiscal) year (*YEAR*)

2) *CUSIP* Company Number (Issuer Code) (*CUSIP*)

3) Sales – Net (*SALES*)

4) (Company-funded) *R&D* expense (*CRD*)

5) Industry classification number (*DNUM*)

Because the Federal Procurement Data Center and Compustat use different schemes for coding companies, a concordance between the *DUNS* and *CUSIP* schemes was required to merge the two files; this was obtained from Harvard Business School. Most of the (smaller) companies included in the Federal Procurement Data Center file are not publicly traded companies and are therefore excluded from the Compustat file. Only companies represented in both files (and with nonmissing data on *SALES* and *CRD*) were included in our sample. *NONGOV* was defined as *SALES* minus the total value of contract actions.

The instrument used for the value of competitive contracts awarded to firm i in year t is the value of competitive contracts that were "potentially awardable" to firm i in year t. "Potentially awardable" contracts $PCOMP_{it}$ is defined as the total (across all firms) value in year t of competitive contracts for two-digit Federal Supply Code products and services that the firm *ever* sold to the government during the period 1979–85. This may be expressed algebraically as follows:

$$PCOMP_{it} = \sum_j D_{ij} * AGG_{jt},$$

[15] See the Federal Procurement Data Center publications cited.

where $D_{ij} = 1$ if firm i ever sold product j to the government during the period 1979 to 1985;
$= 0$ otherwise.
AGG_{jt} = total (across firms) value of competitive contracts for product j in year t.

(It seems reasonable to maintain that both the lines of business the firm was engaged in, and the aggregate volume of government procurement in those markets, is exogenous with respect to the firm's rate of *R&D* investment.) An analogously defined instrument is used for noncompetitive contracts. The instrument for $NONGOV_{it}$ is the aggregate value of *SALES* in year t of all firms in the *Compustat 1987 Annual Industrial File* with the same industry classification number (*DNUM*) as firm i.

A complete list of the *CUSIP* numbers of the firms included in the sample is available from the author and is on file with the *American Economic Review*.

REFERENCES

Danhof, Charles H., *Government Contracting and Technical Change*, Washington: The Brookings Institution, 1968.

Griliches, Zvi, "Productivity, *R&D*, and Basic Research at the Firm Level in the 1970's," *American Economic Review*, March 1986, *76*, 141–54.

______ **and Hausman, Jerry,** "Errors in Variables in Panel Data," *Journal of Econometrics*, February 1986, *31*, 93–118.

______ **and Lichtenberg, Frank,** "*R&D* and Productivity at the Industry Level: Is There Still a Relationship?," in Z. Griliches, ed., *R&D, Patents, and Productivity*, Chicago: University of Chicago Press. 1984.

Kihlstrom, Richard E. and Riordan, Michael, "Advertising as a Signal," *Journal of Political Economy*, June 1984, *92*, 427–450.

Levy, David and Terleckyj, Nestor, "Effects of Government *R&D* on Private *R&D* and Productivity: A Macroeconomic Analysis," *Bell Journal of Economics*, Autumn 1983, *14*, 551–61.

Lichtenberg, Frank, "The Duration and Intensity of Investment in Independent Research and Development Projects," *Journal of Economic and Social Measurement*, October 1986, *14*, 207–18.

Mansfield, Edwin, *Technological Change*, New York: W. W. Norton, 1971.

Nalebuff, Barry and Stiglitz, Joseph, "Prizes and Incentives: Towards a General Theory of Compensation and Competition," *Bell Journal of Economics*, Spring 1983, *14*, 21–43.

Reppy, Judith, "Defense Department Payments for 'Company-Financed' *R&D*," *Research Policy*, 1977, *6*, 396–410.

Roberts, Edward, "How the United States Buys Research," in David Allison, ed., *The R&D Game: Technical Man, Technical Managers, and Research Productivity*, Cambridge: MIT Press, 1969, 280–96.

Scherer, F. M., "Using Linked Patent and *R&D* Data to Measure Interindustry Technology Flows," in Z. Griliches, ed., *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, 1984, 417–61.

Scott, John T., "Firm versus Industry Variability in *R&D* Intensity," in Z. Griliches, ed., *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, 1984, 233–45.

Spence, A. Michael, *Market Signaling: Informational Transfer in Hiring and Related Screening Processes*, Cambridge: Harvard University Press, 1974.

White, Halbert, "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica*, May 1980, *48*, 817–38.

Department of Defense, *Prime Contract Awards, Fiscal Year 1984*, Washington: USGPO, 1985.

Federal Procurement Data Center, (1982a), *Reporting Manual*, Arlington, VA, October 1982.

______, (1982b), *Product and Service Codes*, Arlington, VA, October 1982.

______, *Standard Report*, Arlington, VA, January 1988.

National Science Board, *Science Indicators/The 1985 Report*, Washington: USGPO, 1985.

U.S. Congress, Senate, Committee on the Judiciary, "Competition in Defense Procurement, Hearings before the Subcommittee on Antitrust and Monopoly," Washington: USGPO, 1969.