

## Government and Science: A Dangerous Liaison?

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### **SUMMARY**

We survey the relationship between government and science (concentrating on the situation in the U.S.). We discuss the theoretical rationale for government funding, showing that it is open to serious question – its model of science as market is highly suspect, and its implications for the remedial effects of intervention do not stand up to even casual empirical scrutiny. Calling attention to the nakedness of the standard economic rationale, however, does not touch the very real political rationales, and it is the interaction of these with the understandably strong desire of scientists to be well-funded to which we direct attention. We describe various ways in which government funding can interact with scientists and scientific activity to produce the unanticipated effects that concern us.

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## 1. Introduction

With the rise of the modern state, science has been increasingly drawn into the sphere of government intervention in terms of the funding of scientific activity and the direction of that activity. The underlying driving force of this tendency has been the growth of government itself. The impetus by governments to somehow ensure politically determined adequate levels of scientific R&D and to manage such efforts took hold in the 20<sup>th</sup> century principally as a consequence of nationalistic hostilities or perceived threats of external aggression. Later, this rationale was augmented by more broadly based social agendas and by the “market failure” claim advanced by academic economists in the 1950’s and afterward with respect to the production of R&D – especially so-called “basic research.”<sup>1</sup> Since then, the extent of government engagement in science, as seen on Chart 1 (below, p. 5), has trended upward significantly, and the prevalent thinking of our times is that only fiscal constraints should limit the magnitude of government funding of science.

There are serious reasons, however, for thinking that this liaison between government and science carries with it unanticipated dangers for the functioning and integrity of science as a reliable generator of knowledge. It is not so much that government seeks to exert a blatant and crude control over the content and direction of scientific inquiry – although that is not without precedent, notably in the U.S.S.R. – but that there are side-effects of the seemingly benign and generous government funding of science that result from the structure and conduct of that funding, effects that, in the short run, generate instabilities in scientific

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1. Nelson (1959), Griliches (1960), Arrow (1962).

activity and, in the longer run, are corrosive with respect to the structure and adaptability of the system of science itself.

We briefly survey the relationship between government and science (concentrating on the situation in the U.S.) both pre-WW II and (with some illustrative statistics) in the post-war era. We discuss in some detail the theoretical rationale for government funding, showing that it is open to serious question – its model of science as market is highly suspect, and its implications for the remedial effects of intervention do not stand up to even casual empirical scrutiny. Calling attention to the nakedness of the standard economic rationale, however, does not touch the very real political rationales, and it is the interaction of these with the understandably strong desire of scientists to be well-funded to which, following other commentators – particularly Greenberg (2001) – we direct attention. But, while we find Greenberg's detailed descriptions of unease within science compelling, we find his diagnosis and program for cure to be, at best, naïve, and in order to develop a more comprehensive alternative we devote considerable attention to an exposition of the various ways in which government funding can interact with scientists and scientific activity to produce the unanticipated effects that concern us.

## 2. Historical Background

The U.S. government has funded isolated scientific research projects (broadly conceived) since the early days of the Republic, as evidenced for example by the War Department's support of the Lewis and Clark Expedition and Congressional appropriation to support

Samuel Morse's electric telegraph. The Civil War accelerated and broadened a Federal presence in science, including the use for wartime purposes of scientific advisors, the establishment by Congress of the National Academy of Science (NAS) in 1863, and the passage of the Morrill and Holmstead Acts, establishing the Department of Agriculture and the land-grant system of colleges, both of which provided institutional bases for government funded scientific research that have persisted to this day. The Pure Food and Drug Act of 1906 established a permanent regulatory demand for scientific expertise. With the outbreak of WW I, the Department of the Navy constituted a naval consulting board (headed by Thomas Edison) to seek out applications of technologies for military purposes; it would become the Naval Research Laboratory after the war. President Wilson created the National Research Council (NRC) as an offshoot of the NAS tasked with addressing the scientific needs of the government. The NRC coordinated wartime projects in optics and gas warfare which involved the military, contracted private industries, and government sponsored university R&D. At the end of the war, this government-industry-university establishment was largely dismantled, and although the NRC was given permanent status, its activities during the 1920's greatly diminished due to a lack of funding.<sup>2</sup>

While a government presence in scientific and technological R&D was well established by the beginning of WWI, it was not based on a principled, coherent, or explicit "national science policy." Instead, government support for science served largely transitory wartime exigencies. But this would change under the Roosevelt administration with the onset of the depression and the approach of war. In 1933 FDR set up the Presidential Science Advisory Board and the National Planning Board (NPB) to enlist scientific expertise for solutions to

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2. See Rahm *et al.* (2000), ch. 2; Dupre and Lakoff (1962).

the depression. In 1934 the National Resources Board (NRB) replaced the NPB and also subsumed within its jurisdiction the Science Advisory Board. As Feldman *et al.* (2002) point out: “after all the organizational issues were settled, the federal government recognized ... that it had and would continue to have an important coordinating role to play in science and technology planning toward a national goal of economic well being” (p. 13).<sup>3</sup>

Of special note was the publication by the NRB in 1938 of a report entitled *Research – A National Treasure*. This was a comprehensive survey of government, industry, and university scientific activity that would provide the rationale and justification for a governmental science policy. The report argued that the government

1. is constitutionally obligated to support science and technology that is related to defense, scientific standards of weights and measures, and certain regulatory functions;
2. is more effective in carrying out research than the private sector, especially when private costs of research are high relative to its practical or social value; and
3. can stimulate industry research that is expensive and has unpredictable or delayed financial payoffs.<sup>4</sup>

Once war broke out, the government moved to harness scientific resources for defense purposes. Of the 92,000 working scientists prior to the war, about 19,400 held employment in the government, while over 72,000 were employed equally at universities and at the more

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3. It is worth noting that the idea that science should serve social and political objectives, as opposed to seeking “scientific truth,” was not confined to America. Indeed, such enthusiasms were especially pronounced in England during the 1930s. Fueled by beliefs of the presumed success of Soviet central planning, the British government came under increasing pressure to organize scientific institutions so as to establish central planning for science. This movement was countered, almost single-handedly, by John Baker and Michael Polanyi and their Society of Freedom in Science. This episode is analyzed in detail by McGucken (1984).

4. See Feldman *et al.* (2002), pp. 13-14.

than 2200 industrial laboratories (Feldman *et al.* 2002, p.14). In 1940 Roosevelt established the National Defense Research Committee, replaced in 1941 by the Office of Scientific Research and Development (OSRD), to organize scientific and technological resources for the war effort. Under the chairmanship of Vannevar Bush, the former President of the Carnegie Institution in Washington and a one-time vice-president of MIT, the OSRD did not conduct research, but it did establish contractual relations – a proto-contractual framework – governing collaboration between funding government agencies and university and industry entities that undertook and administered sanctioned research.<sup>5</sup>

As WW II drew to a close, unlike the post-WW I experience, there was no concerted effort to dismantle the government's wartime involvement in science. Instead, Roosevelt asked Bush to prepare a report analyzing how the success of the OSRD could be applied to the *peacetime* collaboration of government and the scientific community for the purpose of achieving “improvement of the national health, the creation of enterprises bringing new jobs, and the betterment of the national standard of living.”<sup>6</sup> Bush's report, published in 1945 as *Science – The Endless Frontier*, is perhaps the decisive document charting the institutional framework for science in the later part of the 20<sup>th</sup> century and into the 21<sup>st</sup>. Bush argued for a “national policy for scientific research and education” in which government would provide funds to industry and universities to conduct research. According to Bush, material progress depends on new scientific knowledge; such knowledge, he asserted, in turn depends on what he called

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5. The University of California's Los Alamos Laboratory in New Mexico is an example of the OSRD's efforts. The laboratories built for the Manhattan Project came under the aegis of the OSRD and would later begin the U.S. national laboratory system.

6. Letter from FDR to Bush (Nov 17, 1944), quoted in Feldman *et al.* (2002), p. 15.

“basic research” – research performed without thought of practical ends, as he defined it.<sup>7</sup>

Bush’s report received crucial support with the timely publication of *Science and Public Policy: A Program for the Nation* in 1947 by The President’s Scientific Research Board under the direction of John Steelman, Assistant to the President. The Steelman report broke ground by arguing that the government should allocate 1% of GDP to R&D, while reaffirming the centrality of basic research for economic prosperity and growth, the belief that such research cannot be reliably sustained by the private sector, and that R&D should be conducted principally by government funding to universities and industry.<sup>8</sup> The Steelman report also called for the creation of a National Science Foundation to dispense government research funds; the NSF was created by Congress in 1950 under the National Science Foundation Act. Since the 1950’s, the essential contours of government and science interaction in the U.S. have followed the thrust of the post-WW II recommendations of the Bush and Steelman reports.<sup>9</sup> The principal divergence has been in the magnitude of the funds dispensed by the government.

