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R&D expenditures and U.S. economic growth: A disaggregated approach

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Abstract

Based on U.S. data for the 48-year-period 1953–2000, this study makes a contribution on the R&D-growth relation along five dimensions. First, we note several descriptive patterns that may be regarded as stylized facts relative to R&D outlays in the U.S. during the half-century period. These include (a) a dramatic increase in the share of non-federal R&D outlays, (b) a corresponding decline in the share of federally funded R&D expenditure, and (c) an even more dramatic decline in the share of defense R&D spending. Second, in a departure from most of the literature on the topic, we study the R&D-growth nexus at a disaggregated level by considering the roles of federal, non-federal, and defense R&D outlays. Third, we use the relatively new bounds-testing and ARDL (autoregressive distributed lag) procedures of Pesaran et al. [Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*, 289–326] to estimate the (long run) relation between R&D outlays and growth in a fairly standard model. Fourth, contrary to the almost universal belief, our estimates indicate a larger role of federal R&D relative to non-federal R&D in growth, and also a stronger role of defense R&D than of non-defense (federal) R&D. Last, to the extent our estimates are reasonable, the above-noted temporal movements in the shares of federal, non-federal, and defense R&D outlays seem to reflect socially perverse trends in the context of economic growth and well-being, and indicate the need for appropriate policy interventions for a substantial enhancement of federal defense R&D and non-defense R&D outlays.

JEL classification: O38; O40; H40

Keywords: R&D; Economic growth; Defense R&D; Federal R&D; Non-federal R&D

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1. Introduction

The relation between outlays on research and development (R&D) and economic performance has attracted much scholarly attention. Since the pioneering work by Griliches (1958) for the U.S. agriculture, many studies have considered the effect of R&D activities on productivity, output, and economic growth. U.S. Bureau of Labor Statistics (BLS, 1989) provided a good review of the research until around the middle 1980s. Goel and Ram (1994) also gave some indication of the extensive research in the area. As a result of the findings of these studies and the general awareness about the contribution of R&D to economic growth, governments have tried to bolster research spending via numerous policy initiatives. However, not enough is yet known about the role different types of R&D play in their impact on economic growth. For example, different types of research spending, e.g., defense R&D and non-defense R&D, might not have similar impacts on economic growth.

Several approaches have been adopted to study the relation between R&D expenditure and economic performance. Most scholars have sought to relate R&D outlays with productivity, output or economic growth in econometric models. Several of these (and other) studies have also generated private or social rates of return to R&D expenditure.[1] Some scholars have estimated the contribution of R&D activities to economic growth through a growth-accounting framework by working with R&D stocks and estimated or assumed rates of return.[2] Our work broadly follows the econometric methodology of relating R&D expenditure with aggregate output growth in a simple "exogenous" growth format. While focusing on data for the U.S. covering the last half-century, we make a contribution on the topic along several dimensions. In particular, we note several "stylized facts" relative to trends in R&D funding for some major categories. These seem important at a descriptive level. Second, in a departure from almost the entire literature, we study the R&D-growth nexus at a disaggregated level by considering the roles of federal, non-federal, and (federal) defense R&D. While it may be useful to work with aggregate R&D measures for some purposes, the logic and the character of federal R&D funding seem inherently different from those of non-federal R&D funding by industry and other R&D investors. Similarly, the logic and the nature of defense R&D within the federal sector is quite different from that of non-defense R&D funding by the U.S. government. It should be of considerable interest to study the relative growth effects of these components. This seems particularly useful since there are marked trends in the shares of federal, non-federal, and defense R&D. Third, given the time-series structure of our data and the problems associated with most of the numerous "traditional" econometric procedures for handling such data, we employ the relatively new approach proposed by Pesaran, Shin, and Smith (2001) for analyzing level relations in time-series observations through bounds-testing and ARDL (autoregressive distributed lag) procedures. The main merit of these procedures is that there is no need for pretests to judge the order of integration (cointegration) of the variables, and the procedures are applicable whether the variables are $I(0)$ or $I(1)$ and whether they are cointegrated or not.

[1] Besides many others, Jones (2002) and Jones and Williams (1998) have provided indication of returns to R&D. Archibald and Pereira (2003) have also made some contribution on the subject. Baumol (2003) discussed two aspects of the relation between innovations and growth. Kwack and Sun (2005) studied the role of technological progress in Korea's economic growth by estimating cost and cost-share equations. More recently, Wang (2007) studied R&D efficiency and its relation with economic performance in a cross-country context.

