

DOES FEDERAL FUNDING "CROWD IN" PRIVATE FUNDING OF SCIENCE?

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Proposed cutbacks in government science funding have caused many to expect that the rate of scientific progress will significantly decline. Before the magnitude of the decline can be estimated, a preliminary question must be answered: what is the extent to which private funding of science may be expected to fill the gap left by the declining government funding? Using data on government and private funding of science, preliminary estimation indicates that past government funding of science has not "crowded out" private funding of science. If this finding is supported by further research, it would indicate that private funding could not be expected to replace lost federal funding of science. (JEL H4, H1, O3, D6, L3)

I. INTRODUCTION

The new growth theory (Romer, 1990) has focused our attention on the creation of new knowledge as a crucial source of economic growth. Empirical work by Mansfield (1991), Griliches (1986), Adams (1990), and others has reinforced the message. If scientific knowledge is a crucial source of economic growth, then we should want to identify and advocate those institutions and reward structures that are most efficient at creating new scientific knowledge. Recently, these issues have taken on increasing importance due to reductions in federal funding of science.

Actual or proposed reductions in federal funding for science have several sources. One is the decline in defense-related support for science, related to the end of the Cold War. Another is political pressure that a higher proportion of federal funding should go to pro-

jects that will be quickly applicable by industry and hence lead to higher short-term economic growth. A final source of a proposed decline in federal funding arises from the effort to balance the federal budget. This source has diminished temporarily due to the current modest budget surplus, but is sure to return with the looming future deficits resulting from financing entitlements for aging baby-boomers in the next two or three decades.

Since the United States has been one of the leading sources of progress in basic science¹ in the world, recent and proposed cutbacks in science funding have led to concern among scientists and policy makers about how such cuts will affect the quantity and the quality of science produced in the United States. The goal of the paper is to examine how severe the effects are likely to be.

The federal government is one of several sources of funding for science. As Colander (1989) has pointed out, the main source of sci-

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1. Concerning the scope of fields included, "science" can be defined most narrowly as the "hard" sciences (physics, chemistry, and perhaps biology and mathematics) or, at the other extreme, most broadly as any discipline that is considered by its practitioners to be a science. In this paper science is operationally defined as the fairly broad set of disciplines generally classified as science by the National Science Foundation (NSF) in its *Science & Engineering Indicators* series of reports (e.g., National Science Board, 1991, p. 118 and passim). In those and many related reports, "science" is defined to include medical sciences, biological sciences, physical sciences, engineering, environmental sciences, social sciences, computer sciences, and mathematical sciences.

ence funding is the faculty research release time provided by many universities. Other sources of funding include industry and private foundations. Most estimates of the effects of cutbacks in federal funding implicitly assume that such funding will not be replaced by funding from other sources. Although evidence has not specifically been collected for science funding, evidence from funding of other activities indicates that when the federal government increases its funding of an activity, the private funding that had been supporting that activity diminishes. It may reasonably be hypothesized that the converse would also be true: when the federal government withdraws from funding an activity, private money will enter to partially fill the gap.

The effect of decreasing government funding depends not only on the percentage of that decrease that will be replaced by private funding, but also on the effectiveness of the private spending as compared to the government funding. Some research (e.g., Diamond 1999) indicates that private funding is indeed spent more efficiently than government funding. To the extent this is true, the damaging effect of a decline in federal support might be partially ameliorated.

The ultimate purpose of the paper is to obtain a preliminary estimate of the effect of cuts in federal science funding on the progress of science.²

II. THEORY AND PREVIOUS WORK

Economists have studied the decision-making process of governments and the nonprofit sector, but they have rarely applied these theories to funding decisions in science. Although Martino (1992) may be a rare exception for the case of government funding, the author knows of no similar exceptions for the case of private foundation funding.