To summarize: the long standing incursion of government in science since the 18<sup>th</sup> century (albeit on a largely piecemeal basis) gave way in the 20<sup>th</sup> century to the creation of formal government institutions and associated funding mechanisms during WW I and especially WW II. Most of this was war-related. But in the aftermath of WW II, initiatives were afoot to promote government in science on the grounds of economic development in addition to national defense – the Bush and Steelman reports were pivotal in molding the post-WW II

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7. See Feldman *et al.* (2002), p.16. Bush’s claim that basic research necessarily precedes applied R&D and its eventual effects on material progress is often referred to as the “linear model,” a paradigm that dominated the views of policymakers and academic researchers for decades. See section 4 below for a discussion.

8. *Science and Public Policy: A Program for the Nation* (1947), v. I, pp. 3-7. The President’s Scientific Research Board was composed entirely of Cabinet Secretaries and government agency officials and administrators, including Vannevar Bush.

9. See Feldman *et al.* (2002), p. 19 for an overview.

stance of governmental science policy. The creation of the NSF in 1950 actually brought to an end a controversy over science policy within the government that had raged for several years among those like Bush and Steelman who argued for an indirect role for government in science (as defined by government financing of university and industry science via a collection of mission-oriented agencies) and those who argued for a direct role for government in terms of coordinating and managing science. This latter position, most famously adopted by democrat Senator Harley Kilgore of West Virginia, envisioned a centralized government agency that would “*direct and consciously plan* the advance of scientific research and technology” (Kleinman 1995, p. 6). For about five years beginning in 1942, Kilgore introduced several legislative proposals for the creation of a centralized government science agency controlled and administered by representatives of a wide range of social interests, including scientists and nonscientists alike (Kleinman, 1995, ch. 5).

The eventual defeat of Kilgore and his New Deal associates by Vannevar Bush, both legislatively and in the widespread acceptance of Bush’s *Science – the Endless Frontier* (1945), is traditionally viewed as a victory for a decentralized approach to government science policy.<sup>10</sup> But if this is to be called a victory, it is certainly a shallow one. In the aftermath of WW II, government involvement in science followed the outlines of the Bush approach, but the scale of government funding swept away historical precedents and established funding norms that have persisted with little change into the present.

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10. Feldman *et al.* (2002); Kleinman (1995).

### 3. Science Funding Since WW II

The precedent for increased government funding of science, established during the war years with an emphasis on national defense R&D, and the subsequent legitimizing of a broader justification for government in science, set the stage for substantial increases in government funding after 1949 (see Chart 1, below).<sup>11</sup> In 1949 total federal R&D spending (measured in 2001 dollars) was about \$5 billion; by 1964 it had increased to about \$65 billion – a thirteen-fold increase in real terms, a trend bolstered by the political considerations that attended the Cold War. The proportion of defense to nondefense R&D spending was about 5 to 1 in 1949 but decreased steadily to about 1.4 to 1 by 1963, a ratio that is typical for much of the period since 1964. During the period 1964 to 1969, nondefense spending (of which NASA was a large component) increased dramatically, and total R&D spending hovered in the \$60 to \$70 billion range. The period from 1970 to 1983 saw some retrenchment, with federal spending hovering around the \$55 billion mark, but thereafter defense spending increased sharply (while the nondefense component shrank modestly) so that total R&D spending edged toward \$75 billion. Declines in defense spending beginning in 1991 and continuing until 2001 were more than offset by nondefense increases that kept total federal R&D spending around the \$75 billion mark during the decade.

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11. As defined by the National Science Foundation (2005, p. 1), research is “systematic study directed toward fuller scientific knowledge or understanding of the subject studied” and comprises *basic research* (“systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind”) and *applied research* (“systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met”). Development is “systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.”

Chart 1

Federal Spending on Defense & Nondefense R&D: 1949-2002

(billions of 2001 dollars)

Source: OMB Historical Tables

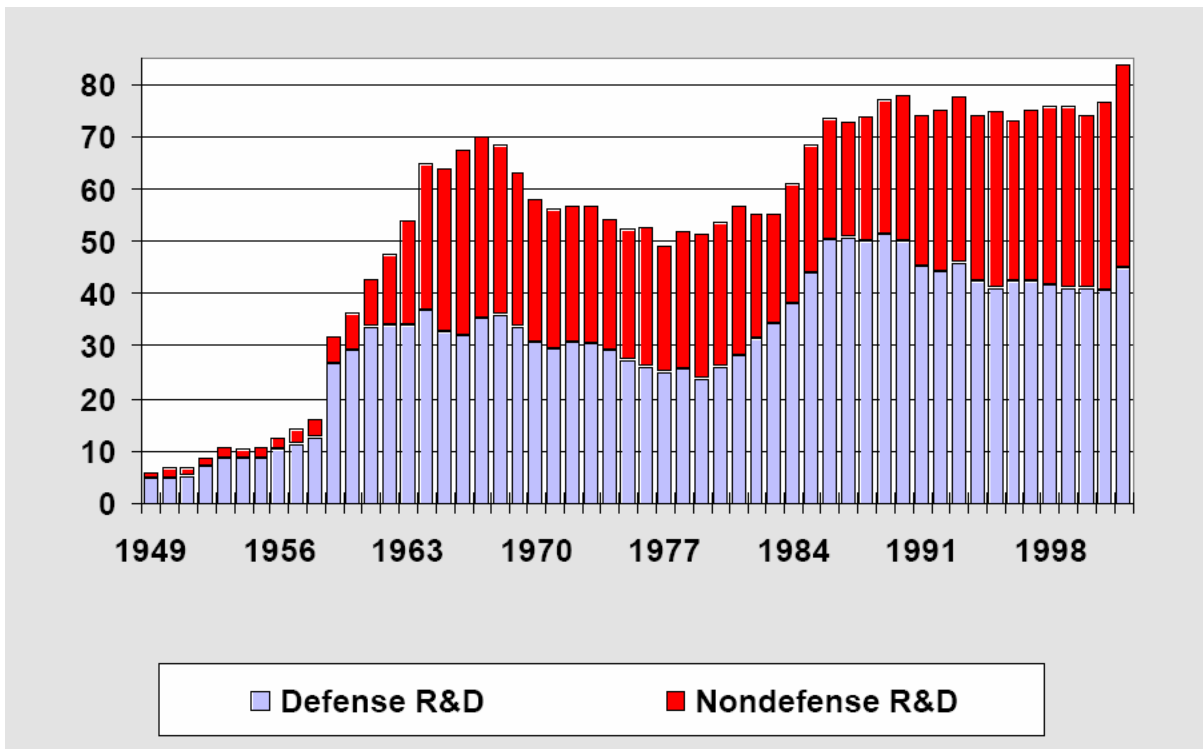


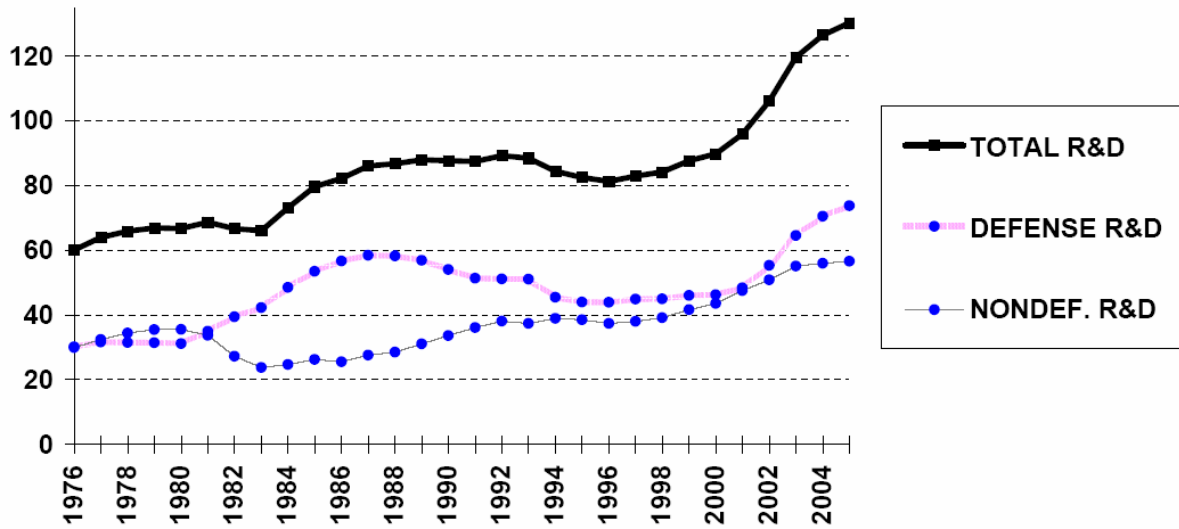
Chart 2, which contains more recent data on total federal R&D expenditures on defense and nondefense, illustrates more clearly the relative sizes of these two R&D components. Also, in the years since 2002, there has been a rather steep increase in R&D outlays for defense, bringing the President's 2006 R&D funding request to about \$130 billion.