[2] Of many such studies, Comin (2004) and Fraumeni and Okubo (2005) are two recent examples.

2. Model, data, and estimation methodology

We adopt a simple "exogenous" growth model of the kind used by Goel and Ram (1994), which resembles Eqs. (19) and (20) of Jones (2002, p. 233).[3] As indicated by Goel and Ram (1994, pp. 403–404), the model can be derived from a conventional production function (i.e., output (*Y*) as a function of labor (*L*), capital (*K*) and R&D (*R*)), by treating R&D as another form of capital besides the traditional inputs of labor and physical capital. As indicated by them, by an appropriate manipulation of the expressions, the growth equation may be written as follows

$$\dot{Y}_t = a + b_L \dot{L}_t + a_K \left(\frac{I_K}{Y}\right)_t + a_R \left(\frac{I_R}{Y}\right)_t + u_t \tag{1}$$

where $\dot{Y}_t$ and $\dot{L}_t$ are the rates of increase of aggregate output and labor force in period (year) t, I_K/Y and I_R/Y are shares of conventional investment and R&D outlays in aggregate output, and a and u denote constant and error terms.

The difficulties associated with such a model are well known and have been ably discussed by Griliches (1979) and other scholars. Despite these difficulties, the model provides a fairly reasonable framework for a preliminary assessment of the role of R&D in economic growth.

Since our focus is on disaggregated R&D measures, we consider two sets of R&D variables. One consists of federal and non-federal R&D funding, and the other consists defense and non-defense categories of federal R&D along with non-federal R&D outlays.[4] The non-defense federal spending may be seen as including research outlays at universities, R&D spending on environmental initiatives, and health-related research.

2.1. Data

Information on R&D funding is taken from U.S. National Science Foundation (2002). It provides total R&D expenditure in constant (1996) dollars, and also the total, federal, and non-federal components as percentage of GDP. The share of defense R&D is taken from U.S. National Science Foundation (2005, p. 80). We consider the period 1953–2000 since data for 2001 and 2002 were preliminary. Real (constant price) GDP is the proxy for aggregate real output and is taken from 2005 edition of Economic Report of the President (U.S. Printing Office, 2005, Table B-2), which is also the source for labor force (Table B-35) and the share (percent) of gross private domestic investment in GDP. All shares (percentages) have been taken in real terms, and number of employed persons is used as the labor force variable.

2.2. Estimation methodology

Due to the difficulties associated with most of the many tests for order of integration (and cointegration), we use a relatively new approach proposed by Pesaran et al. (2001) for testing the existence of a level relation between time-series variables and estimating such (long run) relations, which are similar to cointegrating vectors in the traditional methodology. The main appeal of the

[3] See Barro and Sala-i-Martin (2004) and Jones (1995) for alternate formulations.

[4] Since our main purpose is to relate different types of R&D funding with economic growth, our variables are based on funding source and not the location of the R&D activity. As is well known, a large part of federally funded R&D activity is located in non-federal organizations.

procedure is that it obviates the need for pretesting the variables for the order of integration (and cointegration) and it does not require that the variables be of the same order of integration. It can be used whether the variables are $I(0)$ or $I(1)$ irrespective of whether they are cointegrated or not. The procedure first tests for the existence of a relation in levels and, if there is one, estimates it. The methodology consists essentially of the following three steps.

First, bounds tests are used for judging whether a level relationship exists between the variables of the model. This is done by estimating a conditional ECM (error correction model) of the form indicated in Eq. (8) of Pesaran et al. (2001, p. 293). We used that form, but did not include a time-trend term since none is expected in the rate of growth of aggregate output. To keep the model simple, we also avoided postulating exogenous shocks to the growth rate. Following the observation by Pesaran et al. (2001, p. 308), in estimating the ECM we tried to strike a balance between taking the lag length to be large enough to mitigate the residual serial correlation but small enough so as not to overparametrize the ECM in view of limited degrees of freedom.

Second, under the null of no relation in levels, lagged dependent-variable term and one-period lag on regressors are tested for joint significance through an F-test in terms of upper and lower bounds of the critical values tabulated by Pesaran et al. (2001, p. 300, Table C1.iii). If the F-statistic is larger than the upper bound, the null is rejected, existence of a relation may be inferred, and one may proceed to estimate the relation. A supplementary t-test for the significance of the lagged level of the dependent-variable may also be conducted to check on the inference from the F-statistic. Upper and lower bounds for the non-standard t-statistics have also been tabulated by Pesaran et al. (2001, pp. 303–304).

