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# The End of Pure Science: Science Policy from Bayh-Dole to the NNI

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**Abstract**. The science policy of the United States federal government has undergone a series of changes in emphasis since the Second World War. Most of the debate about what federal science policy should be, has focused on two questions – what is the role of science and technology in national security and what is the role of science and technology in economic growth. This paper details the shift from military to economic motives for American science from 1980 through the turn of the century. While this shift was caused in part by the end of the Cold War, the economic challenges of the late 1970s and early 1980s first laid the ground for a new kind of federal involvement in scientific research as an economic engine. This new economically driven science policy has culminated in the National Nanotechnology Initiative of 2000.

## Introduction

In 1995, Charles Vest, President of MIT, claimed that, "We are in a period of fundamental reconsideration of US science and technology policy. The end of the Cold War, the changing nature of US economic competitiveness, and the increasing direct involvement of Congress in science policy have led to a lack of stability in goals and philosophy. The roles of government, industry, and academia are being examined in a fundamental way." (MIT 1995, p. 2) From practitioners like Vest to policy scholars like Lewis Branscomb to politicians like Bill Clinton it is common to find claims that science and technology policy today is rather different from the science and technology policy of the Cold War. But exactly what is the nature of this difference? Just as importantly, when and why did key underlying assumptions about the government's role in science and technology change? Determining when these changes began to occur and the particular historical circumstances of the changes promises to help answer the question of why changes began to occur. This paper is a historical examination of these changes – focusing in large part what problems policy makers saw in federally-sponsored science and technology research, and how they expected individual policies to address those issues. Still, while individual pieces of legislation were crafted to meet particular concerns, the sum total of changes between the late 1970s and the present suggest that some broadly defined sea-change has occurred – the change Vest referred to in his quotation above.

Nanotechnology emerges exactly in this reconsidered moment of science and technology policy, and some would argue that it rises to prominence in part because of this new regime. Nanotechnology policy has become a centerpiece of science and technology policy at the turn of the 21st century. Arguments about whether nanotechnology constitutes a new way of doing and thinking about science must, therefore, consider the role the government has come to play in scientific and technological research as a result of the changing governmental attitude toward research beginning in the 1980s. Perhaps more so in the case of nanotechnology than in any other area of scientific research, government policy has played a role in the formation of the field. At least from the current vantage point, the changing motives and aims of US federal science and technology policy beginning in the 1980s appear to culminate in Bill Clinton's National Nanotechnology Initiative of 2000. Consequently, it is important to examine the history of federal science policy to understand the policy environment in which nanotechnology has developed.

## 1. The Complexity of Science and Technology Policy in the United States

It is tempting to focus largely on how science and technology projects have been funded in order to determine the government's goals. However, doing so often results in overlooking the early phases of change. In many instances, structural and institutional changes precede new funding. These social changes are designed within particular historical contexts to address specific issues, even though in many cases there are unintended consequences. Context matters to the construction of policy, because it defines a 'room for maneuver,' or a limited array of choices that are feasible given the political, economic, and social context of the moment.[1] A policy environment is formed when many different policies, created in different contexts to solve different problems come together in contingent ways. Seeing trends in science and technology policy requires looking at the changing environment, that is, the interaction between many different kinds of policies designed to do different and occasionally contradictory work.

As many policy analysts have pointed out, there exists no institutional or agency structure for science and technology policy – policies, for this reason, lack a single, overriding vision.[2] In 1993, Lewis Branscomb wrote, "U.S. S&T policy is largely uncodified; it must be deduced by observation of the laws, organization of government, and the actions of government managers and agencies. That policy is continuously in flux and it is unclear what direction the de facto policy will take in the next decade" (Branscomb 1993, p. 4). Daniel Sarewitz describes US science and technology policy as "Balkanized" and claims that the lack of a centralized science and technology policy is one reason that studies of changing funding levels and allocation plans take center stage in policy studies (Sarewitz, 2003, p. 2). Recently, Sarewitz wrote, "It is not only axiomatic but also true that federal science policy is largely played out as federal science budget policy" (*ibid.*, p. 1). But in the period of the 1980s and the 1990s studying budget allocations to determine the importance and direction of science and technology policy is not particularly productive because federal R&D funding has remained so stable. As a result, small changes in allocations are examined in detail for their hidden meanings. However, if the full array of policy shifts, and not just funding, are taken into account and placed in their historical perspective, a dynamic picture of science and technology policy arises. The striking aspect of this fully dimensional picture is that it shows how the political notion of what science and technology were expected to do for the nation was, in fact, changing. I will argue here that structural, educational, regulatory, and particularly legal changes in the 1980s set the stage for changes in how money has been allocated in the 1990s, giving a much clearer picture of what has happened to the place of science and technology in US federal government.