Chart 2

Trends in Federal R&D: 1976-2006

(billions of 2005 dollars)

Source: AAAS, *Reports VIII-XXX*

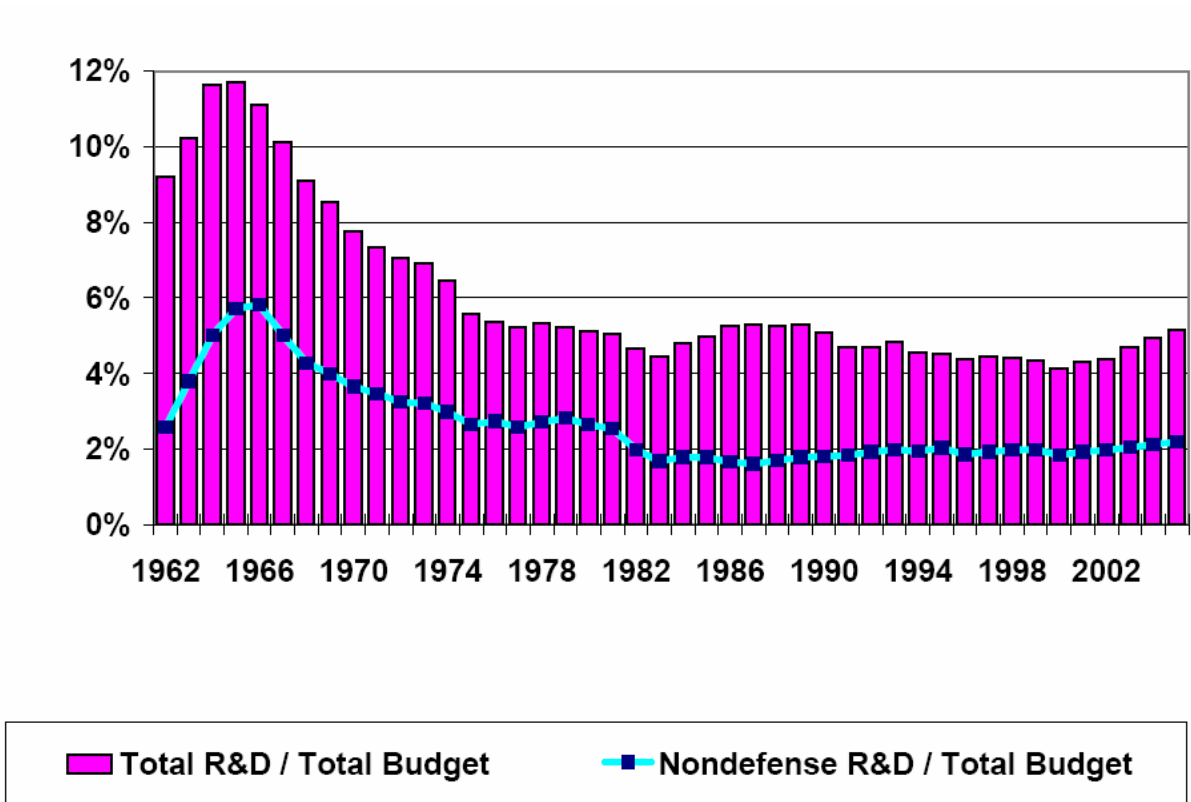


We also note that since the mid-1960's the share of federal R&D expenditures relative to total budget outlays has declined and given way to a more or less stable ratio. As shown in Chart 3 below, this ratio has averaged approximately 5% of the federal budget since the early 1970's. Of course, given the rise in federal budgets during this period, the declining and now stable ratio of federal R&D to total budget outlays represents significant increases in federal funding for R&D in absolute (and constant dollar) terms.

Chart 3

Federal R&D Expenditures as a Percent of Federal Budget Outlays:  
1962-2005 (preliminary)

Source: *Budget of the U.S. Fiscal Year 2005, Historical Tables*



The empirical record presented above suggests that the explosion in government funding of science following WW II in the United States has been significant and without precedent. This ratcheting in the magnitude of government funding in science reflects the effects of the interplay between the machinations of the political process and justifications stemming from threats to national defense, the desire to attain top shelf world ranking in (nondefense) basic

research, and more recently, post-9/11 antiterrorist R&D funding.<sup>12</sup> But whatever the perceived immediate need (real and otherwise) or political pressure used to justify government funding of science, behind the screen a set of arguments do exist that claim to establish a theoretical legitimacy to government funding in general. These arguments are identified and critically examined below.

#### 4. Rationales for Government Funding

The principal theoretical justification for involvement by government in funding and directing the activities of scientists and the dissemination of scientific knowledge rests on a “market failure” argument in which scientific knowledge is presumed to be a public good with positive external effects which, without intervention, will be produced in suboptimal quantities. We find this to be less than convincing on two fronts: first, it rests on a model of science as a type of market and therefore ignores the profound institutional differences between science and market, and second, its empirical implications and predictions are called into serious question by the facts on the ground.

The cogency of the “science as market” analogy dissolves under even a cursory examination.<sup>13</sup> Most obviously, in the domain of science, there are no market prices in the sense of science producing a tradable output having a monetary price. Since market prices

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12. Budget appropriations to combat terrorism have been one of the fastest growing aspects of federal R&D funding. For example, from fiscal years 2002 to 2003 appropriations for counterterrorism from various agencies, including Defense, Health and Human Services, National Institutes of Health, Environmental Protection, and Justice increased from \$1.2 billion to \$2.9 billion (National Science Board, 2004, pp. 4-28 & 4-29). Subsequent budgets (and since the creation of the Department of Homeland Security in January 2003) have not separated counterterrorism R&D from other R&D programs.

13. This is an elaboration of similar material in McQuade (2006).

are an emergent phenomenon of the market system, their absence in science points to deep dissimilarities in the processes of interaction through which, in the case of markets, market prices are formed. And there is a very good reason why the institutions of interaction are different. The content of the interactions (the goods, services, and money in the case of markets and the published articles and citations in the case of science) have very little in common. Published scientific articles, and whatever it is about their content that may be citable, are not regarded as property; the publication process necessitates interaction not with those who may cite the article but with an editor assisted by referees and therefore to call the publication-citation sequence an “exchange” is to take great liberties with the meaning of the word; and the acceptance of articles for publication may be based on appraised significance or interest or the author’s reputation or connections, but not on expected profitability. To imagine scientific knowledge – or knowledge codified as “information”, as Dasgupta & David (1994) have it – as a “good” that is “exchanged” stretches credulity, for it would be a very unusual good, difficult to define (let alone quantify) and not subject to enforceable rules of property and contract. In short, the major form of interaction in science does not involve property, does not involve exchange, and does not involve economic calculation – so science is not a market.<sup>14</sup>

The tack of shifting the analogy to one of “science as firm,” evident in the work of Arrow (1962), Boulding (1966) and Machlup (1980), for example, fares no better. Much scientific activity is conducted by individuals whose scientific interactions (with editors, referees, critics, or conference participants) are as likely as not to involve complete strangers. Even in

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14. For further discussion about the applicability of the “science as market” concept, see Wible (1998), Butos & Boettke (2002), McQuade & Butos (2003), and McQuade (2006). Also, Mäki (1999) argues (although on generally different grounds to those discussed here) that free market economics does not provide a useful basis for understanding science.

areas where research teams are formed, these tend to be much more fleeting and considerably less structured than is seen in the organization of the average firm. Scientists, even as members of research teams, do not interact with customers and do not transmit feedback on perceived customer needs back into the “production” process – indeed, there are no customers in the sense that firms have customers, paying customers from whom sales revenue crucial to the continued viability of the firm is directly obtained.<sup>15</sup> Again, there are very good reasons why the institutions of interaction in science are different from those in firms. Goods are not being produced for sale at a profit; papers are being generated based on investigative research for possible publication and citation. The “product” in science cannot be planned in advance, costed out, and appraised for profitability, for the whole point is to follow wherever the evidence leads. In short, in science there is no production process aimed at the profitable generation of a specific good, there are no paying customers to court and maintain, and there are no internal mechanisms to assess and incorporate responses to perceived user needs – so science is not a firm.

Bad analogies make for bad analysis. Criteria suitable for analyzing one domain of social interaction do not automatically carry similar force or explanatory value in other domains of social interaction if the institutional arrangements in the two domains are significantly different. Analyses that depend on viewing science as a market activity mistakenly apply a framework that makes sense in one domain to another (where they do not) and thereby incur a double liability: the analytical results derived for the domain of interest are likely to be suspect and, second, important features of that domain will tend to be masked or ignored.

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15. Scientists can, and do, sell their services to paying customers in the sense of agreeing to direct their research toward topics which are of interest to those supplying the funding. But this is a far cry from agreeing to develop a product whose attributes are appealing to customers. Indeed, were the findings conditioned by the need to please the customer, the research would be considered fraudulent.

