An Evaluation of the Relationship Between Private and Public R&D Funds with Consideration of Level of Government

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Introduction

Economists have long scrutinized the public funding of research and development. Work in this area often aims to determine if public R&D funding is either a compliment or substitute to private R&D investment. If complimentary, public funding can correct well known market failures related to private R&D funding. If these are instead substitutes, then public funding will displace private funding via crowding out. Given these consequences and the importance of R&D efforts to economic growth, it is no surprise that this question attracts interest.

This paper builds a macroeconomic model that relates the quantity of private R&D funds to the quantity of R&D public funds, with appropriate controls, in an attempt to identify the relationship between them. The model presented here adds to the existing literature on this subject in two ways. First, it will consider data in the span 1961-2007, a time interval sixteen years longer than used in previous studies. Second, it considers the level of government making R&D expenditures. Prior works in the literature only looked at spending by the Federal government, ignoring the increasing role of state and local governments in furnishing R&D funds. To identify how the effects of these funds may differ, this paper presents three regressions. The first uses the aggregate of public funds, the second uses only Federal funds, and the last separates funds by level of government. Analysis shows that state and local funds are complimentary with private funds while Federal funds have a mixed relationship with private funds. This contributes to the literature by demonstrating complexity in the relationship between private and public R&D funding.

A review of the literature follows this introduction, followed by descriptions of data and methodology.

Literature Review

Levy and Terleakyj (1983) attempted to identify the relationship between public and private R&D funds by comparing the amount of Federal R&D spending with the amount of private R&D spending using time series data in the interval 1949 to 1981. Results varied between types of Federal R&D spending. The paper found every dollar of Federal R&D spending given to the private sector on a contract basis increased private R&D spending by twenty seven cents. This result was significant at the .1% level. All other government R&D spending, generally internal expenditures by Federal agencies, was found to decrease private R&D spending. When lagged three years, the size of this latter effect was a drop of about nineteen cents per dollar of federal spending, significant at the five percent level. This study controlled for the unemployment rate, R&D stock, and the prior year's revenue from the corporate tax. A similar study, Robson (1993), found a one for one increase in private funds for basic research with increases in Federal funds, significant at the five percent level.

Goolsbee (1998) seeks to qualify these findings. This paper argues scientists and engineers largely pocket increases in government R&D funding in the form of wages, cutting the actual increase in R&D activity. Goolsbee finds a "one standard deviation increase in increase in R&D spending (10 percent) would increase incomes by about 3 percent" (Goolsbee 1998). If this is the case, Goolsbee suggests private R&D may be crowded out by the need for firms to raise wages.

David and Hall (1999) responds to Goolsbee. It builds a theoretical framework linking public R&D funds to the labor market for scientists and engineers. Analyzing this framework, it argues the effect of rises in public funding on wages has a negligible effect on private R&D

funds in the long run. The paper acknowledges short run effects caused by increases in public R&D funding that go to items other than basic research.

More contemporary research focuses on microeconomic evidence. A popular approach is to compare the amount of public R&D funds received by a given firm with the firm's own R&D expenditures. An example is Holger and Strobl (2007), which evaluates Irish firms. The paper finds public funds complement private funds but that this effect declines as the amount of public funds increases. Specifically, it found the coefficient of the log of the value of the R&D grant to be 0.102 and the coefficient of this term squared to be -0.034, significant at the ten percent and five percent level, respectively. The response variable was the log of the quantity of private funds. The results also suggested the largest grants of public funds act as a substitute for public funds. A similar paper, Cerulli and Poti (2012), studies R&D funding in Italy. Interestingly, this paper found substantial variability between different selections of response variables and econometric methods. Despite this, no method demonstrated evidence of a full substitution effect. In 2016, economists at Stratferdshire University performed a metaregression of fifty two microeconomic studies on this topic published since 2000. The resulting paper, Dimos and Pugh (2016), concluded "findings reject crowding out of private investment by public subsidy but reveal no evidence of substantial additionality" (Dimos and Pugh, 2016). The paper warned complimentary effects increase when researchers fail to consider endogeneity.

