“Entrepreneurial Energy Its Creation and Capture Part II: Policy and the Innovation System”

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CHAPTER 2
MANAGEMENT IN FIRMS AND ORGANIZATIONS

Entrepreneurial Energy Its Creation and Capture Part II: Policy and the Innovation System[1]

Craig T. Scalise[2]

Abstract: This paper applies the concepts developed in "Entrepreneurial Energy. Its Creation and Capture, Part I (Theory and History)", which addresses the common misperception that government funding for research violates free market principles.

It focuses on practical innovation policy issues and defines an economy's "innovation system". In the light of the economic principles and historical validations presented in Part I, it analyzes National Science Foundation data to identify challenges of maintaining a policy that is conducive to a balanced innovation system with efficient public and private research funding.

The data indicate that ordinary political costs may be a primary challenge for the innovation system's efficiency. Recognizing and managing these political costs is crucial for developing the industries that stimulate growth, increase productivity and reduce inflation.

Keywords: entrepreneurship, innovation, basic research, research funding, public goods, private goods, microelectronics, biotechnology

JEL Classifications: H11, H41, L63, M13, O31, O38

I. Innovation and Policy

> *Some good men, and even of respectable information, consider the learned sciences as useless acquirements; some think that they do not better the condition of a man; and others that education, like private and individual concerns, should be left to private individual effort…This would leave us, then, without those callings which depend on education, or send us to other countries to seek the instruction they require.*
> –Thomas Jefferson, Report: University of Virginia, Aug. 4, 1818[3]

"Entrepreneurial Energy. Its Creation and Capture, Part I (Theory and History)" showed that in cause of their development innovations pass through various distinct phases. They start with the public sector's creation of public goods, which is achieved through basic research breakthroughs. These breakthroughs advance the economy's technology platform, enabling private industry to compete for value-capturing innovations and profits. This is the process that creates and captures the entrepreneurial energy which pushes economic progress forward.

The examples of the semiconductor and biotechnology industries illustrate the process. For semiconductors, the result of the process is that it generated the US information industry, which accounts for not only for 8% of US GDP, but also for over 30% of GDP growth while tri-

[1] Next part of the paper will be published in next issue of the magazine.

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[3] Appleby, Joyce and Terence Ball (eds.), "Jefferson - Political Writings," Cambridge University Press, 1999.

pling productivity growth and reducing inflation by 0.5%.[1] All of this substantially and broadly increases the standard of living. Biotechnology has the potential for a similar impact on society as do other innovative industries, many of which are not yet even known.

Part II (Policy and the Innovation System) focuses on the entrepreneurial energy creation side of the process, which revolves around government policy. Part III (Strategy for Innovative Business) will focus on the other half, the entrepreneurial energy capture side, which revolves around managing business strategy.

The Economy's Innovation System

The semiconductor and biotechnology examples identified a wide variety of institutions that are crucial for moving innovations from esoteric scientific inquiries to industry-generating, value-creating technologies.

Key institutions for the semiconductor study included the university research system (where the electron was scientifically identified and explained), government research labs (where the scientific principles were first intensively studied for useful applications) and for-profit research labs, both regulated (which performed further basic research to translate previous advances into the transistor) and nonregulated (which captured the value of the preceding achievements and created the semiconductor and electronics industries). Institutions such as these made similar contributions to biotechnology.

These institutions shared two key features. First, they each required substantial investment. Second, they each used these investments to play their complementary roles in creating and capturing entrepreneurial energy. Without the achievements of any of the institutions, the rest would have provided little real value to society in developing the semiconductor or advancing biotechnology. Because of this interdependence, these institutions are major elements of an economy's "innovation system" that creates economic progress through technological achievement.

The economy's innovation system faces two fundamental challenges. The first challenge is the need to maintain public funding for the basic research that creates the entrepreneurial energy and balances the private sector's capability. The second challenge is the need to use that funding efficiently and productively.

Government policy needs to recognize these challenges so that it can manage them and let the economy reach its potential.

In the second half of the 20th century the US provides an especially good opportunity to study these challenges. Because this period followed the events that were analyzed in Part I, the benefits of maintaining an innovation system have become clear. At the same time, the costs of maintaining the innovation system became increasingly clear because of growing budgetary pressures on the US government. In addition, the US enjoyed relative peace and prosperity during much of this period. Given this context, most obstacles to the US maintaining an effective innovation policy would be those that are inherent.

Approach and Organization

This analysis will first describe the scale and distribution of US research and development (R&D) investment by using National Science Foundation (NSF) data to show the state of the US economy's innovation system at the end of the 20th century (Section II).

Section III will look into the NSF data to identify R&D funding trends between the 1950s and 1990s from which policy insights can be drawn. Because of the importance of the innovation system being in balance (as explained in Part I), most of the data series are reported as ratios. In contrast, the analysis does not focus on specifics, such as causes and effects of defense spending, which are important but studied elsewhere and not central to this paper.