Even were one to accept the cogency of the market analogies, problems still remain, particularly with the claim that intrinsic characteristics of the production of scientific knowledge make its provision suboptimal.<sup>16</sup> Since the work by Nelson, Arrow, and others in the late 1950s and thereafter, it is widely accepted among economists that scientific knowledge, and especially basic scientific knowledge, has strong public goods characteristics and that as a consequence science is subject to pervasive market failure. Left to its own, the science market fails to provide sufficient incentives for the production of scientific knowledge and thus it will be systematically underproduced.<sup>17</sup> There are two horns, it is argued, on the failure dilemma: first, private firms are generally unable to hurdle or tolerate the costs associated with basic science stemming from uninsurable risk and uncertainty, and second, scientific knowledge once produced is freely available to all thereby preventing its producers from appropriating the benefits to themselves.

These claims have been increasingly questioned by recent theoretical and empirical work in the economics of science. Rosenberg (1990), for example, argues that the “mere *existence*” of uncaptured benefits “is never an adequate explanation for the reluctance to perform basic research” provided the firm can capture sufficient benefits from its research (p. 167). Even though the research may generate spillovers, it is not their magnitude that matters but the return on investment the firm is likely to realize from derivative commercial applications.

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16. This is not to say that there cannot be instances of “science failure,” i.e., cases where the institutional regime of science fails to prevent fraudulent activity or is so tenuous as to be incapable of producing emergent knowledge.

17. Interestingly, the argument as advanced by Nelson and Arrow referred to the underproduction of “pure scientific research” or what Vannevar Bush originally termed “basic science.” Applied science or technological development, however, has not been identified as a source of alleged market failure in science.

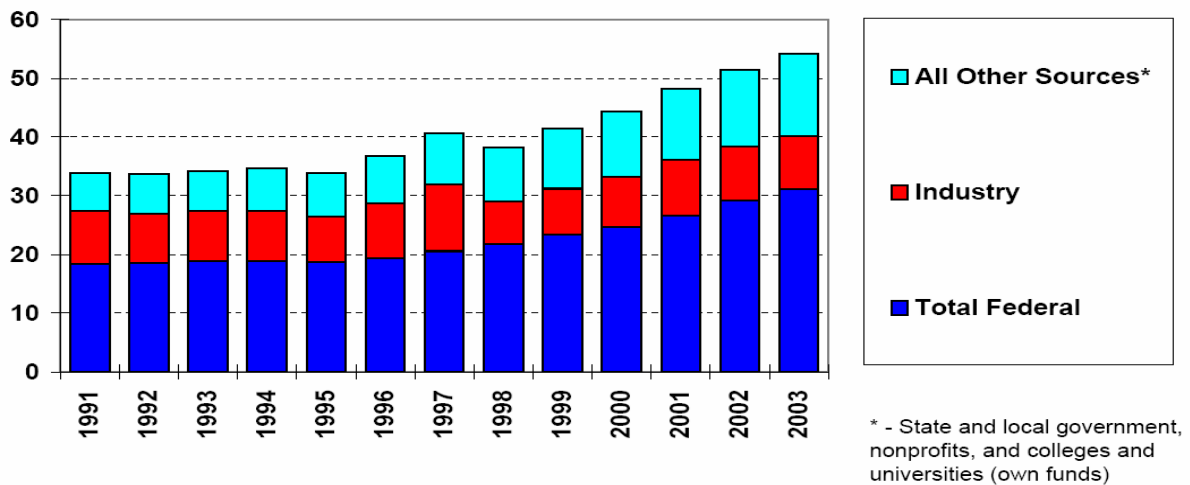
The empirical record suggests that private sources do in fact consistently commit substantial sums to basic research and also to R&D. As shown in Chart 4 below, basic research by firms accounts for about \$8-10 billion per year. Other non-Federal sources of funding for basic research, which include funds originating from nonprofits and universities and state governments, brought the total to over \$20 billion in 2003 or about 40% of the total funding for basic research.

Chart 4

U.S. Basic Research by Funding Source: 1991-2003

(billions of 2003 dollars)

Source: AAAS (based on NSF, *National Patterns of R&D Resources 2003*)



If we now look at total R&D expenditures by source, the data reveal that industry has allocated increasingly significant resources toward R&D. As seen in Table 1 below, since 1980 total industry-funded R&D has exceeded federal R&D expenditure and (based on data from 2003) is about double it.

Table 1

## National Funds for R&amp;D by Source: 1970-2003

(billions of 2003 dollars)

Source: NSF

	1970	1980	1990	2003	Percent Share of Total			
	Actual	Actual	Actual	Prelim.	1970	1980	1990	2003
Federal	57,801	58,909	79,831	85,279	57.0%	47.4%	40.5%	30.0%
Industry	40,307	60,784	107,821	179,615	39.8%	48.9%	54.7%	63.3%
Colleges and Univs.	999	1,808	4,130	7,944	1.0%	1.5%	2.1%	2.8%
State/Local	914	1,020	1,813	2,710	0.9%	0.8%	0.9%	1.0%
Nonprofits	1,323	1,712	3,355	8,247	1.3%	1.4%	1.7%	2.9%
TOTAL	101,341	124,232	196,949	283,795	100.0%	100.0%	100.0%	100.0%

Whether the amounts of basic science and total R&D expenditures undertaken by the private sector are “optimal” survives only as a model-dependent question and is without empirical content. Indeed, the standard neoclassical argument assesses optimality across only the quantity dimension. More is always better. Because the argument cannot rule out utterly

perverse kinds of scientific research funding,<sup>18</sup> it implicitly requires a second-order criterion for the allocation of research funds that must emanate from a political process. And, as we argue below, once account is taken of this political element, the presumed “optimality” argument is underdetermined. In short, all that can actually be said is that the private sector does, of its own choice, undertake the funding of significant amounts of both basic research and R&D.<sup>19</sup>

The claim that scientific knowledge is costlessly available to all once it is produced fails to take account of the fact that such explicit knowledge is rarely useful *as such* for the potential “free rider.” It may be necessary, but it is not likely to be sufficient for garnering free rider profits. It is but one of several complementary factors of production that enable firms to generate profits. The entire entrepreneurial aspect – the assessment that some particular knowledge might contribute to a commercially viable product – is probably the decisive one, although it is generally overlooked in this literature. But account also must be taken of the *tacit* component of knowledge with respect to scientists and managers knowing *how* to use the knowledge they have acquired. This tacit (and unpublishable) knowledge cannot be easily conveyed. Thus, while firms encourage their scientists to publish their research papers in apparent disregard to the presumed free rider problem, Hicks (1995, p. 168) observes they actually find it in their interest to do so for a variety of reasons: it provides access to research networks, it keeps their scientists engaged and up-to-date, and it presents an image in the academic and scientific community conducive to recruitment.

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18. For example, scientific tests of radiation exposure on U.S. servicemen and prison inmates during the 1950s.  
19. The once-dominant dichotomy in the literature of “basic research” versus “development” (or “technology”) has been significantly blurred. See the discussion below on the “linear model” of science on which the distinction rests.

Two pieces of supporting scaffolding have been appended to the basic “market failure” argument: first, that the “underproduction” of basic scientific knowledge will show up in less than optimal economic growth and, second, that this underproduction can be characterized in terms of private returns to basic research being lower than social returns. Kealey (1996) argues that both of these claims are in error.<sup>20</sup>

The first claim involves postulating a “linear model of science.”<sup>21</sup> This model stipulates that the connection between science and material advancement requires the following progression:<sup>22</sup>

basic science → applied R&D → technology → economic growth

Accordingly, without the appropriate level of basic research, technological innovations and material progress will lag. Since it is alleged that basic science involves high risk and lengthy payoffs, firms have an incentive to free-ride on basic research and only later, after basic research has demonstrated its commercial value, will they then undertake R&D leading to new technologies. In short, because private funders cannot capture all the benefits of costly basic research, they will not invest in it. Hence, the argument runs, government must be called upon to fund basic science. This model of the role of science in economic growth, however, is fundamentally wrong. The error derives from the claim that basic science drives technological change: it is existing science and existing technology that has been found to

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20. A third piece of scaffolding is the claim that the institutional regime of government-funded science will result in a more “optimal” production of scientific knowledge than privately funded science. This is taken to be so obvious as not to require proof or even mention. The whole thrust of this paper is to question it.

21. This model of science was recognized as defunct on scientific grounds in the 1960’s, although it still is politically very much alive. See Greenberg (1967), pp. 29-30. Also see Martin and Nightingale (2000).

22. Adapted from Kealey (1996), pp.204-5 and Feldman *et al.* (2002), p. 17.

cause technological change.<sup>23</sup> In short, proponents of the market failure argument exaggerate the significance of basic research as a determinant of economic growth. Relevant here is the absence of any significant correlation between the level of Federal expenditure on basic science and the trend in GDP per capita, as documented by Kealey (1996, p. 162) for the period of the 19<sup>th</sup> and 20<sup>th</sup> centuries.