The existing macroeconomic literature on this topic generally finds public and private R&D funds are complimentary while firm level, microeconomic papers are inconclusive. The literature does contain a number of gaps. First, no macroeconomic paper has evaluated this question with more recent data as the overall value of R&D spending increased. Second, evaluations of the United States consider only Federal R&D spending. As discussed further in

the data and methodology section, state and local governments increasingly form a greater portion of public spending on R&D. Importantly, this spending generally occurs through public universities. R&D spending by universities has well documented "spillover effects"; Berman (1990) found increases in university research spending were significantly correlated with industry R&D spending five years later. A picture of the relationship between public and private R&D funding would be incomplete with only Federal funds. For that reason, this paper will consider state and local funding.

Given that US firm level data is not readily made available, it would be difficult for a senior project to approach this question with microeconomics. This paper takes the macroeconomic approach. The model used here extends the work of Robson (1993) and Levy and Terleakyj (1983) with recent data and non-Federal funding sources. This will contribute to the literature by evaluating whether new data verifies their results. It will also provide further evidence as to the effect of public R&D funds on private R&D funds.

Data and Methodology

To estimate the effect of government R&D spending on private R&D spending, this paper will evaluate the following equation:

$$\ln(BRD) = \beta_0 + \beta_1 GRD + B_2 CTR + B\beta_3 UNEM + \beta_4 NPS + \beta_5 \ln(FEDRC)$$

Where:

BRD is the value of business spending on R&D for a given year in millions of 2005 dollars as reported by the Bureau of Economic Analysis,

GRD is the value of government spending on R&D, lagged three years, in millions of 2005 dollars as reported by the Bureau of Economic Analysis,

FEDRC is the value of Federal Funding for research centers managed by the private sector for a given year in millions of 2005 dollars as reported by the Bureau of Economic Analysis,

CTR is the value of revenue from the corporate tax, lagged one year, in millions of 2005 dollars as reported by the Tax Policy Center,

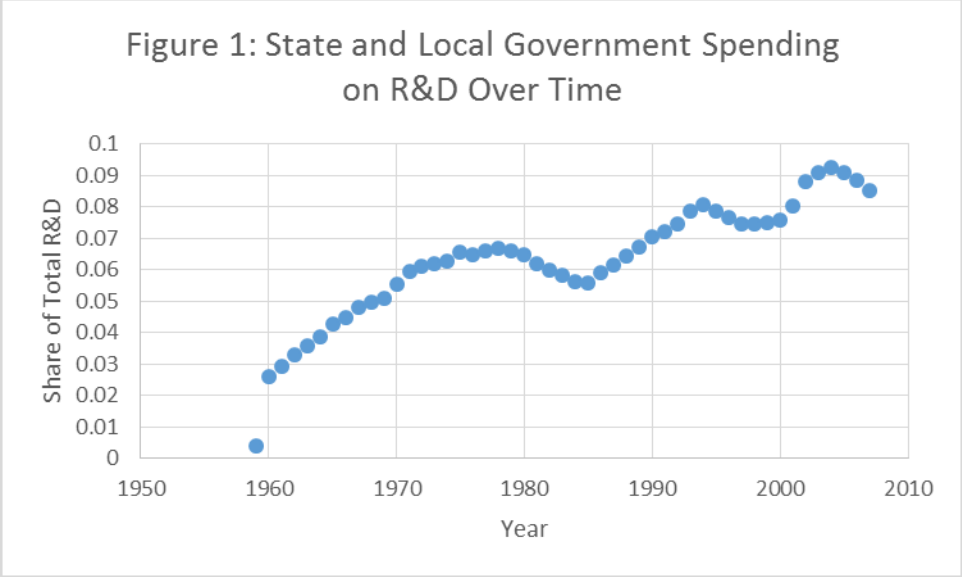
UNEM is the annual unemployment rate for a given year as tabulated by the Bureau of Labor Statistics,

NPS is the Net Private R&D Capital Stock for a given year in millions of 2005 dollars as reported by the Bureau of Economic Analysis.