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[1] "Building Our Broadband Future" Remarks by Bruce P. Mehlman Assistant Secretary for Technology Policy, United States Department of Commerce – 1 http://www.technology.gov/Speeches/BPM_011026_Broadband.htm (September 5, 2003).

Section IV analyzes possible long-term effects of funding trends by looking into the needs and abilities of the institutions within the innovation system.

Section V addresses the second layer of challenges, ensuring that the innovation system uses government research investments efficiently.

II. Profile of US R&D at the End of the 20th Century

According to the NSF, the US spent a total of $247 billion on R&D in 1999, raising US R&D to 2.61 % of GDP.[1] In 1995, the US provided 44% of the industrial world's R&D investment, an amount almost equal to the next six nations' combined investment. Other than in the US, R&D expenditure in 1995 exceeded 1% of GDP only in the Netherlands, Australia, Sweden and Spain.[2]

Table 1

Preliminary national expenditures for research and development, by performing sector and source of funds: 1999
All R&D: Basic Research, Applied Research and Development[3]

Performer	Sources of Funds					
	Total	Industry	Federal Government	Universities and colleges	Other non-profit institutions	Percent distribution, by performer
	(millions of 1999 dollars)					
Total	247,000	169,312	65,853	7,923	3,913	100.0%
Industry	185,892	165,955	19,937	-	-	75.3%
Industry-administered FFRDCs	2,166	-	2,166	-	-	0.9%
Federal Government	17,362	-	17,362	-	-	7.0%
Universities and colleges	28,256	2,163	16,137	7,923	2,032	11.4%
U&C-administered FFRDCs	6,169	-	6,169	-	-	2.5%
Other nonprofit institutions	6,319	1,194	3,246	-	1,880	2.6%
Nonprofit-administered FFRDCs	836	-	836	-	-	0.3%
Percent distribution by sources	100.0%	68.5%	26.7%	3.2%	1.6%	
Key:	FFRDC=Federally funded research and development center; U&C=universities and colleges					
Notes:	State and local government support to industry is included in industry support for industry performance					
	State and local government supports to U&Cs in included in U&C support for U&C performance.					
Source:	National Science Foundation/Division of Science Resources Studies.					

[1] http://nsf.gov//sbe/srs/nsf99335/trends.htm (August 28, 2003).
[2] http:// www.nsf.gov/ sbe/ srs/ seind98/ access/ c4/ c4s4.htm#c4s4l1b (August 28, 2003).
[3] http:// www.nsf.gov/ sbe/ srs/ databrf/ sdb99357.htm, Table 1 (August 28, 2003).

Table 2

Preliminary national expenditures for research and development, by performing sector and source of funds: 1999
Basic Research Only[1]

Performer	Sources of Funds					
	Total	Industry	Federal Government	Universities and colleges	Other nonprofit institutions	Percent distribution, by performer
	(millions of 1999 dollars)					
Total	40,224	12,689	21,020	4,586	1,929	100.0%
Industry	11,778	10,888	890	-	-	29.3%
Industry-administered FFRDCs	601	-	601	-	-	1.5%
Federal Government	3,100	-	3,100	-	-	7.7%
Universities and colleges	18,758	1,252	11,743	4,586	1,176	46.6%
U&C-administered FFRDCs	3,086	-	3,086	-	-	7.7%
Other nonprofit institutions	2,795	549	1,494	-	752	6.9%
Nonprofit-administered FFRDCs	107	-	107	-	-	0.3%
Percent distribution by sources	100.0%	31.5%	52.3%	11.4%	4.8%	
Key:	FFRDC=Federally funded research and development center; U&C=universities and colleges					
Notes:	State and local government support to industry is included in industry support for industry performance					
	State and local government supports to U&Cs in included in U&C support for U&C performance.					
Source:	National Science Foundation/Division of Science Resources Studies.					

Public Sector

According to the NSF, the US Federal Government spent approximately $66 billion on R&D in 1999, accounting for about 27% of US research expenditure. Of this investment, $21 billion was for basic research, accounting for slightly more than 50% of US basic research expenditure.2 These expenditures were made primarily by (in descending order of their R&D expenditures) the Department of Defense, Health and Human Services, National Aeronautics and Space Administration, the Department of Energy, NSF, the United States Department of Agriculture and the Department of Commerce.[3]

[1] http:// www.nsf.gov/ sbe/ srs/ databrf/ sdb99357.htm, Table 1 (August 28, 2003).
[2] http://nsf.gov/sbe/srs/databrf/sdb99357.htm Table 1. (August 28, 2003).
[3] http://nsf.gov//sbe/srs/nsf99335/ trends.htm. (August 28, 2003).