Early models of the nonprofit sector (e.g., Weisbrod, 1975; Feigenbaum, 1980) adopted the common view that the level of government spending is determined by the preferences of the median voter. Private spending then occurs

when nonmedian voters donate their own resources out of dissatisfaction with what they perceive as too low a level of government support for the good. Subsequent economists developed theoretical models focused directly on how government spending on an activity would be expected to "crowd out" private spending (e.g., Warr, 1982; Roberts, 1984; Bergstrom et al., 1986). Less frequently, economists have given reasons why we might expect to find "crowding in": a positive relationship between government and private funding of an activity (Rose-Ackerman, 1981; Khanna et al., 1995; Khanna and Sandler, 1996).

Economists have also performed empirical calculations to measure the magnitude of the crowding out effect (e.g., Abrams and Schmitz, 1978, 1984; Schiff, 1985; Payne, 1998). A useful summary of some of the empirical evidence as of about 1991 can be found in Steinberg (1993). Most of the empirical work has used individual-level data. An important exception is Levy and Terleckyj (1983), who found a modest crowding in effect.³ One of the most recent and most sophisticated attempts to settle the issue (Andreoni, 1993) uses an experimental simulation method and finds a crowding out effect of approximately 71%.

Many studies by economists (e.g., Randolph, 1995; Schiff, 1985; Abrams and Schmitz, 1984, 1978) have emphasized the importance of "economic" variables such as the donor's income and the "price" of giving (largely viewed as a function of the tax deductibility of contributions). Other "noneconomic" variables have also been suggested as mattering. For example, the sociologist Christopher Jencks, in a highly regarded study (1987, pp. 326–328), summarizes the evidence that the following factors are determinants of philanthropic giving: age, family structure, gender, ethnicity and religion, education, community ties, community characteristics, and family background.

Although the theory of crowding out has been developed and general estimates of this effect have been made, the author knows of no attempts to estimate the magnitude of crowding out in science funding and no attempt to

2. The author's broad research program (Diamond, 1996) consists in learning how far economics is useful in explaining the behavior of science and in learning the optimal design of the reward structure of scientific institutions. For this program to be worthwhile, the author assumes that science is worth doing: that it produces knowledge that is sound and useful.

3. Levy (1990) extends this research by examining why government R&D has been shown to contribute less to productivity than private R&D.

understand the implications of the crowding out phenomenon to the hotly contested issue of cutbacks in federal science funding. Here the author conducts a preliminary empirical exploration to examine whether existing data permit measuring the extent of a crowding out effect in science funding.

III. DATA

Information on funding is generally reported for "research and development" rather than for science. Traditionally, R&D is divided into three components: basic research, applied research, and development. The National Science Foundation defines "basic research" as research whose objective is "to gain more comprehensive knowledge or understanding of the subject under study, without specific applications in mind" (National Science Board, 1996, p. 4-9).⁴

The level of private funding is the dependent variable in the analysis. To gauge the robustness of the results, several versions of the dependent variable will be used. Table 1 estimates the effect of federal basic research spending separately on academic basic research spending, nonprofit basic research spending, and industry basic research spending. Table 2, to further gauge the robustness of the results, uses as dependent variables the three pairwise combinations of the sources of private funding, thus separately estimating the effect of federal basic research spending on the sum of academic and industry basic research spending, the sum of academic and nonprofit basic research spending, and the sum of nonprofit and industry basic research spending.

For the purposes of the present study, the key explanatory variable will be the level of federal funding of basic research. At one extreme, a statistically significant estimate of -1 for the coefficient of that variable would indi-

cate complete dollar-for-dollar crowding out between federal and private money. An estimate of 0 for the coefficient would indicate no crowding out. A positive coefficient would indicate "crowding in": a complementarity between levels of private and federal funding.

The most appropriate data to measure the effects of behavioral economic models would be individual-level, time series data. Unfortunately, the only individual, time series data are from the IRS, which does not have a fine-grained classification of the recipients of donations.⁵ Since it is based on taxpayers who itemize and since the accuracy of itemization reports has been questioned, this data source has also been criticized as unrepresentative and inaccurate. An alternative dataset is the National Survey of Philanthropy. This dataset is at the individual level and contains a rich set of variables. Unfortunately, it only covers one year and hence would not permit us to examine how changes in federal spending on basic research affect private spending on basic research.