Data drawn from the BEA is specifically from the 2007 Research and Development Satellite Account. This account is a joint product of the Bureau of Economic Analysis and the National Science Foundation that provides information on the nature of R&D activity in the US economy. Data spans from 1956 to 2007. The satellite account uses a specially developed price index based on the output prices of R&D intensive market actors to adjust R&D spending and investment. Lags in the variables are the same as those in Levy and Terleckyj (1983).

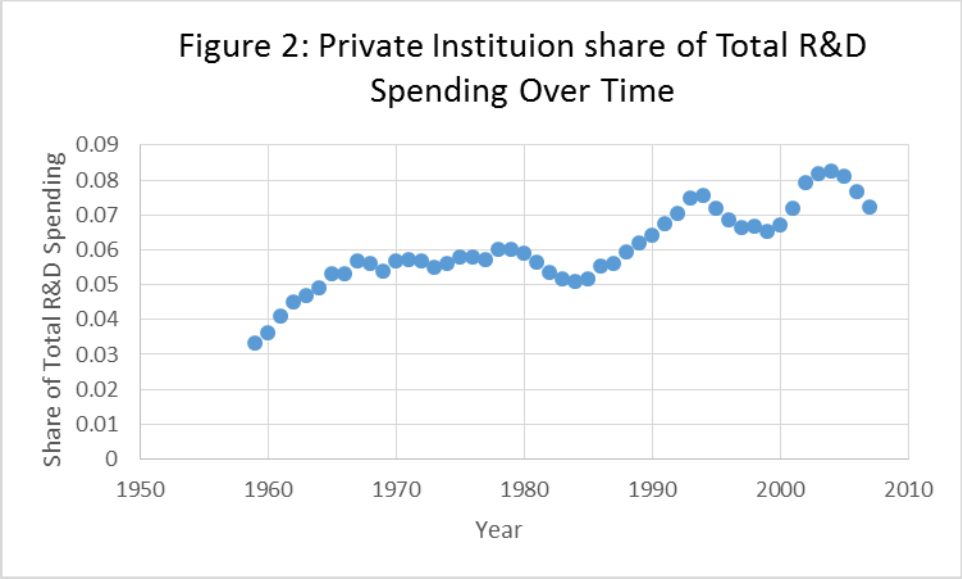
As this is time series data, errors in the regression will be correlated with another. As such, this papers uses the Generalized Least Squares method and will report the Akaike information criterion for each regression. The natural log of variables measured in dollars is used in the model to make the distribution of these variables more normal.

A surface level investigation of the data reveals several surprises that inform this paper. First is the increase in state and local government R&D spending as share of all R&D spending as shown in Figure 1. This primarily occurs in public universities.