Third, if a level relation is indicated to exist, the ARDL procedure is used to estimate the long-run relationship through a parsimonious approach of the kind discussed by Pesaran and Shin (1999). As in Pesaran et al. (2001, p. 313), orders of ARDL for the dependent-variable (growth rate) and the regressors may be selected by defining the maximum number of lags and then searching the lag space for the optimal lags in terms of various criteria. Since we have only 47 observations, we searched the lag space for a maximum of 1, 2 and 3 lags. The entire exercise was conducted in Microfit (version 4.1) software.

3. Main findings

Before the main estimates are presented, we note some descriptive patterns. Table 1 contains sample statistics for the variables. Apart from the somewhat well-known dips in the labor-force

Table 1
Descriptive sample statistics for the main variables

	Mean	S.D.	Minimum	Maximum
Annual rate of growth of real GDP, dY/Y (%)	3.27	2.26	−2.05	7.02
Rate of increase of labor force, dL/L (%)	1.74	0.68	0.21	3.22
Gross private fixed investment as % of GDP	15.43	1.22	13.37	18.42
Total R&D outlays as % of GDP	2.43	0.34	1.36	2.88
Federal R&D funding as % of GDP	1.22	0.34	0.67	1.92
Non-federal R&D funding as % of GDP	1.22	0.35	0.63	2.02
Federal R&D funding as % of total R&D	50.19	11.68	25.00	66.90
Non-federal R&D funding as % of total R&D	49.82	11.68	33.20	75.00
Defense R&D funding as % of total R&D	32.10	11.42	13.50	54.30

Based mainly on data in Appendix A.

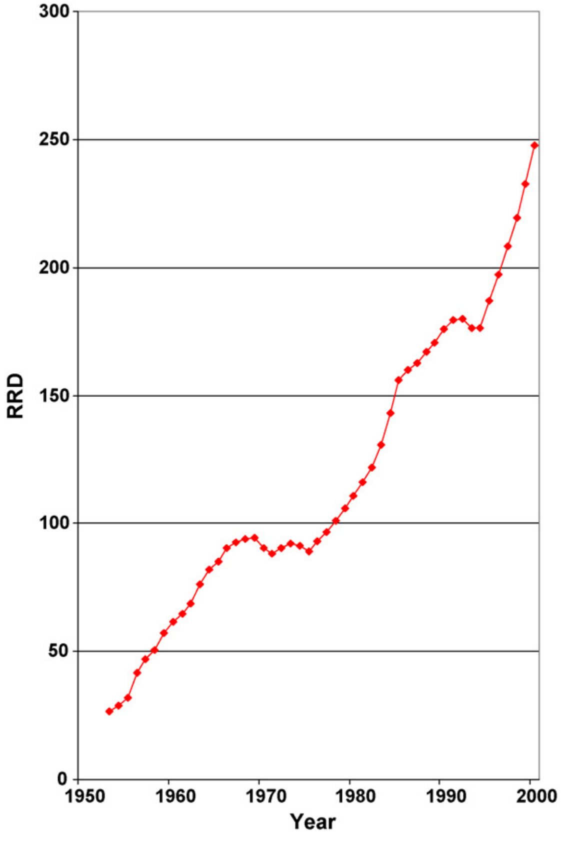

Fig. 1. Real R&D (RRD) spending in the U.S. in billions of 1996 dollars, 1953–2000.
Note: Based on data in Appendix A.

and GDP growth rates, and the relatively stable investment rate, there are huge temporal variations in the shares of federal, non-federal and defense R&D shares, and it is useful to consider the temporal patterns more directly. Appendix A contains information on R&D expenditure categories of main interest. Based on that data, Fig. 1 shows the pattern of (real) R&D outlays in billions of 1996 dollars over the period 1953–2000, and one can see a clear and sizable upward trend with an annual rate of increase of around 3.76%. Fig. 2 depicts temporal pattern for the non-federal share in total R&D funding, Fig. 3 shows the trend in federal share, and Fig. 4 depicts the pattern in defense R&D. Several important points may be noted from Figs. 2–4.

First, the share of non-federal outlays in total R&D spending has undergone a huge increase. Despite the drop during the late 1950s and the early 1960s, when federal defense and space R&D shares show big jumps, the non-federal share increased from 46.1% in 1953 to 75.0% in 2000. The 36-year increase from 33.2% in 1964 to 75% in 2000 is even more dramatic.

Second, correspondingly, share of federal R&D has declined precipitously from 53.9% in 1953 to 25.0% in 2000. Moreover, after the well-known increase during 1953–1963 in space- and defense-related R&D, the federal share declined dramatically from 66.9% in 1964 to 25.0% in 2000.