In the absence of a better alternative, our best data consist of annual aggregates of spending on basic research from four funding sources: the federal government, industry, universities and colleges, and nonprofit institutions. One problem with such data in the past has been the possibility of double-counting. For example, if the federal government supported university research, did those dollars appear both under federal spending and under academic spending? The 1997 data used in this study avoids this potential problem by distinguishing the source of the funds from who performs the research. We focus on the funding source. (So, e.g., federal money spent on federally funded research and development centers in universities, in industry, or in nonprofit institutions was counted as "federal" research spending.)

We have 43 years of funding data from the Division of Science Resources Studies (1999) of the National Science Foundation. The data are available on the World Wide Web in easily downloadable form, as well as in the 1998 *Science & Engineering Indicators* (National Sci-

4. The full passage defining "basic research" is as follows:

The National Science Foundation uses the following definitions in its resource surveys. *Basic research*: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study, without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interest. (National Science Board, 1996, p. 4-)

5. Here and in the remainder of the paragraph, the author relies heavily on Steinberg's (1993) useful discussion of available data sets on the "crowding out" question (pp. 121-122).

TABLE 1
Effect of Federal "Basic Research" Spending on Private "Basic Research" Spending

	Definition of Dependent Variable							
	Academic		Nonprofit		Industry		All Private ^a	
	R #1	R #2	R #3	R #4	R #5	R #6	R #7	R #8
Federal spending on basic research	0.079885 (2.469)	0.08380 (2.660)	0.035898 (2.994)	0.036608 (3.149)	0.62361 (3.146)	0.51307 (2.619)	0.70315 (3.314)	0.63348 (2.976)
Income (personal income for R #1-4, R #7-8; GDP for R #5-6)	0.10842 (0.622)	—	0.019656 (0.305)	—	-1.3975 (-1.918)	—	-1.9291 (-1.689)	—
Constant	37.931 (1.770)	47.336 (3.139)	17.543 (2.210)	19.248 (3.459)	76.911 (0.692)	-46.190 (-0.493)	187.74 (1.336)	20.395 (0.200)
No. observations	42	42	42	42	42	42	42	42
Adjusted R ²	.116	.129	.160	.179	.180	.125	.198	.161

Notes: R # = regression number. All variables in all regressions are in first-difference form. The numbers in parentheses are *t*-statistics.

^a"All Private" is the sum of spending on basic research by the "academic," "nonprofit," and "industry" sources.

TABLE 2
Effect of Federal "Basic Research" Spending on Private "Basic Research" Spending

	Definition of Dependent Variable					
	Academic and Nonprofit R #9	Academic and Nonprofit R #10	Academic and Industry R #11	Academic and Industry R #12	Nonprofit and Industry R #13	Nonprofit and Industry R #14
Federal spending on basic research	0.11578 (2.900)	0.12041 (3.100)	0.66725 (3.186)	0.59687 (2.836)	0.62326 (3.201)	0.54968 (2.783)
Personal income	0.12807 (0.596)	—	-1.9488 (-1.729)	—	-2.0375 (-1.944)	—
Constant	55.474 (2.098)	66.584 (3.580)	170.20 (1.227)	1.1465 (0.011)	149.81 (1.162)	-26.942 (-0.285)
No. observations	42	42	42	42	42	42
Adjusted R^2	.160	.174	.187	.147	.197	.141

Notes: All variables in all regressions are in first-difference form. The numbers in parentheses are t -statistics.

ence Board, 1998). Data on gross domestic product (GDP), the GDP implicit price deflator, and personal income were obtained from the U.S. Department of Commerce's *Survey of Current Business* (August 1998). Federal outlays were obtained from the Office of Management and Budget's (1998) *Historical Tables* for the fiscal year 1998. All nominal dollar amounts have been transformed into real 1992 dollars using the GDP implicit price deflator. Descriptive statistics for the variables included in the research are reported in Table 3.