Private Sector

According to the NSF, US for-profit industry spent approximately $169 billion on R&D in 1999, accounting for 69% of the $247 billion total US R&D expenditures. An additional $12 billion (5%) was provided by not-for-profit institutions, such as universities and private foundations, for a total of $181 billion. Within the $181 billion, about $19 billion was spent on basic research, slightly less than half of the US basic research investment.[1]

These numbers show that the US invests an extraordinary big amount in R&D. The percentage breakdowns are generally in line with what would be expected from the perspective of entrepreneurial energy creation and capture. The exception is government's proportion of basic research funding, which would be expected to be much higher than the 1999 level of 52.3%. Regardless, putting these numbers in a historical context is important for interpreting them and identifying policy-guiding insights.

III. Historical Context: US Research Funding Trends

Because of policy's role in creating entrepreneurial energy through funding basic research, the historical data analysis starts with broad measures of US R&D activity and then focuses on government funding and basic research.

Broad Measures: Reflecting Privatization or Destabilization?

Figures 1-3 show the overall trend in US research and development during the second half of the 20th century.

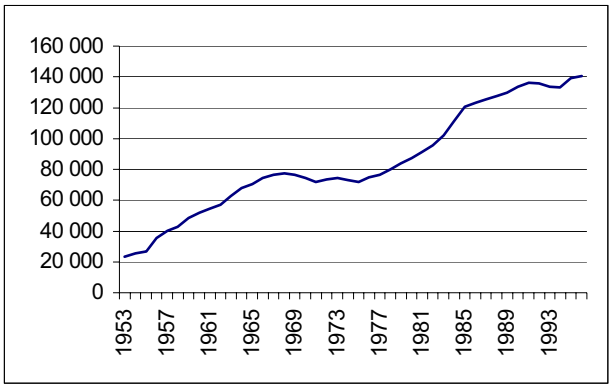

Fig. 1. Total US R&D (millions of 1987 US$) [2]

Figure 1 shows that US R&D investment growth has generally been very strong during the second half of the 20th century. There were periods of weakness, such as the mid-1970s, when the US was experiencing multiple economic challenges, including inflation and recession. R&D investment growth in the 1990s also appears less solid, especially if looked at in respect to the size of the economy in Figure 2.

[1] http://nsf.gov/sbe/srs/databrf/sdb99357.htm Table 1 (August 28, 2003).
[2] http://www.nsf.gov/sbe/srs/nsf96333/appc.pdf, Tables C1, C3 (August 28, 2003).

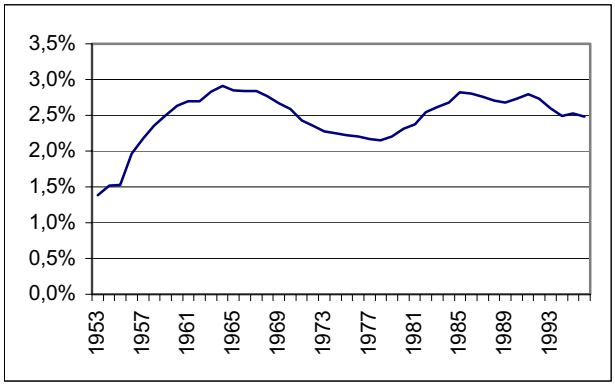

Fig. 2. Total US R&D, as a Share of US GDP[1]

Figure 3 shows that this softness follows a substantial decline in the percentage of GDP that the government spends on R&D, a trend that began in the 1960s.

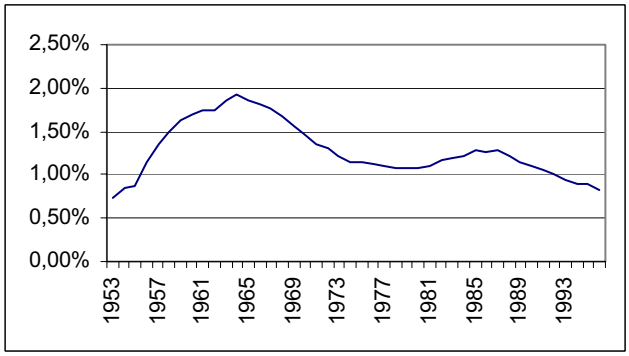

Fig. 3. US Government-Funded R&D, as a Share of US GDP[2]

As is usually the case with broad measures, there are many wide ranging interpretations and policy conclusions that can be drawn from Figures 1-3. One can interpret the data as showing generally strong US R&D growth with the added benefit of increased privatization, and conclude that US R&D policy has been very constructive.

In contrast, one can emphasize the complementarities of entrepreneurial energy creation and capture, in which innovation effectiveness is highly correlated with the preceding government-funded basic research breakthroughs. This, along with the weakness towards the end of the period, would lead to an interpretation that is more complicated, but at least as valid.