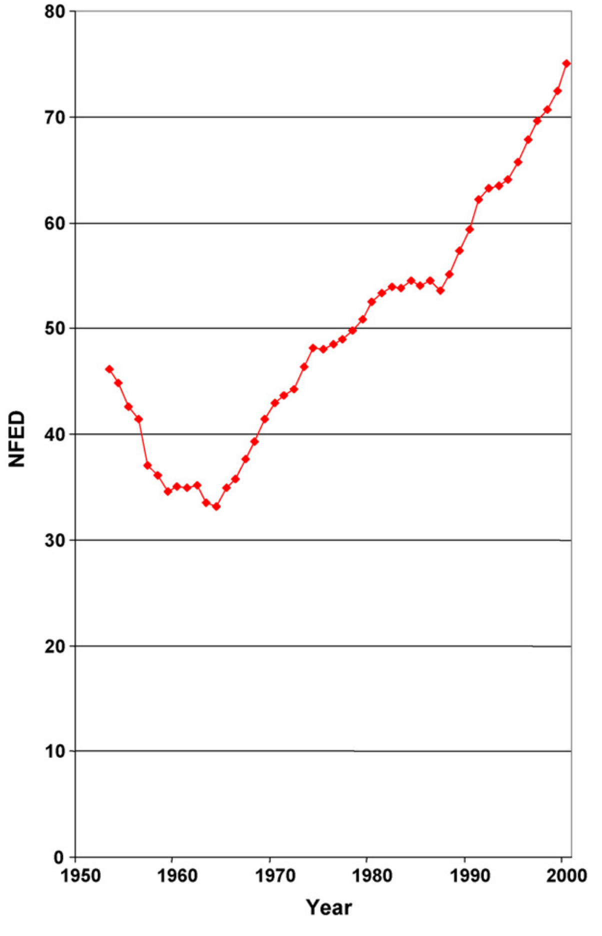

Fig. 2. Share of non-federal R&D outlays (NFED) in total R&D spending (%) in the U.S., 1953–2000.
Note: Based on data in Appendix A.

Third, perhaps contrary to the popular perception, share of defense R&D spending has declined even more dramatically. While it rose modestly between 1953 and 1959, when it accounted for most of federal R&D, it declined by nearly three fourths from 54.3% (of total R&D funding) in 1959 to 13.5% in 2000. Although the non-defense component of federal R&D has also experienced a large decline over the 38-year period from 32.0% in 1965 to 11.5% in 2000, the decline in defense R&D is considerably larger.[5]

Three stylized facts relative to R&D funding in the United States during the last about 50 years may thus be summarized as (a) huge increase in the non-federal share, (b) a corresponding decline in the federal share, and (c) a massive decline in the defense share of R&D outlays.

Table 2 reports the estimates of main interest. Part A indicates the F-statistics (and t-statistics) for several lag structures relevant to the bounds test for judging the existence of a level relation. It

[5] It might be possible to identify several factors behind the huge decline in the share of defense R&D. We do not go into these. Lichtenberg (1995) provides a review of the literature on defense R&D.

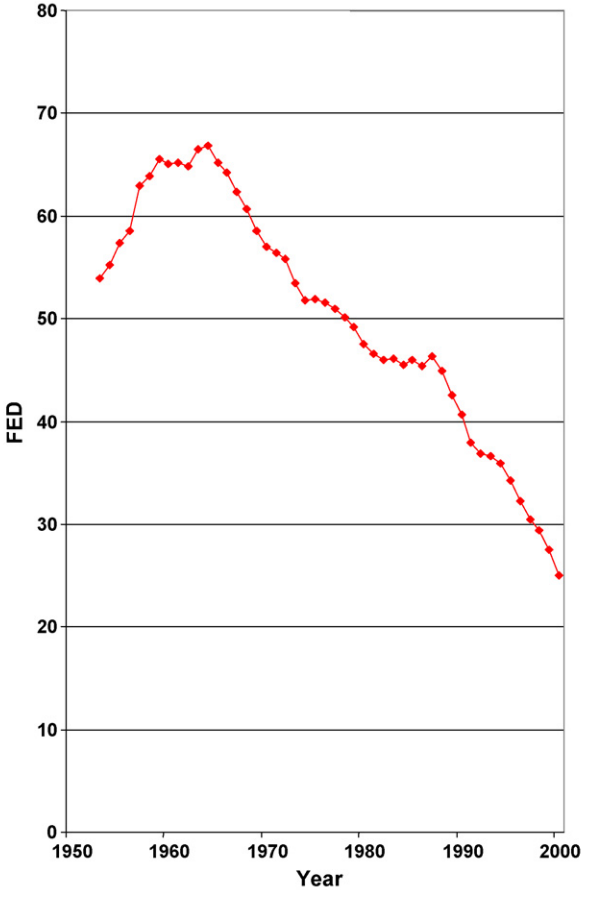

Fig. 3. Share of federal R&D outlays (FED) in total R&D spending (%) in the U.S., 1953–2000.
Note: Based on data in Appendix A.

