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ABSTRACT

Conventional wisdom holds that the social rate of return to R&D significantly exceeds the private rate of return and, therefore, R&D should be subsidized. In the U.S., the government has directly funded a large fraction of total R&D spending. This paper shows that there is a serious problem with such government efforts to increase inventive activity. The majority of R&D spending is actually just salary payments for R&D workers. Their labor supply, however, is quite inelastic so when the government funds R&D, a significant fraction of the increased spending goes directly into higher wages. Using CPS data on wages of scientific personnel, this paper shows that government R&D spending raises wages significantly, particularly for scientists related to defense such as physicists and aeronautical engineers. Because of the higher wages, conventional estimates of the effectiveness of R&D policy may be 30 to 50% too high. The results also imply that by altering the wages of scientists and engineers even for firms not receiving federal support, government funding directly crowds out private inventive activity.

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Substantial evidence has shown that the social rate of return to R&D spending significantly exceeds the private rate of return (see Zvi Griliches, 1991 or Bronwyn Hall, 1996) and conventional wisdom holds that this public good nature of inventive activity makes private R&D spending lower than the social optimum and warrants a role for government involvement to increase it. In the U.S., government funds have provided a large fraction, often an outright majority, of the entire nation's R&D spending.

This paper, however, suggests a practical difficulty with government efforts to increase inventive activity. Specifically, the majority of R&D spending is actually salary payments for R&D workers and the supply of this scientific and engineering talent is quite inelastic. When the government increases R&D spending through subsidies or by direct provision, a significant fraction of the increased spending goes directly into higher wages--an increase in the price rather than the quantity of inventive activity. The conventional literature, by looking at total R&D spending, misses this distinction. The magnitudes found in this paper suggest the conventional literature may overstate the effects of government R&D spending by as much as 30 to 50%. In this sense, R&D policy may be less about increasing innovation and more about rewarding the human capital of scientists. The results also imply that by altering the wages of scientists and engineers even for firms not receiving federal support, government funding crowds out private inventive activity.

The asset market effects of government R&D policy clearly parallel other asset market incidence results such as Goolsbee (1997, 1998) showing that capital investment subsidies are capitalized into the prices of equipment and the wages of capital goods workers or James Poterba (1984) that housing subsidies raise house prices.

The paper is divided into five sections. Section II presents an overview of R & D spending and the role of the government. Section III discusses the market for scientific personnel. Section IV examines micro data relating government spending to the incomes of engineers and scientists. Section V presents implications and section VI concludes.

II. The Government and R&D Spending

Since WWII, the government has been an extremely important part of R&D spending in the U.S. and a large academic literature has evaluated the effectiveness of many government R&D policies (see Hall, 1996). The government has indirectly supported R&D with the patent system, the R & E tax credit, and credits for R & D through multinational tax rules and has also directly provided R & D spending through universities, NASA, the department of defense, energy, health and other specific programs (see the data in the N.S.F.'s *Research and Development in Industry* for an overview).

These R&D programs are costly. R&D spending has comprised between 2% and 3% of GDP since the 1960s and the federal government's share has consistently been between 1/3 and 2/3 of the total. In 1995, it amounted to almost $70 billion in direct funding. Most of the federal money has gone to the defense department (always more than half and up to 70% in some years) and since the 1960s, the biggest variations in government R&D spending have been fluctuations in the defense component. Such R & D spending was high in the late 1960s, fell through the 1970s, rose in the 1980s, and fell again in the 1990s. This variation can be used to identify the effect of R&D spending on the market for scientists and engineers.

III: The Market for Scientists and Engineers

Although the N.S.F. data on R & D spending are widely used in the literature, minimal attention has been paid to where the data show the money goes. Some work has examined the composition of R & D spending going to basic versus applied research but little has focused on the share going to scientists. N.S.F. (1995) documents that between 45 and 83% of total spending is wages and benefits of scientific personnel (depending on how one counts overhead which includes individual benefits). A reasonable approximation for the total share might be 2/3. So when the data show that in 1995 the government spent almost $70 billion on R&D, $45 billion of that was wages and benefits for R&D workers.

The supply of R & D workers, however, is inelastic. Scientists and engineers have extremely high human capital that takes many years to accumulate and entry is small. The data in Jaewoo Ryoo and Sherwin Rosen (1992) show that the biggest graduating classes ever generated only about 4,000 engineering Ph.D.'s, 20,000 M.S.'s and about 75,000 B.S.' s--a modest amount relative to the 1.4 million stock of engineers--and it is likely that the supply of ideas is probably even less elastic than the supply of personnel.