This would suggest that a destabilizing imbalance is emerging in which the private sector is increasingly built around innovation, but the public sector is not replenishing the stock of basic research breakthrough that fuels private innovation. In this case, an under-productive economy with slowing innovation could be expected. In contrast with desirable privatization, this interpretation would lead to the conclusion that R&D policy is not maintaining the economy's innovation system with maximum effectiveness.

[1] http://www.nsf.gov/sbe/srs/nsf96333/appc.pdf, Table C1, C3 (August 28, 2003).
[2] http://www.nsf.gov/sbe/srs/nsf96333/appc.pdf, Table C1, C3 (August 28, 2003).

Focus: Government Funding and Basic Research

These alternative views can be further analyzed by focusing on government and basic research funding.

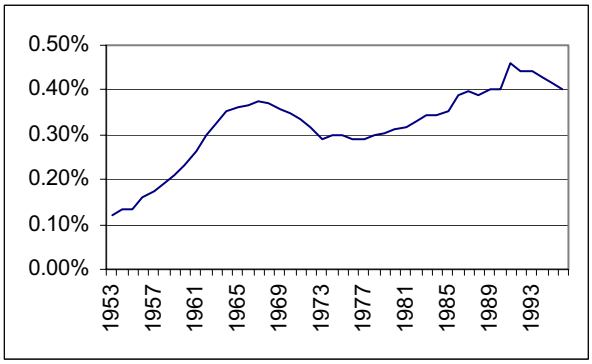

Fig. 4. US Investment in Basic Research as a Share of US GDP[1]

Figure 4 shows that the 1990's softness in R&D growth is associated with a sharp, steady decline in US basic research investment relative to the size of the economy as a whole. Figure 5 shows that government investment is a key driver of the 1990s decline in total US basic research investment. Much additional analysis would be needed to draw strong conclusions about cause and effect within these trends. However, the data do seem to be more consistent with the entrepreneurial energy interpretation that US government basic research funding policy is allowing basic research progress to fall behind, with private innovation expected to follow.

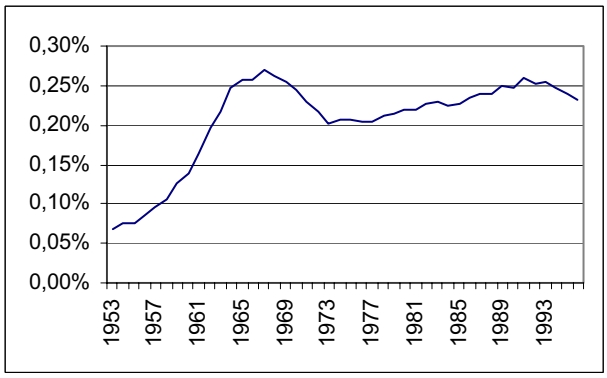

Fig. 5. US Government Funded Basic Research as a Share of US GDP[2]

[1] http://www.nsf.gov/sbe/srs/nsf96333/appc.pdf, Table C1, C5 (August 28, 2003).
[2] http://www.nsf.gov/sbe/srs/nsf96333/appc.pdf, Table C1, C6 (August 28, 2003).

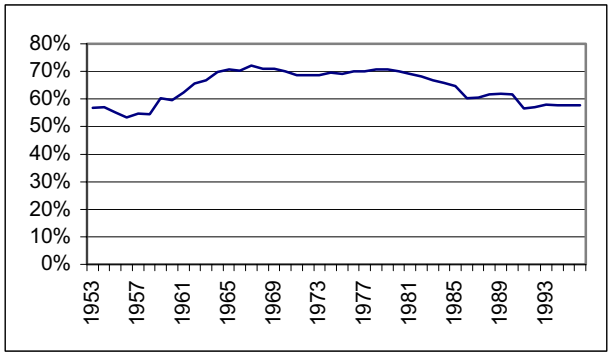

Fig. 6.US Government Funded Basic Research as a Share of Total US Basic Research[1]

A stronger statement seems to be made by Figure 6. This figure shows that government funding regularly accounted for approximately 70% of the basic research during the 1960s and 1970s, the period when the payoffs of earlier US basic research were becoming very clear. Since that time, the government's share of basic research funding has fallen persistently, accounting by only 52% in 1999.

Given the extent that government's share of basic research investment has fallen and taking into account length of time over which it has occurred, this trend can be considered significant. Looking into why this shift away from government basic research funding could have occurred provides further insight into whether US government policies are leading to efficient R&D privatization or to a damaging destabilization

The Shift Away from US Public Funding of Basic Research: Cause and Effect

Figure 6 isolates the question, "Why would funding basic research become *relatively* less attractive to the government?" The answer can be driven from four forces, or a combination of them: 1) a decline in costs of private basic research funding, 2) a decline in government benefits 3) a rise in government costs, and 4) a rise in private benefits. These can be looked at separately:

Candidate 1: Decline in the costs of private basic research funding

Most explanations of how costs could have fallen for private basic research (e.g. industry scientists and engineers are better equipped, clearer direction leads to less waste etc.) suggest that highly sophisticated applied research and development is actually being confused with basic research. While this may be happening to some extent, this force probably does not provide a useful explanation of the data.