includes the specification where federal and non-federal R&D outlays are entered separately and also that in which defense, (federal) non-defense and non-federal components enter separately. Given that we have 47 observations, explorations based on 1, 2 and 3 lags seem reasonable. It is evident from the table that the predominant pattern rejects the null of no-relation in levels. Three of the four *F*-statistics exceed the upper bound at least at the 5% level, and one exceeds the upper bound at the 10% level. Although weaker, the *t*-statistics also broadly support the rejection of the null.

Part B reports several ARDL estimates for the two sets of specifications. The estimates are based on search over 1-lag, 2-lag and 3-lag spaces. While the reported numbers correspond to lag structures chosen by the SBC criterion, numerous unreported estimates corresponding to other criteria (AIC, HQ, and Adj.-R^2) show the same pattern as the reported numbers.[6] The high plausibility of the labor parameter is evident. Despite the low statistical significance of the

[6] As is well known, SBC here denotes Schwartz Bayesian Criterion, AIC stands for Akaike Information Criterion, and HQ denotes the Hannan-Quinn rule.

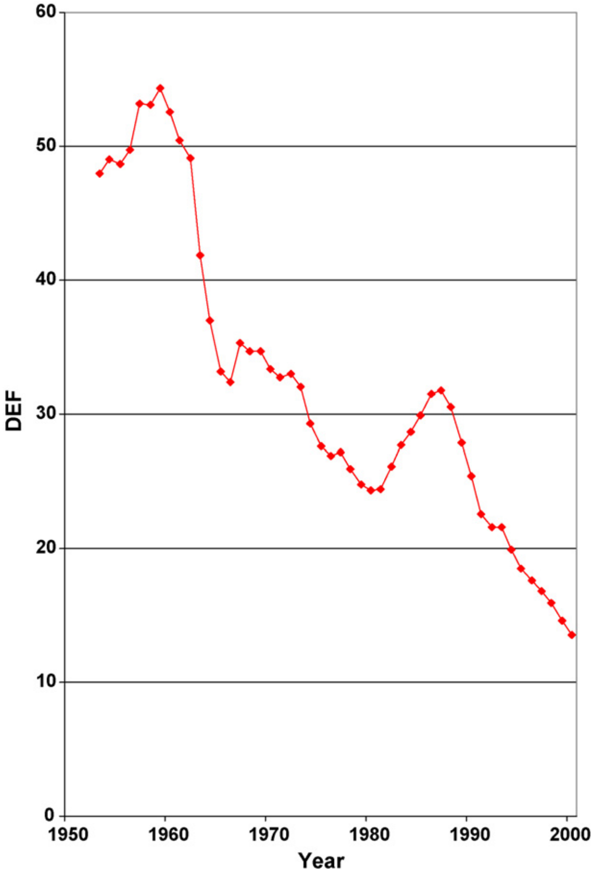

Fig. 4. Share of defense R&D (DEF) outlays in total R&D spending (%) in the U.S., 1953–2000.
Note: Based on data in Appendix A.

investment parameters, these carry a fair numerical consistency with the conventional wisdom. Although R&D parameters tend to be high, the estimates suggest two major points.

First, there is a consistent indication of federal R&D being more productive than non-federal R&D. This is the scenario in every reported and unreported ARDL choice, and the numerical superiority of federal R&D over the non-federal component is sizable in all cases. This pattern casts doubt on the practice followed in almost all growth-accounting studies that routinely assume the return to federal R&D to be substantially lower than that on non-federal R&D. The pattern revealed here is a sharp contrast from almost all research on the topic, and perhaps merits a reconsideration of the nearly universally accepted paradigm or stylized fact on the topic.[7]

[7] Despite the small cross-country samples, Sylwester (2001) also indicates government R&D to be more productive than industry R&D. In a somewhat similar manner, Lederman and Maloney (2003) estimate from cross-country data several regressions that are similar to ours, but do not consider public and private R&D separately. On a slightly related note, a strand of the literature has focused on examining whether public and private R&D are complementary. Leyden and Link (1991), David, Hall, and Toole (2000) and Goel and Hsieh (2006) are examples of such studies.