The second claim – that the private return to basic research is lower than the social return and that despite whatever role technology has in generating new technologies, basic research by private funders will nonetheless be insufficient – also does not fare well when evidence is sought.<sup>24</sup> Kealey's (1996, pp, 225-230) analysis is particularly instructive here and it is based, first, on identifying two kinds of advantages associated with basic research and, second, in recognizing some pertinent institutional detail about firms, scientists, and R&D. Basic science, he says, confers "first-mover advantages" on a company when it discovers something first. This may position the company further along the learning curve in developing the commercial applications of the discovery. At the same time, though, because basic science is commercially unpredictable, if companies only derived first-mover advantages from basic research (as Nelson and Arrow assumed), such research would be unlikely to enjoy widespread commercial support. "Second-mover advantages," on the other

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23. See Kealey (1996), Martin & Nightingale (2000).

24. Mansfield (1980) estimates an implicit rate of return of 27% on total R&D (1960-76) for chemical and petroleum firms. He finds a strong independent relationship between basic research and productivity; however, this may "reflect a tendency for basic research findings to be exploited more fully by industries and firms responsible for them (p. 871). He suggests that basic research may in fact be a proxy for long term applied R&D (p. 866). Griliches (1986) finds that R&D, but especially basic research, and the fraction of research financed privately (versus federally) all contribute positively to productivity growth. According to his estimated results, "raising the stock of R&R by 20 percent but shifting it all into the private component doubles the effect of such dollars" (p. 149). Interestingly, he acknowledges that such results may be flawed because R&D often aims at creating new products as opposed to increasing productivity. Griliches finds that firms tend to capture high returns from basic research, even if it is assumed that 50% of the positive effects of basic research are diffused throughout the industry (p. 149). Kealey (1996) claims that their findings support the notion that private companies "fund basic science comprehensively" and that it is "highly profitable" (p. 225).

hand, derive from a company's ability to generate commercial applications of *existing* basic research; these second-mover advantages are less risky and more profitable than basic research.<sup>25</sup> Although this seems to suggest that a classic free-rider problem exists, such is not the case because of institutional arrangements within firms that work to essentially internalize the costs of basic research via an alignment of incentives between scientists and the firms that hire them. Firms have an incentive to employ scientists as in-house specialists to maintain currency with ongoing research around the world in the hope of reaping second-mover advantages. But to secure the services of scientists, firms finance the basic research scientists prefer to do. This, in turn, feeds into the second-mover advantages desired by firms because scientists maintain their cutting edge profile by remaining current with the work of other scientists. As Kealey (1996) observes: "first- and second-mover advantages are indissolubly linked, and one cannot be performed without the other ... [Thus,] second-mover advantages enforce a vast expenditure on basic science" (p. 229).<sup>26</sup>

Our conclusion is that the economic justification for government funding of science is (1) theoretically unconvincing because it ignores institutional differences between science, market, and firm that negate the force of the public goods argument and (2) empirically suspect in that it ignores the fact that substantial evidence points to the robustness of the private provision of scientific knowledge. Further, while it would predict that increased government funding above trend would result in increased economic growth above trend, there is no evidence at all for such a link. Nevertheless, the extent of government engagement in science has trended upward for decades. This would indicate that the forces

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25. Kealey reports on a 1992 study of Japanese pharmaceutical firms by Odagiri and Murakimi that found rates of return from basic research and "second-mover" research to be 19% and 33%, respectively.

26. Rosenberg (1990) reports that firms fund basic research because they generate the cross-fertilization of ideas, problem-solving, and creativity among scientists and other company employees. Such interactions dispute the "linear model" of R&D mentioned earlier. Also see Kealey (1996, pp. 229-230).

driving the increase have more to do with a confluence of interest between politicians and scientists, and this dynamic has been investigated in some detail by several scholars, including Savage (1999) and Greenberg (1967, 2001).

Greenberg's (2001) work is particularly enlightening. He describes in detail the history of the increasing entanglement of science and politics in the US from WWII to the present – the enormous growth in the level of government funding of the physical and biological sciences, the ways in which scientists and their universities have operated to claim and to foster the increase of that largesse, the surprisingly unscientific, but politically effective, propositions they have promoted to justify their right to public funding on a large scale, and the practical political reasons why legislators should have the incentive to go along with the arrangement. Greenberg sees scientists as having succeeded beyond their wildest dreams in extracting public funds for their own use but cautions that this has come at the expense of “the ethics of science”. The threat to scientific integrity, he claims, comes from two sources: the recourse to blatantly untrue or at best unproven assertions in justifying public funding (an attitude plainly at odds with the scientific ideal of truth-seeking above all else), and the growing tendency toward the adoption of “marketplace values” that is the result of increasing entanglement with business interests driven by an addiction to large-scale funding and often explicitly encouraged by government. Access to funding is surpassing reputation as a motivating force in science. And this has led to an undermining of collegiality and, in some cases, honesty, within science. Science's traditional standards have been corrupted by decades of misleading representations to the public and the government in pursuit of public money, to the point where scientists are willing and even eager to deal with – and even to adopt the less than purely altruistic attitudes and behavior of – people whose commitment is

not to “Truth” but to their own enrichment. The open discussion and dissemination of information, a core characteristic of science, is a ready casualty of association, in pursuit of funding, with business interests.

But Greenberg’s antipathy to “marketplace values” has led him astray. In thrall to the too-quick assumptions of economists who (unlike the entrepreneurs who have actually sought to fund scientific research for profit) have crudely oversimplified science as a producer of “public goods”, he has failed to realize that mercantile profit and scientific openness are not necessarily incompatible. And his prescription for an institution in the hangover of an intense and heady dalliance with the political world is the hair of the dog – only this time more so.<sup>27</sup> Yet, Greenberg’s sense that there is a problem rings true, even if he cannot coherently pin down exactly what it is or what, if anything, could be done about it. There is indeed a problem with government funding of science, but why there should be is not as obvious as one might expect. The following section contains the outline of an argument – hopefully a more convincing one than Greenberg’s – as to the many-faceted nature of the problem.

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27. Greenberg’s solution (2001, pp. 473-475) is for science to become more “accountable” in a political sense. More scientists should run for office; organizations within science should openly support such candidates much as is currently done by doctors, lawyers, and teachers. In such an environment, the press and the funding agencies should no longer act as cheerleaders for science but should subject scientific activity and the internal politics of science – and especially the details of science-business collaborations – to the same scrutiny that other, less revered, professions endure.

## 5. An Analysis of Science Interventionism

We suggest that the evolution of government policy toward science in the post-WW II period is best understood as a variant of an interventionist system rather than a system, as imagined by Vannevar Bush and others, of benign, decentralized support. Further, while the U.S. government's current role in science is not technically that of a central planner, we shall argue that many of the considerations that apply to centrally planned economic systems also apply in some degree to the ongoing arrangements between government and science.<sup>28</sup>

Science, in the absence of outside intervention, is a decentralized system of social interaction operating according to generally understood rules, the basis of which are the institutions of publication and citation.<sup>29</sup> There is no controlling authority, because power is distributed (not necessarily evenly, but still widely) across the population of participants. The institutional arrangements of science explicitly cater to the self-interest of all of the participants. The process of interaction constrained by these arrangements results in observable side-effects stabilized by negative feedback – the corpus of scientific knowledge and the generally acknowledged reputations of participating scientists. This stabilization is not such as to preclude variation of the side-effects in response to environmental changes. And these relatively stable side-effects provide not only general and nondiscriminatory benefits even to nonparticipants but also the incentive for a positive feedback effect on participation in the system.

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28. See Ikeda (1997) for a similar argument in the context of government-market interactions.

29. See McQuade & Butos (2003).

But science in and of itself generates no revenue<sup>30</sup> and so the expenses associated with scientific pursuits must be funded by other sources. Since very few scientists are independently wealthy, it is common for them to be employed as teachers in academic institutions, receiving both a salary for personal maintenance and some financial support for the operational expenses attendant to scientific activity. Scientists can also be supported directly by private donors or by corporations.<sup>31</sup> And they can be financed through grants of public funds. It is not surprising that these different funding sources should have different effects on the practice of science, and an examination of such effects leads directly to a consideration of intervention in science, for it is through funding that organizations outside of science can most easily affect the actions of scientists, introduce new incentives, exercise control, and alter the adaptive characteristics of the knowledge-generating system as a whole.

The three broad sources of outside funding (donors, businesses, and legislatures) have an obvious similarity: in none of these cases is funding, or its continuation, without strings attached. Donors may be motivated by civic duty or a desire for the immortality of association with a fundamental advance or with a large institution, businesses by the indirect profitability of such funding, and legislators by the benefits produced by the spending of the

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30. We have treated science as a distinguishable social process – the publication/citation regime – a regime that clearly does not involve monetary exchange and hence revenue. We do not deny the obvious fact that, in practice, science is embedded in the market, and depends on market-generated revenue for the maintenance of the people involved. Nor do we deny that aspects of scientific knowledge (or even aspects of the individual knowledge of a particular researcher) can be marketed (even patented) by organizations like corporations and universities that employ scientists.