If government R & D spending goes predominantly to scientific labor and the supply of that labor is inelastic, it means the inventive value of a dollar of R & D spending will vary over time depending on demand conditions and that government spending will translate into higher wages.

IV: The Impact of R&D Funding on R & D Workers

To show this is an important issue in practice, I turn to the data in the *Current Population Survey* on the income of scientists and engineers from 1968 to 1994. I restrict the sample to include only full time (35 or more hours per week), white, male engineers and scientists who are between the ages of 21 and 65 and have at least a college degree. These restrictions eliminate little of the sample because this has been a very white, male, college degree dominated field. The sample includes 17,700 individuals.

The first row of table 1 presents a regression for the log of real income on the log of total R&D spending as a share of GDP, the GDP growth rate to represent business cycle fluctuations, a dummy equal to one if a person has greater than a college degree, a dummy equal to one if the individual is married, a dummy equal to one if the individual is in a scientific (non-engineering) occupation, experience, experience squared (experience is defined as age minus 22 for people with a college degree and age minus 26 for people with an advanced degree), and a time trend. For reasons of space, I report only the R&D coefficients (the other coefficients had conventional magnitudes and signs).

The R&D coefficient clearly shows that higher spending increases the incomes of scientists and engineers. A one standard deviation increase in R&D spending (10%)

would increase incomes by about 3%. The N.S.F. (1995) estimates that there were 768,500 full-time equivalent R&D workers in 1994 but the *Occupational Employment Statistics* reports 1,722,000 who describe their occupation as physical scientist, life scientist, or engineer. The results here imply that wages rise for all scientists and engineers but I cannot distinguish between wages rising by 3% for everyone and wages rising by 6.75% for the 45% of actually engaged in R&D and zero for the others.

Since the issue of the paper specifically concerns the effectiveness of government policy, row (2) uses the log of the ratio of federally funded R&D to GDP. The coefficient is slightly smaller but still highly significant. Other specifications using income relative to average manufacturing earnings or the real level of R&D spending rather than as a ratio of GDP gave similar results.

Rows (3) and (4) break (2) into a wage and an hours component The wage variable used in (3) is defined as annual income divided by 50 times the number of hours last week (i.e., assuming two weeks vacation) and shows that wages account for about 95% of the income increase. The hours variable used in (4) is the log of hours worked last week and the coefficient is extremely small and is not significant (accounting for censoring with a Tobit gave identical results).

Together these results strongly suggest that R&D spending increases wages and not effort. Directly estimating a short-run supply curve by regressing the log of hours on the log of wages and demographic factors while instrumenting for wages with R&D spending gave elasticities of supply between .1 and .2 which were highly significant.

Row (5) looks at the longer-run effect of R&D spending on salaries by including not just current federal R&D spending but also the average level of the previous four years. There is no reduction in the salary gains over this longer period. In fact, a permanent one standard deviation increase in R&D spending raises wages 1% immediately and an additional 2% more over the next four years. Thus the supply of scientific personnel does not seem to be especially elastic in the medium-run either.

Because the measures of R&D are annual variables, it is not possible to include year dummies to control for other important time-series variables which are unobserved and possibly correlated with federal spending. The results in table 2, however, suggest that omitted variables are not causing the estimated response. The table breaks the scientists and engineers into groups by specific occupation for those occupations which remain consistent over the full sample including aeronautical, chemical, civil, electrical, industrial, metallurgical, and mining engineers, agricultural scientists, biological scientists, geologists, and physicists. Since federal R&D spending has had a heavy defense and space focus (85-95% of federal spending went to defense, space, and energy throughout the sample), if R&D spending is the true source of salary increases, salaries for aeronautical engineers and physicists might rise more than for civil engineers and agricultural scientists.

The results clearly show this. Federal R&D spending has no significant effect on the salaries of mining, civil, industrial, and chemical engineers (groups with little overlap to federal R&D spending) but has a major impact on aeronautical, mechanical, metallurgical, and electrical engineers. Among scientists, physicists are the major beneficiaries. A further regression (not reported in the table) found that, predictably, biologists benefit most from the health component of federal R&D.

V: Implications

The first implication of the results is that evaluations of government R&D policy may significantly overstate their effects on inventive activity. The Reagan defense buildup, for example, increased federal R&D spending as a share of GDP by 11% from 1980 to 1984. The results here imply that this would increase the salaries of scientists and engineers by 3.3% and, at a more disaggregated level, of physicists by 6.2%, aeronautical engineers by almost 5%, mechanical and metallurgical engineers by more than 4%, and electrical engineers more than 2%.