Table 2
Estimation of growth Eq. (1) by bounds-testing and ARDL procedures

Part A: F-statistics and t-statistics for bounds tests

Lags (dependent-variable and regressors)	F-statistics	t-statistics
With federal and non-federal R&D variables ($k = 5$)		
1	5.94*	−3.96+
2	3.79*	−3.33
With (federal) defense and non-defense and non-federal R&D variables ($k = 6$)		
1	4.93*	−3.95+
2	3.58+	−3.57

Part B: selected ARDL estimates

ARDL lags (SBC criterion)	Coefficient of (t-statistics are in parentheses)				
	Constant	dL/L	I/Y	FEDR&D/Y	NONFEDR&D/Y
Federal and non-federal R&D comparison					
(1, 0, 1, 0, 0)	−0.05*	0.64*	0.09	2.71*	1.79*
	(−2.03)	(3.74)	(0.74)	(5.19)	(3.60)
(2, 0, 2, 1, 0)	−0.06*	0.71*	0.02	3.56*	3.01*
	(−2.76)	(4.26)	(0.14)	(6.81)	(5.40)
(1, 0, 3, 0, 0)	−0.06*	0.54*	0.06	3.58*	2.70*
	(−3.11)	(4.17)	(0.56)	(7.81)	(6.01)

ARDL lags (SBC criterion)	Coefficient of (t-statistics are in parentheses)					
	Constant	dL/L	I/Y	DEFR&D/Y	NONDEFR&D/Y	NONFEDR&D/Y
(Federal) defense, non-defense and non-federal R&D comparison						
(1, 0, 1, 0, 0, 0)	−0.06*	0.67*	0.14	3.37*	1.95*	2.07*
	(−2.51)	(4.03)	(1.12)	(5.10)	(2.75)	(4.03)
(2, 0, 2, 0, 0, 0)	−0.07*	0.63*	0.10	4.16*	2.45*	2.79*
	(−3.14)	(4.12)	(0.86)	(6.63)	(3.52)	(5.48)
(1, 0, 3, 0, 0, 0)	−0.07*	0.57*	0.08	3.97*	2.91*	2.81*
	(−3.43)	(4.46)	(0.82)	(7.72)	(4.65)	(6.34)

*Denotes significance at least at the 5% level; +denotes significance at 10%. Although SBC-selected estimates are shown in Part B, numerous other estimates where lag lengths were selected by other criteria are very similar. Significance in Part A is based on critical values in Pesaran et al. (2001). R&D variables in Part B are ratios of R&D outlays to GDP.

Second, it is evident that defense R&D has a substantially larger parameter than non-defense R&D and the difference is rather pronounced. While our data do not allow us to judge the channels through which research spillovers might occur, these findings suggest that defense R&D may have greater positive externalities than non-defense R&D.[8]

To summarize, our disaggregated approach indicates federal outlays to be sizably more socially productive than private R&D, and also shows defense R&D to be more growth-enhancing than non-defense R&D.

[8] The research by Klenow and Rodriguez-Clare (2004) is relevant to these aspects.

4. Discussion and some additional considerations

Considering the temporal patterns in the shares of federal, non-federal, and defense R&D in the United States during the last half-century, the most significant thought would be that trends in the shares of these components seem to have been socially perverse. Defense R&D, which appears to be the most productive component, has suffered a substantial decline in its share. Similarly, socially more productive federal R&D has experienced a dramatic fall in its share relative to the less productive non-federal R&D. The relevant patterns, and the growth implications of the estimates, deserve further careful study. There could perhaps be several explanations for the stronger association of federal and defense R&D with growth. For example, federal and defense research projects are likely to go through a tougher screening and accountability criteria than private R&D. Moreover, while federal R&D is motivated by social benefits, private R&D is guided by the limited profitability criterion and is thus likely to generate fewer positive externalities. There may also be a significant difference in the nature of the research "products", and an "asymmetric" or one-sided complementarity of public R&D relative to private R&D. The expositions by Leyden and Link (1991), Tassey (2004) and other scholars seem relevant to such possibilities. As suggested above, the issues appear to deserve more careful attention.