Candidate 2: Decline in the benefits of government basic research funding

Given the new scientific frontiers opened by 20th century success of government-funded basic research, which lead to more basic research investment opportunities rather than to fewer, it is difficult to argue that there has been a decline in the benefits of government-funded basic research funding. Again, this force probably does not provide a useful explanation of the data.

Candidate 3: Rise in the costs of government basic research funding

It is possible that the costs of basic research are rising for the government. With greater sophistication, larger scale projects would require larger investments. But, along with the argument for Candidate 2, why wouldn't the increased cost of investigating science's expanded frontiers be matched by increased benefits? An explanation of the data that focuses on the increased cost of government investment is also unlikely to be useful.

[1] http://www.nsf.gov/sbe/srs/nsf96333/appc.pdf, Table C5, C6 (August 28, 2003).

However, there could be large increases in powerful "political costs". This is suggested by the fact that the relative decline of government investment in basic research started during the 1970s and then continued during the 1980s and 1990s. The 1970s were an economically challenging period for the US and federal budget pressures increased through the 1980s and into the 1990s.

At the same time, waves of innovation were delivering the payoffs of earlier government-funded basic research investments. This success in innovation, ironically, can mask the need to renew investment in basic research to those who do not distinguish entrepreneurial energy's capture from its creation. Those who do not make this distinction fail to realize that the surge in capture signals the importance of renewing its creation. Combining the budget pressure with competition from more easily promoted uses of federal money (such as initiatives that have more dramatic appeal or faster payoffs) could lead to a significant increase in the political cost of government basic research funding.

Candidate 4: Rise in the benefits of private basic research funding

As with the fall in private costs, arguing that basic research is becoming more valuable to its private financers – despite the increasing depth of inquiry making payoff more distant and less certain – again suggests that sophisticated applied research is being confused with basic research, and that this is a direction that probably is not useful.

However, the *marginal*, *relative* benefit to private basic research investment could rise to the extent that it is political costs – rather than reduced opportunity – that is decreasing government basic research. In this case, private industry could be investing in basic research to try to compensate for its expectation of not receiving the basic research breakthroughs that fuel its innovative structure,[1] not because it is prepared to efficiently create those breakthroughs.

Among these four potential explanations, the strongest candidate for a root cause explanation of the shift away from government basic research funding shown in Figure 6 is that the cost of government funding has increased because of political costs associated with budgetary pressure. Since this is not driven by the costs and benefits of government-funded basic research – nor by the innovation system's opportunities and interdependencies – it further favors the conclusion that the data are consistent with an emergence of an imbalance in the innovation system.

Such an imbalance could reduce the effectiveness of private innovation. It could also lead to additional long-term effects through damaging the elements and the economy's innovation system itself, and generally reduce the creation and capture of entrepreneurial energy.

IV. The Elements of the US Economy's Innovation System

Looking more closely at the various types and various sources of R&D that form the innovation system can provide more insight into the policy payoff of maintaining the balance between government funded basic research and the rest of the innovation process.

For-Profit Research Labs (corporate research labs)

According to the NSF data shown in Table 1, for-profit firms funded 68.5% of all US R&D but only 31.5% of basic research. Similarly, for-profit firms performed 76.2% of all US R&D, but only 30.8% of basic research. This profile is heavily skewed towards non-basic research, which is consistent with the view that private industry's comparative advantage lies in capturing entrepreneurial energy rather than in creating it. Many examples from industry illustrate this principle, such as the AT&T example in Part I; although it made great contributions, AT&T did not capture the bulk of the profits generated by the transistor and semiconductors.

Despite the private sector's natural emphasis on development, there are sub-categories of corporate research laboratories that have (or had) focuses other than applied research and should be looked at separately.

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[1] For example, the semiconductor industry spends 9% of revenue on R&D that squeezes more and more value out of the quantum mechanics and transistor basic research (Semiconductor Industry Association, Technology, R&D Funding, http://www.sia-online.org/pre_stat.cfm?ID=63, October 22, 2002).

Research Labs in Regulated Industries

Historically, regulated laboratories have been a very important sub-sector of for-profit laboratories, as was demonstrated in the semiconductor example of Part I. This was because regulated firms had weaker financial constraints, providing easier access to risk-tolerant financing for basic research. This, in turn, fits into collaborative, science-focused environments similar to federally funded public good creating institutions.

However, these weaker financial constraints also weaken the profit incentive that drives efficiency. While Bell Labs was incredibly productive in producing research, other regulated firms, like regulated utilities, were not.