31. People working within corporations or government departments engaged in research which is not openly published are not participating in science as defined here. (Or, they may be doing so on a small scale, limited to the confines of their organization, if they circulate papers and cite the work of others within their local circle.) But such organizations often do employ scientists, paying them a salary while allowing them to publish in the usual scientific outlets. This is not to deny that a researcher who does not publish is doing “science” in the sense of doing some of the things that one would expect scientists to do – experimenting, thinking, formulating hypotheses, for example. But in order to affect scientific knowledge, a contribution must be published in some form. Only published contributions can be assessed, criticized, interpreted, reinterpreted, and recontextualized, i.e., submitted to the process of becoming absorbed into scientific knowledge.

funding in their districts or on the enhancement to their electability from being associated with the promotion of a good and popular cause. But the first two of these source types have constraints which are more or less tied to the scientific results produced. The third, however, measures success not necessarily by the science produced but by the perception among voters and constituents that they might benefit from the particular funding. The funding constraints are therefore much less pressing for government funding (for the amounts potentially available through government taxation, borrowing, or money creation are huge) and yet are the least connected with the success (in terms of usefulness to other scientists in follow-on research) of the scientific activity itself. This characteristic, compounded by the organization of the government funding apparatus into a small number of large bureaucracies, has potentially corrosive effects in several ways, as we will see. We divide these effects, for ease of exposition, into incentive effects, “Big Player” effects, problems of boom and bust, and problems of bureaucracy.

- **Incentive effects:** Under government science incentives matter, just as they would in markets. These altered incentives will affect the institutions involved in the administration of science, including funding agencies recipient institutions, and also how scientists behave. Funding agencies are not autonomous, but operate as a bureaucracy within the government sector. Their incentives emanate, at least in part, from the legislative and the executive branches, thereby establishing a political dynamic for explaining their behavior along any number of margins, including the areas of science receiving funding, institutional recipients, and its geographic disbursement. There is also a symmetry of interests between the funding agencies, including the military, and recipient institutions (industry and universities). This carries implications for the dynamics of government science because it creates a

potentially powerful lobbying nexus whose interests are geared to sustaining and expanding government funding.<sup>32</sup>

One well known example of this occurs in academic “earmarking” – “a legislative provision that designates special consideration, treatment, funding, or rules for federal agencies or beneficiaries” (Savage, 1999, p. 6). Academic institutions use their influence and lobbyists to secure appropriations for specific (i.e., “earmarked”) university research projects or facilities. As Table 2 below shows, during the decade of the 1990’s, such funds averaged about \$550 million per year, but tripled in 2002.

Table 2

Funds for Congressionally Earmarked Academic Research Projects:

1980–2002

(Millions of current dollars)

Sources: 1980–92: U.S. House of Representatives, *Academic Earmarks: An Interim*

*Report by the Chairman of the Committee on Science, Space, and Technology*

(Washington DC, 1993); 1993–2000: *Chronicle of Higher Education* 46:A29 (July 28,

2000), 47:A20 (August 10, 2001), and 49:A20 (September 27, 2002); 2001–2002: NSF,

*Science & Engineering Indicators – 2004*

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32. See Ikeda (1997).

Year	Amount	Year	Amount	Year	Amount
1980	11	1988	232	1996	296
1981	0	1989	299	1997	440
1982	9	1990	248	1998	528
1983	77	1991	470	1999	797
1984	39	1992	708	2000	1,044
1985	104	1993	763	2001	1,668
1986	111	1994	651	2002	1,837
1987	163	1995	600		

The enormous growth in academic earmarked funds reflects the increasingly significant influence of academic institutions in securing federal funding. As seen in Chart 5, the growth in federal funding is principally accounted for by the funding to academic institutions. In 2002, federal funds to academic institutions were over \$22 billion. In addition, of the \$11.5 billion allocated to Federally Funded R&D Centers (FFRDCs) over \$7 billion went to the 16 university administered centers.<sup>33</sup>

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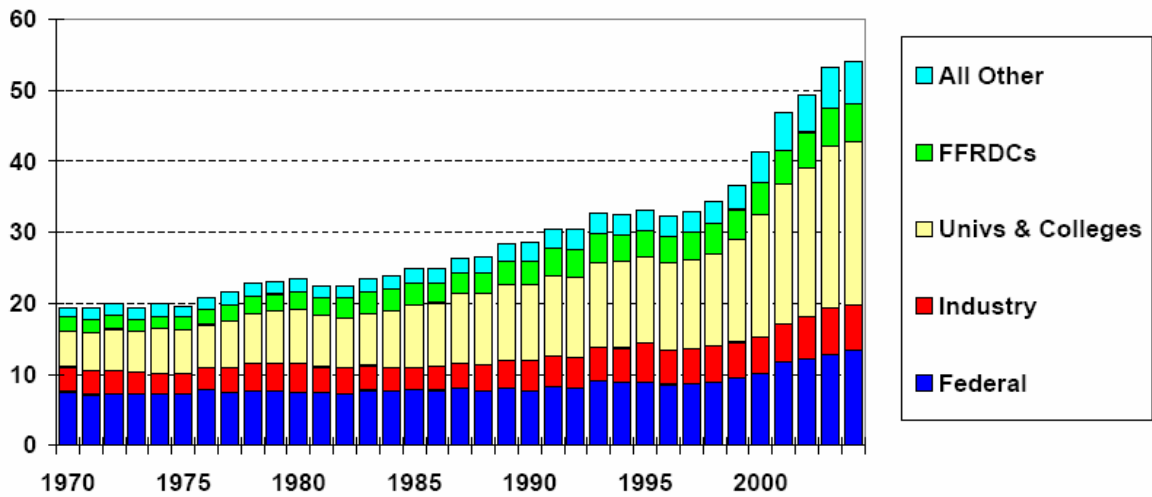
33. NSF, *National Patterns of Research and Development Resources:2003*, Table B-15, pp. 86-87. FFRDCs include such well known facilities as Los Alamos National Laboratory (University of California), Jet Propulsion Laboratory (California Institute of Technology), Lawrence Livermore National Laboratory (University of California), and Argonne National Laboratory (University of Chicago). These four account for over \$5 billion of the \$7 billion total.

Chart 5

Federal R&D Funding by Performer: 1970-2004

(billions of 2004 dollars)

Source: NSF



A closer look at R&D expenditures at academic institutions for 2001 and 2002 shows that 67% of the total funds supplied originated from federal and state and local government (see Table 3). Funding sources from academic institutions themselves accounted for nearly 20% of the total amount, while industry and other sources (principally non-profit institutions) accounted for 6% and 7.4%, respectively. Most of these funds (59%) went toward research in the life sciences; engineering with 15% and physical sciences with 8% were the next largest.

Table 3

## Academic Institutions R&amp;D Expenditures

Source: NSF, *Survey of Research and Development Expenditures at Universities and Colleges, Fiscal Year 2002, 2004*, Table 1-8, p. 58

	FY 2001	FY 2002	% Change FY 01-02	% of Total (FY 02)
<b>(R&amp;D expenditures in millions of dollars)</b>				
- by funding source:				
Federal Government	19,213	<b>21,834</b>	13.6%	60.1%
State and Local Government	2,316	<b>2,501</b>	8.0%	6.9%
Industry	2,214	<b>2,188</b>	-1.2%	6.0%
Institutional Funds	6,587	<b>7,109</b>	7.9%	19.6%
All Other Sources	2,438	<b>2,701</b>	10.8%	7.4%
<b>Total</b>	<b>32,767</b>	<b>36,333</b>	10.9%	100.0%
- by science and engineering field:				
Engineering	5,007	<b>5,504</b>	9.9%	15.1%
Physical Sciences	2,805	<b>3,008</b>	7.3%	8.3%
Environmental Sciences	1,830	<b>2,022</b>	10.5%	5.6%
Mathematical Sciences	359	<b>387</b>	7.8%	1.1%
Computer Sciences	954	<b>1,126</b>	18.0%	3.1%
Life Sciences	19,213	<b>21,404</b>	11.4%	58.9%
Psychology	583	<b>671</b>	15.1%	1.8%
Social Sciences	1,440	<b>1,583</b>	9.9%	4.4%
Other Sciences, n.e.c. *	577	<b>627</b>	8.8%	1.7%
<b>Total</b>	<b>32,767</b>	<b>36,333</b>	10.9%	100.0%
- by character of work:				
Basic Research	24,273	<b>26,959</b>	11.1%	74.2%
Applied Research and Development	8,494	<b>9,374</b>	10.4%	25.8%
<b>Total</b>	<b>32,767</b>	<b>36,333</b>	10.9%	100.0%

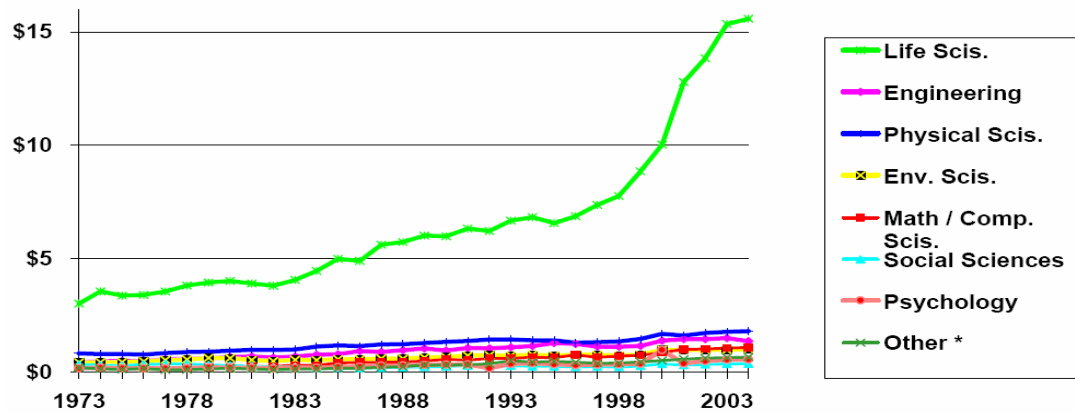
(\* not elsewhere classified)

While trends (1973-2004) in the use of funds by academic institutions show that R&D for engineering, the physical sciences, environmental science, mathematics and computer science, psychology and the social sciences have been rather stable over that 30 year period, the increase in R&D in the life sciences has been nearly six fold over the same period. Table 4 documents these trends.