Besides the desirability of a further study of the channels that link economic growth with non-federal and federal non-defense and defense outlays, some policy implications of the reported estimates merit elaboration. Since defense R&D seems to contribute most to growth, an enhancement of defense R&D outlays deserves careful consideration. Although U.S. National Science Foundation (2005, p. 13) indicates that defense R&D share increased over the period 2001–2003 (and possibly in later years), the very large contribution of this component to growth reflected in Table 2 suggests that further increases might be appropriate so as to reverse the nearly steady fall in its share between 1987 and 2000. Three additional observations are relevant here. First, our suggestion should not be misunderstood as recommending an increase in overall defense outlays; the implication relates only to the *R&D component*, which is less than one-seventh of the defense budget. Second, defense R&D includes several different items, and our analysis does not indicate which of these might deserve greater increase than others. Third, U.S. National Science Foundation (2005, p. 13) notes that the increase in defense R&D after 2001 is related largely to counter-terrorism measures. Our estimates show that the growth objective might be at least as important, and a combination of growth and terrorism-related considerations should indicate a greater increase in defense R&D than the counter-terrorism consideration alone.

The estimates show that federal non-defense R&D also makes a large contribution to economic growth, and its enhancement should be considered. The share of federal non-defense R&D declined substantially from 16.0% in 1994 to 11.5% in 2000. U.S. National Science Foundation (2005, p. 13) shows that federal non-defense basic research funding supports, besides space projects, National Science Foundation's programs in general science and health programs of National Institutes of Health. These health and general science programs are likely to have large positive externalities directly and by raising the productivity of private R&D effort. U.S. Office of Science and Technology Policy (2006) described the President's American Competitiveness Initiative (ACI) and the commitment toward a substantial increase in federal R&D to support basic research in science and engineering. It may be appropriate to recognize more directly the consideration of economic growth also relative to federal non-defense R&D funding. A combination of the objective of direct economic growth with that of the ACI should suggest a larger allocation to federal non-defense R&D than the consideration of ACI alone.

In a study of the R&D-growth nexus, the issue of lags is obviously important. It might seem that our Eq. (1) overlooks lags. However, at least a limited consideration of lags is inherent in the Pesaran–Shin–Smith procedure. As they noted (2001, p. 307), "The ARDL model . . . automatically allow(s) for . . . lagged effects."

We focus on the long-run relations and do not consider the ECM versions of the model because the R&D-growth nexus is primarily a long-run investigation. The importance of long-term effects of R&D has been recognized in the literature.

As done by most researchers, we use a single-equation framework to which the bounds-testing approach is applicable. As Pesaran et al. (2001, p. 299) note, within the single-equation context, their approach is more general than cointegration analysis of partial systems carried out by almost all scholars.

While our R&D estimates are on the high side, the large difference between the parameters for investment rate and R&D outlays supports qualitatively the suggestion made by Jones and Williams (1998, p. 1119) that there may be substantial underinvestment in R&D, and the underinvestment seems particularly severe in the federal R&D outlays.[9]

5. Concluding remarks

The importance of R&D for economic growth is well-known, as indicated by the numerous studies in the last two decades. However, as David et al. (2000) also note, the impact of different types of research spending is not understood very well. Using disaggregated U.S. data for nearly half a century, a fairly standard growth model, and a relatively new and appealing approach to estimation of long-run relations in time-series observations, this study considers trends in various components of R&D outlays and the link between economic growth and R&D funding in several sectors. The main points may be summarized in seven statements. First, there has been a dramatic decline in the share of defense R&D outlays. Second, the entire federal R&D share has also experienced a substantial decline. Third, correspondingly, the share of non-federal R&D outlays has increased greatly. Fourth, contrary to most existing research, every estimate indicates economic growth to have a stronger association with federal R&D than with non-federal R&D. Fifth, the estimates also indicate a considerably stronger association of growth rate with defense R&D than with non-defense (federal) R&D. Sixth, therefore, observed trends in the shares of defense, federal, and non-federal components in total R&D outlays might seem perverse in the context of economic growth and social well-being. Specifically, the share of defense R&D, which has the strongest association with growth, has suffered the most severe decline along with the share of total federal outlays, while the socially less productive non-federal R&D experienced a huge increase. Seventh, trends in the shares and the relative growth contribution of each component indicate need for a substantial enhancement of defense R&D and federal non-defense R&D being considered. Such growth-related enhancements would be additional to the increases envisaged in terms of counter-terrorism measures and the American Competitiveness Initiative.

In closing, as appropriate data become available at a finer level of detail and there are better quantitative measures of some of the institutional factors involved, more light can be shed on the various channels through which research outlays may have a bearing on economic growth.[10]

[9] Comin (2004) refutes the Jones-type suggestion that there is large underinvestment in U.S. R&D.