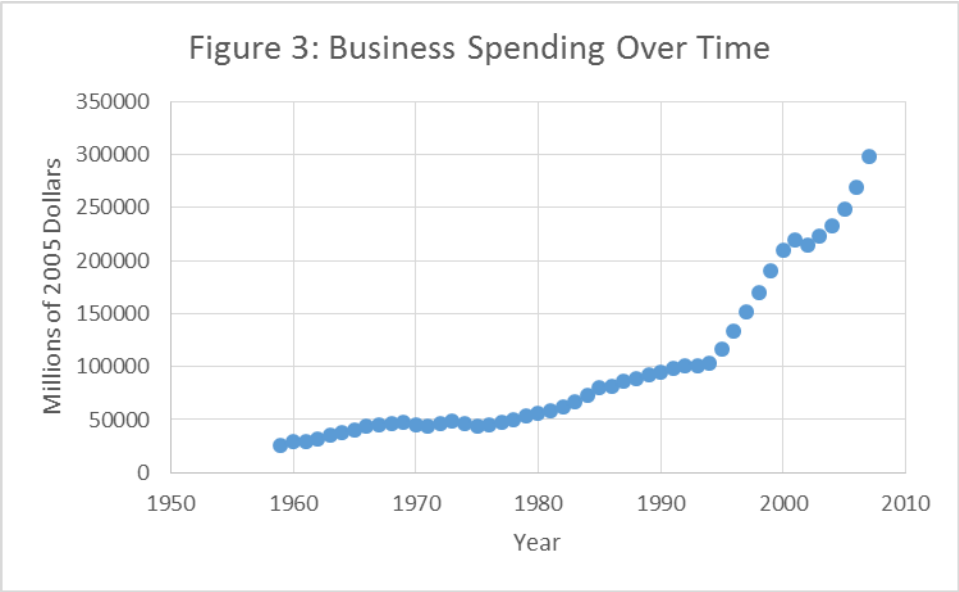
By 2007, state and local government spending on R&D was about 8.5% of all R&D spending in the United States. Prior macroeconomic works mentioned in the literature review were generally published in the 1980's and considered only Federal R&D spending. Given this growth, GRD will initially be the sum of all public R&D spending.

Another interesting trend is the rise in the proportion of R&D spending by private institutions other than business. This category includes research hospitals, private universities, and similar institutions.



It is interesting to consider how this rise may impact business R&D spending. While that question is beyond the scope of this paper, it is important to note as a potential qualification to the findings found here.

To place the prior two figures in context, Figure 3 displays the value of business spending on R&D over time, in 2005 dollars.



Finally, the lines between types of R&D are not always clear. For example, the Federal government funds research centers run by non-profit private institutions. This paper follows the established literature by including a variable for government funded research centers run by private industry and neglecting those run by non-profit private institutions.

With these features of the data in mind, regression results of the above equation are as follows:

Table 1: Impact of Aggregate Public R&D Funds on Private R&D Funds

	Estimate	Std. Error	t-Value	P-Value	Significance
Intercept	2.138	1.375	1.555	0.127929	-
FEDRC	0.893	0.2257	3.978	0.000284	***
GRD (T-3)	0.2671	0.1135	2.352	0.023673	**
UNEM	-0.04293	0.01786	-2.404	0.020954	**
NPS	4.496e-7	2.311e-7	1.945	0.058820	-
CTR (T-1)	1.089e-6	8.361e-7	1.303	0.20027	-
Significance Values: * 10%, ** 5%,*** 1%. N = 45. AIC = -45.258					

Table 1 indicates a one percent rise in R&D spending by government produces an expected rise of 0.2671% in private business R&D spending three years later, significant at the 5% level. This has less of an effect than funding for research centers. A 1% increase in Federal spending on research centers managed by the private sector leads to a predicted 0.893% rise in business R&D spending, significant at the 1% level. These results suggest government R&D spending and private R&D spending are compliments.

The results offer some contrast with Levy and Terleckyj (1983). That paper found a one dollar increase in Federal spending on research centers managed by the private sector led to a predicted twenty-seven cent rise in private R&D spending. The direction of the result for that type of spending in this paper is similar. However, this paper predicts all other types of government R&D spending, lagged three years, increase business R&D spending whereas Levy and Terleckyj found weak evidence they decrease private business spending.

There a few possible reasons for this divergence. First, this regression includes state and local government spending on R&D, which often occurs in public universities, while Levy and Terleckyj do not. This funding may go to basic research that private firms develop further. Second, this difference may be a result of the time frame differences in the papers (1949-1981 vs. 1961-2007). Finally, it may be statistical noise.

An additional regression of this data using only Federal spending may be instructive. Results of that regression are in Table 2.