Taking the wage increase at 3.3%, and the wage share of R&D spending at 2/3, the effect on the true "quantity" of R & D is not the 11% increase in total R&D spending but rather 7.6%--30% smaller. If all the spending went to physicists, aeronautical, and mechanical engineers, the true quantity increase would even smaller--as much as 40-50% lower than the spending increase would indicate. This same reasoning could similarly reduce the estimated impact of the R & E tax credit on true inventive activity such as Hall (1993).

The second implication is that government R&D directly crowds out private inventive activity. By increasing the wages of electrical engineers, for example, government R&D spending increases R&D costs for computer manufacturers who do not receive federal funding but are forced to pay their scientists higher wages. The simple correlation between the federally funded R&D to GDP ratio and the nonfederally funded R&D to GDP ratio is -.4 so this may be important.

This general equilibrium-type effect may also help explain why the response of R&D spending to R&D tax subsidies is usually estimated to be larger using cross-sectional data than using aggregate data (see the evidence discussed in Hall, 1993). If subsidies raise the wages of R&D workers and thereby shift R&D spending away from firms which cannot use the subsidy toward the firms which can, this will make the cross-sectional elasticity large even if the aggregate elasticity is small. This response is consistent with the evidence of Philip Berger (1993) that R&D spending among firms which cannot use R&D tax subsidies *falls* when the subsidies rise.

VI. Conclusion

The evidence shows that a major component of government R & D spending is windfall gains to R&D workers. Incomes rise significantly while hours rise little and the increases are concentrated within the engineering and science professions in exactly the specialties most heavily involved in federal research. The implication for the evaluation of government R&D policy is that government spending is likely to have significantly smaller effects on the quantity of inventive activity than implied by looking at R&D spending alone and also that government spending directly crowds out private spending by raising wages.

The evidence means that federal R&D policy is, in large measure, just a way of subsidizing scientific human capital and its acquisition. The importance of increasing the share of the labor force engaged in R&D should not be downplayed, however. Endogenous growth theory such as Paul Romer (1990) has focused our attention on its potential importance for growth and some evidence (Kevin Murphy et al. 1991) indicates that encouraging people to become engineers may help society simply by reducing the number of lawyers! Ryoo and Rosen (1992) have shown that college engineers are quite elastic in their choices of majors.

We should recognize, however, that there may be better ways to encourage scientific careers than by subsidizing the wages of all scientific personnel through R&D spending, just as it can cost less to subsidize corporate investment than to reduce the corporate income tax. Whatever the motivation, the results in this paper make clear that the difference between R&D spending and true inventive activity should be part of any analysis of government R&D policy.

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TABLE 1: THE EFFECT OF R&D ON INCOME AND HOURS OF ENGINEERS AND SCIENTISTS

	$\frac{RD}{GDP}$	$\frac{RD_{FED}}{GDP}$	4 yr Mean $\frac{RD_{FED}}{GDP}$	R^2
1. ln (Income)	.300 (.038)			.288
2. ln (Income)		.232 (.030)		.288
3. ln (Wage)		.219 (.032)		.255
4. ln (Hours)		.009 (.013)		.012
5. ln (Income)		.094 (.043)	.171 (.038)	.277

Notes: Each row presents the R&D coefficient from a regressions including the experience, experience squared, dummies for marriage, scientific occupation, and post college education, GDP growth and a time trend. The dependent variable is listed in the first column. The sample in each is 1968-1994. There are 17,700 observations in each regression and the standard errors are in parentheses. The second column is the ratio of R&D to GDP. The second column is the ratio of federal R&D to GDP. The mean variable is the log of the mean federal R&D to GDP ratio for the four previous years.

TABLE 2: RESULTS DISAGGREGATED BY OCCUPATION

	(1)	n	R^2
Engineers:			
Aeronautical	.447 (.122)	723	.354
Mechanical	.380 (.088)	2186	.276
Metallurgical	.375 (.220)	205	.312
Electrical	.180 (.062)	3693	.305
Chemical	.077 (.155)	706	.254
Industrial	.061 (.092)	1454	.265
Civil	.021 (.086)	1996	.264
Mining	-.148 (.353)	103	.295
Scientists:			
Physics	.564 (.202)	328	.461
Geology	.192 (.226)	436	.294
Biology	.169 (.204)	497	.312
Agriculture	.157 (.281)	194	.384

Notes: Each row presents the results of the regression in table 1 but for a single occupation. The total does not sum to 17,700 because occupations with classification changes are not included. The dependent variable in each is the log of real income. The sample in each is 1968-1994. Standard errors are in parentheses.