Regardless, changes in the regulatory environment have decreased this category's significance in the US innovation system. For example, since the Bell System was broken up in 1984, rate-making regulations have only applied to some local service telephone companies (the remaining monopolists) and some access tariffs. This rate-making is now very remote from R&D, because the carriers buy their R&D from unregulated competitive firms such as Lucent and Nortel in the forms of products and services. The research performed by these firms has been migrating towards applied research and development as competition has forced investments to focus on direct payoffs. As a result, this once great source of basic research breakthroughs has faded into a nearly indistinguishable sub-sector of the general for-profit laboratory category.

Industry Consortia / Joint Venture

Within the corporate research laboratory category, industry consortia and joint ventures have unique features, which make them very useful for working with basic research and moving technology from public good status to private good status. They are well suited for performing pre-competitive research that individual firms may avoid.

This is because they have access to the industry's pooled resources, allow increased collaboration and risk diversification while maintaining the individual firms' profit motives. But as with individual firms, their performance measures and reward systems are not conducive to true basic research's remote payoff profile.

Consortia and joint ventures also introduce serious competitive issues. Cooperation among competitors raises antitrust issues and the participants are ultimatel rivals, which must be addressed.

Combining these factors, industry consortia and joint ventures have the potential to be of great value in efficiently driving innovation forward. However, most of their value is limited to the pre-competitive research stage, which follows basic research.

These points support the view that corporate R&D well suits to development and some applied research but not basic research. This is consistent with the view that a destabilizing impact on the innovation system can be expected if government funded basic research falls behind the rest of the system.

Universities

According to the NSF, US colleges and universities funded 3.2% of total research but 11.4% of basic research. Similarly, colleges and universities (including federally funded research and development centers) performed 13.9% of all research and 54.3% basic research. This is the reverse of industry's development-focused profile.

Perhaps even more significant is the source of the academic research funds. The US government provided $22 billion of the $34 billion that colleges and universities spent on research. Similarly, government provided $15 billion of the $22 billion that colleges and universities spent on basic research. As a result, US government funding was responsible for two-thirds of university basic research and R&D in general.

These figures demonstrate that the US research university system (including colleges) is able to play its complementary role that enables industry to work smoothly because of US government support. The university research system plays this role through multiple capabilities

Workforce Education

A second critical capability that publicly-funded universities provide in the creation and capture of entrepreneurial energy is that they are the most effective method of developing the people within whom entrepreneurial energy has life and creates value.

This is of great importance because entrepreneurial energy does not exist exceptionally within people who can recognize opportunity and respond with commitment and high expectations. Since the educational system forms the skills, attitudes and expectations of the future workforce, a workforce educated in the midst of great basic research advances will be better equipped to carry advances through the capture stage. With the technological sophistication that the US has inherited from prior investments, this may be truer than ever.

Efforts to Make University Basic Research Self-Sustaining

The narrow free-market response to these issues is that if university basic research is truly of value, then it should be able to capture this value in a way that makes university research self-sustaining. An example of a mechanism in the US innovation system that could help with this is the 1984 Bayh-Dole Act, which allows universities to patent federally funded innovations, possibly providing funds that reduce the need for future government support.

The original purpose of this Act was to improve technology transfer from universities to industry by creating a financial incentive for overcoming the regulatory hurdles that have left many university-achieved innovations unused. Data indicate that the Act is succeeding in meeting its technology transfer objectives.

However, the Bayh-Dole Act or other market mechanisms we unlikely to substitute for federal funding in a meaningful way. The Bayh-Dole Act does not address creation of entrepreneurial energy because most true public good-creating basic research breakthroughs would not be patentable. Quantum mechanics was not patentable – the Bayh-Dole Act will not support the "next quantum mechanics revolution."

Instead, it does raise a concern that profit opportunities could distract universities from their mission and pull resources away from unpatentable public good-creating basic research. While this does not discourage supporting the Bayh-Dole Act and other methods of technology transfer, it does show the need for government to support university basic research so that universities will not lose site of their missions.

University Research Efficiency

The financial freedom provided by government funding conflicts with the profit motive that allocates resources and directs research efficiently. To some degree, this is inherent in basic research investments and minimizing its impact is of great importance, perhaps as important as ensuring that basic research funding is maintained. Regardless, it would be self-defeating to overemphasize this issue and allow it to cause under-funding basic research in universities. This issue is further addressed in Section V.

Government Laboratories

According to the NSF, US government laboratories performed 7.0% of all US research and 7.7% of US basic research. All funds were provided by the federal government.

Government laboratories are similar to university labs, but occupy a significantly different niche. The 20 government labs, including Argonne National Laboratory, Ames Laboratory, Lawrence Livermore National Laboratory and Los Alamos National Laboratory, are generally chartered under the Department of Energy and run through partnerships with universities or other research organizations. The system was established during the World War II era to provide a venue for carrying out large-scale sophisticated research that was crucial to the US' strategic needs.