IV. ECONOMETRIC METHOD

The augmented Dickey-Fuller test for stationarity⁶ was applied to all of the variables in the analysis. For all variables used in the regressions, the result was robust for both the linear and log versions of the variables: in all cases the null hypothesis of a unit root could not be rejected, indicating that all of the variables are nonstationary. The Dickey-Fuller test was then applied to the first difference of each variable, in both linear and log forms. All variables, except for GDP and personal

income, remained nonstationary when first differenced, whether in linear or log form. Both GDP and personal income became stationary when first differenced, using either the linear or the log versions of the variables. Because the log transform did not improve stationarity, the simpler linear results are reported in Tables 1 and 2, for both the standard and first-differenced regressions. Since the income proxy was never statistically significant in any of the regressions, a second regression, omitting the income proxy, was estimated for each version of the dependent variable.

V. RESULTS

Preliminary conclusions can be drawn from the regressions reported in Tables 1 and 2, concerned with whether federal spending crowds out private "donated" spending on science. The preliminary evidence seems to indicate that instead of crowding out, there is "crowding in." The robust positive coefficients on federal spending would seem to indicate that donors may view federal and private spending on basic research as complements rather than as substitutes.

Regressions 5 and 6 in Table 1 report results for industry spending on basic research. Although industry spending is presumably motivated as an investment for profit rather than as a donation for altruistic purposes, there also

6. Two versions of the test were applied for each variable, one with and one without trend. In most cases the results were the same by both tests. But when they differed, the author conservatively judged the series to be nonstationary.

TABLE 3
Descriptive Statistics ($N = 43$)

Variable Name	Mean	S.D.	Min.	Max.
Spending on basic research				
Federal	8754.5	4435.5	1316.1	15943.
Academic	1344.5	972.34	55.679	3248.3
Nonprofit	703.51	381.81	141.73	1490.1
Industry	2791.5	1928.9	779.51	7384.8
Total (all sources)	13594.	7547.2	2293.0	27568.
Gross Domestic Product (GDP)	4012.5	1511.0	1912.6	6758.3
Personal income	3256.1	1306.8	1482.6	5645.1
Total federal spending for all functions	813090.	367200.	332830.	1409100.
Percentage of federal spending going to basic research	0.0000104	0.00000278	0.00000342	0.0000158

Notes: All dollar variables are in millions of real (1992) dollars, except for "GDP," "personal income," and "total federal spending for all functions," which are in billions of real (1992) dollars.

appears to be a complementarity, or "crowding in," effect between federal and industry spending on basic research.

A few caveats are in order. One is that the coefficients on the income proxies (personal income and GDP) vary in sign and are never statistically significant at the .05 level. Regressions were also estimated including a variable measuring the percentage of total federal spending spent on basic research.⁷ Log versions of the regressions and versions with various lags were also estimated. The regressions had many differences, but one result almost always appeared: the coefficient of federal spending was positive and statistically significant.

The economic magnitude of the crowding in effect is worth noting. For academic spending and for nonprofit spending, the effects are not large. Using regression 1 in Table 1, a \$1 million increase in federal spending on basic research results in about an \$80,000 increase

in academic spending. Using regression 3 in Table 1, a \$1 million increase in federal spending results in about a \$36,000 increase in nonprofit spending. The effects on industry are larger. Using regression 5 in Table 1, a \$1 million increase in federal spending results in about a \$620,000 increase in industry spending. The overall effects on all private spending are dominated by the effects on industry, such that using regression 7 in Table 1, a \$1 million increase in federal spending results in about a \$700,000 increase in total private spending. Table 4 provides the exact magnitudes (point estimates), as well as 95% confidence intervals for each of them.