Table 4

Federal Academic Funding Obligations by Discipline: 1973-2004  
 (constant 2004 dollars)

Source: NSF, *Federal Funds for Research and Development, 2004*



The obvious success of academic institutions in securing substantial governmental assistance reflects an increasing kind of “partnership” between government funders and academic institutions. Although this development is partially justified on the grounds that nearly 75% of the R&D performed at academic institutions is “basic research,” it also suggests that the direction and character of university science has become increasingly intertwined with government determined priorities and oversight.

Scientists’ success at securing funding will bear the imprint of proposals most likely to receive a favorable hearing by the funding agencies. This also suggests that scientists

have an incentive to develop and nurture professional relationships with agency members, advisors, and consultants. Finally, government funding of science, including that associated with military R&D, unavoidably establishes linkages between the funding agencies' preferences (or legislative charge) and scientific activity performed by university and industry researchers. These linkages refer to the purposes for which funds are made available, thereby affecting the direction and regulation of scientific research, as well as specific protocols for military R&D.<sup>34</sup> Greenberg (2001) does a particularly good job of documenting this complex of interlocking incentives.

- **Big Player effects:** The source structure of science funding matters in the sense that, while an environment with a small number of large funders provides the potential for those desiring to control the direction (or, in the extreme, even the content) of science to have systemic effects, whereas in an environment with a large number of small funders the effects of individually power-oriented operations are much more likely to be localized and constrained. This effect is the analog of the Big Player phenomenon in markets.

Following Koppl and Yeager (1996), government is a Big Player in science whose behavior is capable of dominating the flow of signals guiding the direction and intensity of scientific research. The magnitude of government's influence exposes science to self-reinforcing path dependent processes that may be analogous to herding and bubbles in financial markets. However, while in markets the prospect of self-correction is strong because underlying market realities sooner or later prevail, science has no analog of resource constraints for its products and has to rely only on its internal coherence as

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34. Mukerji (1989) points to the military's direction over classified research by controlling scientists' access to research technology. Although scientists working for the military cannot publish their research, "they are able to get access to restricted information for their own use" (p. 116).

established by its own critical procedures. Big Player effects are known to produce herding and bubbles in financial markets. The corollary in science is the funding opportunities provided by government for designated areas of research, such as AIDS or environmental issues. Because such government-funded research enthusiasms are inextricably linked to the political process, the presumption must be that the direction of research is driven by the same incentives and constraints as any other politically-based funding program. This suggests that the basis for such funding is arbitrary and no more or less justifiable than any other possible use of taxpayer funds. Moreover, the development of the direction of research itself is likely to be sustainable only for as long as the funding continues, after which new funding objectives will replace previous ones.<sup>35</sup> Government funding, in this sense, is not too unlike Congressional Omnibus Transportation Bills: a predictable amount of funding will occur, but for what and for whom is always up for grabs.

- **Problems of boom and bust:** In recognizing that government science operates along a significant political dimension, we propose that the path of science will also reflect the shifting funding priorities of government institutions, both elected and otherwise. It seems clear that the *level* of government intervention in science can be explained in part by “public choice” considerations. But economists have long understood that the *cyclical* activity or dynamic stability of the economy reflects the effect credit policies of central bankers and very possibly the electoral cycles of representative democracies. In economics we can think of fiscal policy’s effect on the average level of economic activity as opposed to monetary policy’s affect on the dynamic stability of the system.

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35. We cannot discount the path dependencies government funded science will create. In the present context, it is possible that the prior existence of funding will establish an ongoing presumption for the value of continued funding in those prior designated areas on the basis of results already achieved by that funding.

In proposing a similar kind of distinction for analyzing government intervention in science, our discussion considers such intervention in the context of the dynamic stability of science.

Windfall funding for science is like artificially cheap credit for business – the immediate effect is a growth in investment (including employment) and, with a lag, output. The general quality of the output is not necessarily compromised, although by making it possible for people who would otherwise work elsewhere to pursue a scientific career the tendency may be to lower the average quality of the practitioners. What may be noticeable is an increase the “far-outness” of the investigations pursued – in the sense of the resulting papers being of little or no interest to other researchers and generating minimal, if any, citations and follow-on publications.

One would expect to see, in the distribution of government science funding, bursts of heavy funding in some areas, cutbacks or neglect in others, with the identities of these areas changing as the political winds change direction.<sup>36</sup> When the Russians threaten to lead the way into space, astronautics and space science is favored, building up an impressive edifice of research capability and trained scientists ready to push the discipline further. When the Japanese threaten to develop a “fifth-generation” computer, attention switches to computer science and the growth in space science funding becomes insufficient to maintain the talent already developed. When the Japanese are no longer seen as a danger to national prestige, political attention wanders away from computer science and its newer PhDs find employment in the area of

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36. Such effects may be observable in changes in the spectrum of paper citations. A trend toward greater numbers of papers published that receive very low numbers (particularly zero) of citations might be able to be correlated (with a lag) with changes in funding levels. Zero-citation papers are the scientific analog of goods produced in excess of consumer desires. One would expect a period of lavish funding to be followed by an increase in the number of “useless” papers published – and the reverse trend observed after funding downturns. Similar trends might be observed in journal start-ups and closings.

research they have been trained for much harder than expected to come by. It is a scenario of localized booms and busts – “science cycles” – accompanied by a real disruption of individual lives and waste of talent and resources similar to that characteristic of business cycles.

The problem with temporarily unconstrained funding is that it fosters unstable growth. Lavish funding results in more scientists being trained as the recipients of funds require assistants to pursue the funded projects; in turn, these assistants, if they are to become researchers in their own right will require funding of their own.<sup>37</sup> Private funding sources naturally limit the growth of the system of science in a way that has a relatively direct connection to the perceived usefulness of the science itself to other scientists, and this sort of stabilized growth is likely to be more durable and productive than spurts of growth and retrenchment based on factors external to science.

The danger to quality of output and integrity of behavior comes with the downturns in funding, when the rate of increase of funding ceases to keep pace with the structural growth fostered by prior funding. At this point, scientists are in competition with each other not merely for scientific reputation but for their very livelihood.<sup>38</sup>

- **Problems of bureaucracy:** Concentration of funding in large government-financed organizations brings to bear the usual symptoms of bureaucracy – success measured by

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37. Changes in the numbers of trained scientists who are unable to find employment *as scientists* might be able to be correlated with changes in funding levels. One would expect to find unemployment level trends in particular areas within science characteristic of economic boom and bust. Even if science funding levels never decreased in absolute terms, unemployment increases should be observed in the periods following a slowing of the rate of increase below that required to adequately fund the new scientists minted in times of plenty. Since politically motivated funding will tend to concentrate on particular areas of current political attraction, the analysis would have to be at the discipline or subdiscipline level.

38. This may be exceedingly difficult to document, but reports of erosion of “scientific ethics” should increase in periods of scientific recession and decrease in periods of scientific boom. Increases in “unethical” behavior driven by competition for funds would be the science analog of a scramble for loans at the height of a boom as businesses strive to complete production projects in the face of resource scarcity or credit hardening. For a more standard economic discussion of fraud in science, see Wible (1998).

budget rather than results, unwillingness to take risks which may subject the organization and its managers to criticism, and a concentration on areas of research likely to be politically popular. And, as pointed out by Greenberg, bureaucratic control of the funding process has led to conservatism (“calcification”, as he puts it). While this may not affect the general quality of research work, it will tend to channel scientists seeking funding into more conservative, more obviously “acceptable” lines of inquiry, and will make it more difficult for mavericks to be funded. Again, bureaucratic effects are competently discussed in Greenberg (2001).