As a federally funded organization similar to the university research system, the National Labs' performance measures and reward systems provide a good environment for pursuing research with "remote" payoffs. Since the national labs were established, they have achieved many

great basic research breakthroughs in areas ranging from nuclear technology to environmental technology. The success of their research has been rewarded with numerous Nobel Prizes and other measures of excellence.

Although it is important to maintain the national security value that national labs are capable of providing, they substitute for neither academic research nor private R&D. Only industry has a strong profit motive, so industry is the only appropriate performer of applied research and entrepreneurial energy capture. Similarly, the national labs cannot match the university system's scale, human capital formation or broad scientific competencies. Consequently, the National Labs are unlikely to do more than fill the niche of ensuring sensitive national strategic initiatives accomplishment.

Technology Import

Non-US research accounted for 56% of global R&D in 1995. To the extent that these R&D investments create public goods or capturable private goods, technology import provides another important source of R&D for the US innovation system.

The semiconductor example in Part I demonstrates the value of importing foreign technology. Without the theoretical breakthroughs in quantum mechanics achieved at European universities, there may not even be a semiconductor industry in the US. In addition, the example showed the importance of interaction between US scientists and European scientists. These lines of communication increase the pool of intellect, which generates greater intellectual power. Further, one could argue that a country benefits when foreign taxpayers and corporations bear the cost of research, especially unsuccessful basic research.

For reasons such as these, it is critical to keep the lines open for technology import – especially at the basic research stage. However, this does not imply that foreign breakthroughs would lead to the same outcome as investing in domestic breakthroughs.

Technological import is a complement – not a substitute – for domestic basic research for several reasons. Perhaps most important of these is that entrepreneurial energy tends to be concentrated in geographically compact communities because entrepreneurial energy exists within people. While the ideas may spread freely, the people who are best prepared to fully capture and develop them are those who are experienced with the ideas and are in constant interaction with one another – entrepreneurial energy is not as mobile as information.

Because of this, the firms that capture the greatest entrepreneurial energy tend to cluster. Examples include Silicon Valley, which is clustered around great universities such as Stanford University and the University of California – Berkeley, Boston's Route 128, which is clustered around great universities such as Harvard and MIT and England's Silicon Fen, which is clustered around the great Cambridge University.

In fact, the semiconductor example illustrates the fact that entrepreneurial energy is not as mobile as is information. The US was slow to pick up on the quantum revolution during the early twentieth century when the scientific advances were occurring in Europe, making the US an unlikely home to the electronics industries. However, US entrepreneurial energy leapt forward, and the US moved to the front of the technological progress, during the extraordinary immigration waves that brought many of the great European scientists, such as Einstein, to work, research and teach in the US. The more of these scientists were present, the more the US captured and mastered the value of their ideas.

Entrepreneurial energy lies within people, it is delivered to them through their experiences, and it is sustained through local basic research investment. These points highlight the principle that entrepreneurial energy is created domestically, even if it is maximized through global interaction. Being the ultimate source of entrepreneurial energy creation is the best means of capturing it.

Table 3

Summary of the US Innovation System

	Competencies				
	Basic Research	Pre-Competitive Research	Applied Research	Product Design	Late 20th Century Status
For-Profit Research Labs			X	X	strength based on previous university basic research; has lost regulated laboratories' significance
Consortia/Joint Ventures		X			strength based on previous university basic research
Research Universities	X				strong but financially endangered
Government Labs	X				limited impact, mainly for defense purposes
Import	X	X	X	X	limited impact

Table 3 summarizes the state of US research institutions at the end of the 20th century. It shows that the US innovation system is currently very active, but the activity is increasingly unbalanced towards squeezing innovation out of previous generations of government-funded basic research.

This conclusion keeps the focus on the importance of maintaining commitment to government support for basic research. It also raises the importance of ensuring that government basic research funds are used efficiently.

V. Efficient Basic Research Funding

Public funding for basic research is valuable only if the funding is used efficiently. Even if not for a long time, the economy must receive as much payoff from research funding as possible to justify the funding and its management. While private firms have profit maximization to guide their resources to their most productive uses, public R&D funding needs to design analogous means for determining what research to support and how to do so.

Useful standards have been established for addressing this systematically. For example, the American Association of Universities has created guidelines, outlined in "Principles to Guide Expanding Support for Science and Engineering Research Funding". The following lists and analyzes these guidelines[1]:

Research programs grounded in rigorous peer review of investigator-initiated proposals.

In a peer review system, the value of research is estimated through the opinions of scientists who are experts in the area but are not directly involved in the work. Peer review is perhaps the most important standard that is currently used for encouraging research efficiency. In fact, the NSF is committed to ensuring that research funds be provided and renewed in a competitive environment based on peer review.