To further explore the positive relationship between federal basic research spending and private basic research spending, we tested for Granger causality between federal basic research spending, and each of the definitions of private spending considered in Table 1. The general form of each of the eight regressions estimated was

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} \\ + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \beta_3 x_{t-3} + u_t$$

7. The inclusion of the percentage of federal outlays spent on basic research, was suggested by the finding of Hergert and Locay (1979) that British charity changed composition, but not level, as a result of increased government spending on social services.

TABLE 4
Magnitude of "Crowding In" Effect from \$1 Million Increase in Federal
Basic Research Spending (95% confidence interval)

Regression	Type of "Private"	Low End	Point Estimate	High End
1	Academic	69,794	79,885	89,976
3	Nonprofit	32,159	35,898	39,637
5	Industry	561,802	623,610	685,418
7	All Private	637,007	703,150	769,293

Note: All dollar amounts are in real (1992) dollars.

The first four regressions tested for whether federal spending "Granger causes" private spending, for each of the types of private spending in Table 1. None of the regressions indicated Granger causation. The second four regressions tested for whether each of the four types of private spending in Table 1, "Granger causes" federal spending. Two of these four regressions did in fact indicate that private spending "Granger causes" federal spending. (The two regressions were the one using lags of industry spending, and the one using lags of "all private" spending.)

VI. CONCLUSIONS AND FUTURE RESEARCH

Aggregate, annual, time series data from 1953–1995 were used to estimate whether federal spending on basic research crowds out private spending. The estimates provide no support for the crowding out hypothesis, instead suggesting that there may be a complementarity between federal and private spending on basic research.

The aggregate conclusions are suggestive, but must be interpreted with caution. For example, the positive correlation between federal and private spending may be a spurious result due to each responding independently to some other factor. For example, both might be responding independently to changes in the public's understanding of (and optimism about) the positive effects of basic research. Or, both might be responding independently to changes in the costs of performing basic re-

search, due perhaps to changing prices for computation or for scientific human capital. Or, if the returns to basic research vary in Schumpeterian waves, it may be that both respond to changes in the expected return to basic research. More and better data, especially at the firm and individual donor level, are needed before we can understand the causes and implications of the aggregate crowding in measured here. Mansfield and Switzer (1984) have made one contribution to this effort using firm-level data. It is perhaps notable that they also found a "crowding in" effect, suggesting that our results may not be a mere artifact resulting from the use of aggregate data.

The "altruism theory" of private expenditures implies complete crowding out of private spending by public spending. Andreoni and others, while developing and making use of the theory in some contexts, have noted its empirical deficiencies and have begun to develop theoretical alternatives. Andreoni (1988) notes that the altruism model implies that as an economy grows, fewer citizens will contribute. Neither this implication nor the implication of complete crowding out is confirmed by the empirical evidence. Andreoni (1989, 1990) believes that part of the answer lies in expanding the motivations for private spending to include what he calls "warm glow giving" or "impure altruism." Such motivations may help to understand why crowding out is less than complete, but they do not seem as promising in explaining why crowding in might occur. More recently, Andreoni (1998) has been developing

a model that emphasizes the importance of seed grants in the process of fund raising. If the government or private spenders provide seed grants for each other's activities, then the development of this approach might help to explain the crowding in phenomenon.

Since in most activities some level of crowding out occurs, we may need to understand what is different about the funding of basic research. One possible explanation may relate to the high cost of judging the quality of basic research before it is completed. Government and private sources may "free ride" on each other's screening mechanisms. Future studies could examine which source free rides on the other, or whether, as Erenburg and Wohar (1995) have found with private and government investment activity, that there is a more complicated feedback mechanism.

The current research also needs to be integrated with the best available evidence on the relative efficiency of private money and federal money in promoting scientific progress before a full answer can be given on the effects of cutbacks of federal support.

The current research begins to answer a key preliminary question that must be answered before it is possible to answer the ultimate question. The key preliminary question is: how much private money will enter to fill the gap in federal money from future cutbacks? The ultimate question is: how much will scientific progress suffer from future cutbacks?

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