[10] For example, the nature of R&D activities under contracts and grants might be qualitatively different, as David et al. (2000) suggest.

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Appendix A. Basic data on R&D funding in the United States: 1953–2000

Year	Total R&D (billions of 1996 dollars)	Funding as share (%) of total R&D			Funding as share (%) of GDP		
		Non-federal	Federal	Defense	Non-federal	Federal	Defense
1953	26.8	46.1	53.9	48.0	0.63	0.73	0.65
1954	28.9	44.8	55.2	49.0	0.66	0.81	0.72
1955	31.8	42.6	57.4	48.7	0.64	0.87	0.74
1956	41.6	41.4	58.6	49.7	0.80	1.14	0.96
1957	46.9	37.1	62.9	53.2	0.80	1.35	1.14
1958	50.4	36.1	63.9	53.1	0.84	1.49	1.24
1959	57.1	34.6	65.5	54.3	0.85	1.61	1.34
1960	61.8	35.0	65.1	52.6	0.91	1.69	1.37
1961	64.9	34.9	65.2	50.4	0.93	1.74	1.35
1962	68.8	35.2	64.8	49.1	0.94	1.73	1.31
1963	76.2	33.5	66.5	41.9	0.95	1.88	1.19
1964	81.8	33.2	66.9	37.0	0.95	1.92	1.06
1965	85.2	34.9	65.2	33.2	0.98	1.83	0.93
1966	90.2	35.8	64.2	32.4	1.00	1.79	0.91
1967	92.6	37.6	62.4	35.3	1.05	1.75	0.99
1968	93.8	39.3	60.7	34.7	1.06	1.64	0.94
1969	94.2	41.4	58.6	34.7	1.09	1.55	0.92
1970	90.4	43.0	57.0	33.4	1.09	1.44	0.84
1971	88.3	43.6	56.4	32.7	1.04	1.35	0.78
1972	90.3	44.2	55.8	33.0	1.02	1.29	0.76
1973	92.1	46.4	53.5	32.0	1.04	1.20	0.71
1974	91.1	48.2	51.8	29.3	1.07	1.15	0.65
1975	89.1	48.0	51.9	27.6	1.05	1.13	0.60
1976	93.2	48.5	51.5	26.9	1.05	1.11	0.58
1977	96.4	49.0	51.0	27.2	1.05	1.09	0.58
1978	101.1	49.8	50.1	25.9	1.06	1.07	0.55
1979	106.1	50.8	49.2	24.8	1.10	1.06	0.54
1980	110.9	52.5	47.5	24.3	1.19	1.07	0.55
1981	115.9	53.3	46.6	24.4	1.23	1.08	0.56
1982	122.0	53.9	46.0	26.1	1.34	1.14	0.65
1983	130.8	53.8	46.1	27.7	1.37	1.18	0.71
1984	143.3	54.5	45.5	28.7	1.42	1.18	0.75
1985	155.8	54.0	46.0	29.9	1.47	1.25	0.81
1986	159.8	54.5	45.4	31.5	1.47	1.22	0.85
1987	162.8	53.6	46.4	31.8	1.43	1.23	0.85
1988	167.0	55.1	44.9	30.5	1.44	1.18	0.80
1989	170.4	57.4	42.6	27.9	1.48	1.10	0.72
1990	175.8	59.4	40.6	25.4	1.56	1.06	0.67
1991	179.5	62.2	37.9	22.6	1.67	1.02	0.61
1992	180.1	63.2	36.9	21.6	1.65	0.96	0.57
1993	176.2	63.5	36.6	21.6	1.58	0.91	0.54
1994	176.2	64.1	35.9	19.9	1.54	0.86	0.48
1995	187.2	65.7	34.2	18.5	1.63	0.85	0.46

Appendix A (*Continued*)

Year	Total R&D (billions of 1996 dollars)	Funding as share (%) of total R&D			Funding as share (%) of GDP		
		Non-federal	Federal	Defense	Non-federal	Federal	Defense
1996	197.3	67.9	32.2	17.6	1.71	0.81	0.44
1997	208.1	69.6	30.5	16.8	1.77	0.78	0.43
1998	219.3	70.7	29.4	15.9	1.82	0.76	0.41
1999	232.7	72.5	27.5	14.6	1.90	1.90	0.38
2000	247.6	75.0	25.0	13.5	2.02	0.67	0.36

Based on U.S. National Science Foundation (2002, 2005).

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