Through using academic reputation as currency, peer review creates the public good analogy of profit maximization. Scientists essentially invest their all-important reputations by backing chosen lines of research. The scientific payoff would come much more quickly than financial prof-

[1] http://www.news.cornell.edu/Chronicle/98/5.14.98/research-funding.html, (September 15, 2003).

its, because the researchers' reputations are enhanced or diminished when others in the scientific community come to recognize the scientific value of their inquiries.

This provides the appropriate form of oversight because it encourages the right kind of competition, competition for scientific results. In addition, it is appropriate because academic scientists are best able to recognize the value of scientific inquiries. This goes along with the principles that private industry does not have the information necessary to profitably carry out all basic research, and that the government does not possess superior information to industry.

Peer review also promotes the ideas' diffusion across the research university system. This is analogous to the private sector's financial community – information will move much faster, and the facts are more likely to be established, when currency is attached.

Peer review does, however, have its liabilities. Perhaps the greatest weakness is that the politics of academia can be very powerful and damaging. These politics are capable of undermining the peer-review process in favor of the status quo or of an area that is of less social value but is of greater benefit to a powerful faction.

High-quality education of graduate student

High-quality education of graduate students ensures that new people are constantly brought through the university research system, providing fresh perspectives and ideas. This enhances the creation of entrepreneurial energy. In addition, it develops a workforce that will be best prepared to capture entrepreneurial energy.

Funding increases should be allocated across a broad front of scientific opportunity in recognition of the increasing interdependence of research across disciplines

This recognizes that as technological standards become more sophisticated, there is more opportunity for breakthroughs to come through less conventional pairings of ideas.

Stability and sustainability over the long term

Basic research is a long-term proposition. Consequently, anything less than a stable long-term commitment would undermine it. However, as the NSF emphasizes, this "stability" must be maintained within the peer review system to ensure that funds are continuing to be used effectively. The NSF focuses on maintaining competition for funds in order to ensure that funds do not become inefficient "entitlements."

Include infrastructure needs

An aging infrastructure will reduce the returns to even great research efforts and expense. Sustaining progress requires that the tools do not fall behind science.

Full recovery of institutions' appropriately incurred costs of federally supported research conducted on their campuses

Much like the need for stability and sustainability, ensuring that research-performing universities can rely on their funding is necessary for ensuring that long-term progress is achieved.

Universities should assume responsibility for wide dissemination of the results of federally supported research and encourage the use of new knowledge for public benefit

Of equal importance to peer-review, all means must be used to ensure that the public goods are spread broadly and freely, maximizing the pool of intellect and impact.

There are other principles for supporting efficient research funding that may be considered, such as the following:

Increase direct rewards for achieving useful research results

This is potentially very useful. However, as with the Bayh-Dole Act, market financial rewards are not likely to support breakthrough basic research.

Increase industry incentive to fund university research, thereby providing direction

This is another potentially important opportunity. Industry already provides the university research system with billions of dollars, allowing much costly research to be performed. But again, this type of program must only be relied upon with discretion. As with the Bayh-Dole Act, industry influence could shift rewards to applied research that industry could identify and perform very efficiently, distracting universities from their complementary basic research role.

Ensuring that government research investments are used efficiently may be a great challenge, but it is neither new nor unmanageable. The twentieth century's technological progress is evidence that publicly funded university R&D can, in practice, be very productive.

VI. Summary: Building Prosperity through Overcoming Political Costs of Research Funding

> *I think by far the most important bill in our whole code is that for the diffusion of knowledge among the people.*
> -Thomas Jefferson to George Wythe, Paris, August 13, 1786[1]

This paper uses NSF data to develop insights about challenges to innovation policy by analyzing US R&D policy during the second half of the 20th century, a setting relatively conducive to innovation policy.

It presents data on late 20th century funding for the US economy's innovation system, focuses on the historical trends that generated this result, and then uses this information to assess the likeliness that US policies will maintain the US innovation system so that it can continue to enable the full potential of innovation-driven growth.

While there are many ways to interpret the broadest measures of US R&D activity, government funding and basic research data suggest that ordinary political costs may be leading the government to under-invest in basic research. This under-investment, in turn, can destabilize the innovation system's balance by generating insufficient basic research breakthroughs required by private industry for true innovation. In the long run, this imbalance can damage the innovation system as a whole by not maintaining its central elements that build human capital and reach the outer limits of research, such as the research university system.

Given these conclusions do not appear to be driven by extraordinary circumstances, they demonstrate that an economy that wishes to prosper by innovating needs to overcome common but excessive political resistance to government research funding. It needs to do this by focusing on the total impact of the funding within the economy's innovation system, while also trying to ensure that research investments are being used efficiently.

The value of doing so has been demonstrated by the growth and standard of living improvements enabled by the information technology industry, as well as the contributions made by other progressive industries. A key step to repeating this success is ensuring that policy makers and the public understand free market forces deeply and broadly enough to appreciate the unique value of government basic research funding, its role in innovation, and its potential for a great impact on society.

[1] Appleby, Joyce and Terence Ball (eds.).