Underlying many of these untoward effects is the classic “knowledge problem”. As formulated by Hayek,<sup>39</sup> this problem is a consequence of the fact that centralized institutional arrangements make it impossible for planners to adequately marshal the relevant explicit and tacit knowledge dispersed among economic agents, leaving them largely limited to their own personal knowledge in determining the allocation of resources. As Hayek (1937, 1945) reminds us, it is precisely the knowledge peculiar to time, place, and circumstance, possessed by individual market participants but generating, via market interaction, a unique byproduct – a constellation of market prices that allows agents to engage in a process of rational calculation in implementing their plans.

Although science is not a market and does not produce market prices, it nonetheless shares several characteristics with a catallaxy. Science is characterized by a division of knowledge in that any individual scientist knows only a portion of the existing knowledge within or germane to his own field. As scientific knowledge progresses overall, each individual

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39. See the essays on the socialist calculation debate by Mises and Hayek in Hayek (1935). See Lavoie (1985) for a more recent treatment.

scientist knows relatively less, even as his own increasingly specialized knowledge itself increases. Second, science has the capacity, under the appropriate institutional setting, to function as an unplanned complexly organized order. This means that science, like the catallaxy, functions as an emergent order capable of generating novel outcomes. Such outcomes arise as unintended byproducts of the interactions among scientists. If we think of science as generating a particular kind of *classification* over some specified domain of inputs or environments,<sup>40</sup> that classification represents a snapshot of an ongoing process constituted by the individual contributions of past and current scientists that has somehow attained social significance as warranted scientific knowledge. Although constrained by the procedures deployed by scientists, what emerges as scientific knowledge from the crucible of the individual work of scientists is unplanned. Even if we may find it comforting to describe “truth” as an abstract goal of scientific activity, the specific content of that goal is something that can only be discovered as a byproduct of the process itself. In this sense, science is end-independent.

To attempt to centrally plan science, whether overtly or indirectly by monopolization of its funding, is to foster an institutional framework incompatible with science as a self-ordering and self-correcting order.<sup>41</sup> Its implicit aim is to remake science into a constructed order having particular ends specified in advance and resources directed in ways to achieve such ends or serve special purposes. This implies that government science must dominate scientific activity in terms of the specific the allocation of scientific manpower and capital and establish the objectives that scientists are to achieve. Underlying this approach are two incorrect presumptions: first, that the planning board can somehow overcome the inherent

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40. See McQuade and Butos (2006), McQuade (2006).

41. Hayek (1973), Ch. 2. See also Butos and Koppl (2003).

division of both explicit and tacitly held knowledge within the scientific community to rationally organize and direct science, and second, that in establishing specified goals for science and directing scientific activity toward those purposes, the planning board subverts the inherent discovery process associated with free science by reorienting science toward the generation of preordained knowledge. Even if one were to concede that free science is subject to “market failure,” it does not follow that centrally planned science represents a coherent framework for correcting such putative failure.<sup>42</sup>

But there is another kind of knowledge problem which clearly bears an equally and perhaps even more important connection with science. At the very foundation of what science is understood to be is the notion that it has the capacity to generate new knowledge. The circumstances and conditions that induce the creation of knowledge are bound up in the specific institutional arrangements that comprise science and govern the sorts of interactions scientists engage in. As noted earlier, science is a particular kind of order that generates as a byproduct of the activities of scientists something we recognize as “scientific knowledge.” The principal characteristics of social orders like science are their dynamic stability and adaptability that allow them to actually function as knowledge-generating systems. Yet, as we have seen, the structure of government funding of science is such as to carry adverse implications for long-term stability and adaptability and therefore for the generation and use of scientific knowledge.

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42. Machan (2002), pp. xiii-xx, also associates government science with the problem of rational allocation under central planning.

## 6. Conclusions

Government funding (and by implication, at least partial control) of science is widely claimed to involve an appropriate function of government. We have presented arguments that dispute this claim. The analysis of science, we believe, requires a perspective rooted in the actual characteristics of scientific activity and its institutional arrangements. In particular, science is constituted by institutional structures that are not market structures; failure to recognize this has sustained long-standing analyses in the economics of science that are misplaced and muddying. Our approach is one very much geared to distinctions that we believe are crucial for understanding the real world. The standard science-as-a-public good argument turns out on closer inspection to carry less significance than the early work of Arrow and others suggested. As Martin and Nightingale (2000, p. xxii) point out, recent work during the 1990s “has called into question many of the assumptions of the old economics of science, especially that science is a public good ... What is now generally accepted is that the conventional ‘market failure’ justification for the public subsidy is weak.”<sup>43</sup>

By any metric, the role of the Federal government in funding science is significant. For example, expenditures for R&D in the U.S. are estimated to have been \$276 billion in 2002.<sup>44</sup> Of this amount, the Federal government accounted for \$78 billion (or about 28%), with about \$24 billion allocated to Federal government R&D, \$17 billion to industry, and \$27 billion to universities and colleges. Between 1953 and 2002, Federal R&D expenditures

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43. It is significant that Martin’s and Nightingale’s paper is the editors’ introductory essay to *The Political Economy of Science, Technology and Innovation* in the Elgar series of International Library of Critical Writings in Economics.

44. All reported data are from National Science Board (2004b), Tables 4-4 – 4-7.

(in 1996 dollars) have increased from \$5.3 billion to \$70 billion, an average annual increase of 7.8%.<sup>45</sup> We believe such evidence supports our claim that government is indeed a Big Player in science whose funding decisions in terms of absolute magnitudes and the direction of R&D carry important implications for both the economy and science.

If the outlines of our analysis are accurate, it means that there is no political solution to the problem – Greenberg’s advocacy of further politicization of science is like trying to put out a fire at a gas station with gasoline. The current system makes the wellbeing of scientists dependent on the whims of political expediency. It creates winners and losers in the scientific community, where the winning is not necessarily based on scientific achievement but on ability to secure and maintain a flow of politically-motivated funding. The only solution is for the political connections to be bypassed. This is unlikely to happen as a result of initiatives from within science, because the scientists most favored with government funding (who will be those who are held up as the pillars of the scientific community) will naturally be unwilling to forego their political arrangements. The big hope for such bypassing is for the trend in industrial support of science – in the form of the employment and funding of scientists in laboratories that are integral parts of profit-making firms – to continue to increase. Businessmen have realized that scientific freedom and monetary profit are not necessarily incompatible, for scientists free to pursue their research into whatever interests them and free to openly publish the results of such research in normal academic outlets can still, through their expertise and specialized knowledge of the current publications

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45. Over the same period, non-government funding of R&D (industry, universities & colleges, and non-profit organizations) increased per year on average by 26.6%, with the great majority of the absolute increase accounted for by R&D originating in industry and most of that increase (about 80%) since 1982. The evidence also supports the observation that government funding of “basic research” – as defined in National Science Board (2004a), p. 4.8, has crowded out industry and especially university research. See Table 4-8 in National Science Board (2004b). Also, in this paper we have not taken account of government funding of science originating at the State level.

in their field, contribute to in-house projects geared to producing revenue-generating products. In addition, there are areas, particularly in the biological sciences, where access to findings prior to formal publication provides the firm with a jump on the competition that can be profitable in itself.<sup>46</sup>

We can say, with considerable understatement, that such a provisional prognosis is likely to be controversial. We are only too aware that the topic of government funding of science is a large and complex one and, to make things more difficult, one more likely to be discussed in normative rather than positive terms. Our objective in this and future work is to provide a positive analysis of the effects on science of government funding and to illustrate the predicted effects empirically. Our basic approach, hopefully already evident in the current paper, is informed by a model of science as an adaptive knowledge-generating order whose fundamental transactions involve publication, citation, and criticism. In the context of this basic social arrangement, we examine the effects of different regimes of funding. We insist at the outset that assessing such matters in terms of the theory relevant for a market process is not tenable: the market economy is characterized by a pricing process in a system of profit and loss based on enforceable property exchanges, and such features are absent from the knowledge-generating process of science. Science must be analyzed in terms of the incentives and transactions characteristic of science, not those of markets.

That government funding (with both its presumably scientifically well-intentioned aims *and* politically driven orientation) carries significant implications for the kinds of questions scientists ask, for the kinds of knowledge they generate, seems very plausible. But provided

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46. The history of the Human Genome Project, described in Shreeve (2004), is particularly instructive in this respect.

the standard critical institutions are in play, a scientific discovery has the same epistemological status whether it has been funded by NSF or a private patron. The problem, then, is that on the surface the specific characteristics of government-funded science and the knowledge it generates are not evidently any different from those that have originated through private funding.<sup>47</sup> We have suggested, however, that the effects are more subtle and affect the structure and function of the scientific arrangements themselves – government funding actually does affect science in a way analogous to the ways price controls, subsidies, credit expansion, and central planning affect markets, and we have begun in this paper the documentation of an institutional structure in science made more unstable and maladapted to its environment as a consequence.

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47. There are, of course, some notable apparent exceptions to this claim. The Lysenko affair in the U.S.S.R., for example, involved the stipulation and enforcement of government mandated truth. However, this reflects an abandonment and suppression of the critical tradition in science. This does not mean the presence of such a critical tradition is a sufficient condition for avoiding such outcomes.

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