Table 2: Impact of Federal R&D Funds on Private R&D Funds

	Estimate	Std. Error	t-Value	P-Value	Significance
Intercept	2.118	1.569	1.350	.1847	-
FEDRC	1.045	0.269	4.604	4.14e-05	***
GRD (Federal Only, T-3)	0.1558	0.1460	1.067	0.2925	-
UNEM	-.03994	0.01876	2.129	0.0394	**
NPS	5.458e-07	2.446e-07	2.231	0.0313	**
CTR (T-1)	1.275e-06	8.748e-07	1.457	0.1528	-
Significance Values: * 10%, ** 5%,*** 1%. N = 45. AIC = -40.589					

With state and local funding excluded, the coefficient and significance of GRD changes dramatically. GRD is no longer significant at even the ten percent level and the estimate of its coefficient is near zero while the variable's standard error is substantially larger. This result aligns more with the findings of Levy and Terleckyj.

The findings in table 2 imply State and Local Government R&D funding is highly complementary with private business funding. To quantify this, table 3 shows the regression results of the above equation modified so that State and Local funds and Federal funds are different explanatory variables. (Reported as State/Local and Federal, respectively.)

Table 3: Impact of Public R&D Funds by Source on Private R&D Funds

	Estimate	Std. Error	t-Value	P-Value	Significance
Intercept	7.612	1.832	4.156	0.000171	***
Federal (T-3)	-0.5856	0.2114	-2.770	0.008548	***
State/Local (T-3)	0.2818	0.06567	4.291	0.000114	***
FEDRC	0.8981	0.1925	4.666	3.57e-05	***
CTR (T-1)	9.926e-7	7.332e-7	1.354	0.183585	-
NPS	8.853e-7	2.190e-7	4.043	0.000241	***
UNEM	-0.0415	0.0156	-2.650	0.011567	-
Significance Values: * 10%, ** 5%,*** 1%. N = 45. AIC = -56.376					

Here, the difference between funds spent by the different levels of government is strongly apparent. A 1% rise in state and local funds leads to an expected 0.28% increase in private funds

whereas the same increase in Federal funds leads to an expected 0.58% decrease in private R&D spending. Both of these results are significant at the 0.1% level. The results shown in Table 3 confirm the R&D activities of different levels of government have different relationships with private R&D funding; state funding being complimentary and Federal funding causing displacement. No paper in the reviewed literature described this difference in effect. Federal funds that go to privately managed research centers remain complimentary at a large magnitude.

Conclusion

Government in the US of every level spent 65.7 billion real 2005 dollars on R&D projects in 2014, about sixteen percent of all R&D funds that year. As R&D work is crucial to economic growth, the relationship between these and private funds is important. This paper finds the nature of that relationship depends on the type of R&D spending and what level of government makes the expenditure, a distinction not explored in the existing literature. Specifically, state and local funds are complimentary to private funds while Federal funds exhibit a more mixed relationship. Quantitative findings include that the expected rise in the quantity of private funds is about .28% when the quantity of state and local funds rises 1%; the expected decrease in the quantity of private funds is about .5% when the quantity of Federal funds rises 1%; and the expected increase in the quantity of private finds is .89% when the quantity of Federal funds given to research centers run by private business rises 1%. These results are insightful but pose several questions. First, why are state and local funds complimentary with private funds but federal funds are not? As noted, most of these funds go to R&D work in public universities. These institutions exhibit documented R&D spillover effects with private industry that may explain the observed relationship. However, further research is necessary to confirm this mechanism is at work. Second, would further divisions in the type of Federal R&D spending

demonstrate different relationships? The numerous departments of the Federal government conduct a spectrum of R&D activities, ranging from basic research to missile defense development; individually, some of these may not result in the substitution effect the aggregate results display. Finally, the question of why microeconomic and macroeconomic studies on this issue diverge remains. As discussed in the literature review, macroeconomic studies find evidence for a complimentary relationship between public and private R&D funding while microeconomic studies are inconclusive. It would be interesting for future research to why these approaches give different results when evaluating the critical issue of R&D funding.

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