## 2. From Cold War Science and Technology to Technoscience for Global Competitiveness

The socio-economic problems that the new policies of the 1980s and 90s were designed to address first begin to appear in the mid-1960s and early 1970s. Traditional American industry, which obviously played an important role in the overall health of the US economy, began to see itself as under assault from competitors, both foreign ones from East Asia and

West Germany, and domestic challengers from new industries like information technology (Buderi 2002, p. 247). One of the failings of American industry was seen as its inability to apply expensive 'basic' research – research that was often derided for being interesting, but irrelevant.[3] To some extent this was an unfair characterization, but this point of view fueled efforts to remake both federal science and technology policy and the corporate reorganization of R&D in the 1980s. The primary concern of policy makers was how to measure, assess, and increase the productivity of research, especially that which was federally funded.[4] How could American scientific research, seen as one of the nation's great resources, help the American economy, which in the 1970s was in a period of rising prices but stagnant growth?

As a result of looking to science and technology to end economic malaise, government interests in sponsored R&D shifted from so-called basic science, justified by military needs to a new paradigm of directed research, justified by economic needs. In the 1950s and 60s science and technology policy was guided by the 'pipeline' model of the relationship of science to technology championed by Vannevar Bush (Branscomb 1993, p. 9-10). In this scheme, federally funded basic science would provide the new knowledge that underpinned new technological developments. Government spending needed to focus on basic, non-targeted research because this kind of scientific work was both fundamental and less attractive to the private sector. This linear picture was attacked by the 1966 Project Hindsight report. This study, sponsored by the Department of Defense, claimed that 'pure' science contributed little to the actual development of new weapons systems. On the heels of Hindsight, policy makers asked whether it made sense to claim a linear relationship for basic research and civilian technologies, if undirected scientific research contributed little to sophisticated defense technology? As a result, basic, un-directed research was under a continuing assault throughout the 1970s. As economic circumstances worsened after 1973, policy makers wanted to demand more economic bang for their research buck. American scientific research had to be part of the solution; American scientific superiority needed to translate into economic performance. But to do so, the role of the federal government had to change, and these changes took over a decade to put into place. However, by the end of 1980s the new regime was more or less in place, and only an aggressive rhetoric justifying federal spending on science in economic terms had yet to come. The arrival and success of this language in the 1990s is obvious from simply reading the titles of science and technology policy documents from the past decade: "Technology for America's Economic Growth" (1993), "Science in the National Interest" (1994), the Advanced Technology Program's "Prosperity through Innovation" (1999), "The National Nanotechnology Initiative: Leading to the Next Industrial Revolution" (2000), and more.

Several questions remain about how this new regime came into being, and to answer these requires a more detailed look at the policies that, piece by piece, came to constitute the new science and technology policy. For the most part, these new pieces of legislation focused on the issue of technology transfer – of getting more economic productivity out of the research that was already being performed. Policy makers could not see why, given the quality of American science, it was not generating the kind of technological innovation apparent in America's economic challengers, like Japan and West Germany. As a result, the focus of much federal science and technology policy in the 1980s was on problems in the movement and translation of knowledge from the lab through development onto the market.[5] The public-private partnerships that resulted, constructed largely during the Reagan administration, were an acceptable conservative alternative to greater government involvement in industry (Hart 1998, p. 228).

## 3. Science and Technology Policy in the 1980s

Two pieces of legislation were passed in the waning days of the Carter administration that set the stage for the sea-change in science and technology policy evident in the 1980s and 90s. The lesser-known of the two was actually passed first; the Stevenson-Wydler Technology Innovation Act passed into law on October 21, 1980. Stevenson-Wydler was an act to promote technology transfer, particularly from federally supported research performed in universities and federal laboratories to the private sector for commercial development. To do this, Stevenson-Wydler set up a Technology Administration (hereafter, TA) in the Department of Commerce, where efforts to bring new technologies into American industry would be studied and sponsored. The TA would include the already existent National Bureau of Standards (the government's first physical science laboratory, established in the late 19th century) and a new Office of Technology Policy. Stevenson-Wydler also empowered the TA to create organizations to study innovation and the relationships between technologies and their economic and industrial impacts, with an eye toward world trade and international competitiveness. Stevenson-Wydler represented the federal government's recognition that technology was an important determinant of economic progress and one that could not be left solely to the private sector. The federal government needed more than just military technology policy; civilian technologies also required guidance. This new attitude naturally had predecessors (*e.g.*, the OTA), but coming out of the economic stagflation of the late 1970s, it was also an acknowledgement that old laissez-faire attitudes, at least with regard to technology and industry, had failed to perpetuate the growth rates of the 1950s and early 60s. But the Stevenson-Wydler Act was quickly overshadowed by the next piece of science policy, which also aimed at moving federally sponsored research into the commercial sector.

On December 12, 1980, the Patent and Trademark Law Amendments Act became law. This bill, commonly known as the Bayh-Dole Act, because it was initially introduced by Robert Dole and Birch Bayh, was a more direct attempt to transfer knowledge from universities and federal laboratories to commercial applications. Prior to Bayh-Dole, research funded publicly could be patented, but the licenses were not exclusive unless a waiver could be obtained. Research that was publicly funded was publicly available. As a result, there was a considerable disincentive for private concerns to purchase licenses to university-performed research, since they could not be assured that a competitor would not beat them to market with a similar product. In addition, different funding agencies had different rules about patenting and licensing inventions produced with federal funding. This created an extraordinarily complex set of laws under which universities had to operate; as a result, only a small number of research universities engaged in patenting. Bayh-Dole changed this environment by creating a common set of patenting and licensing rules for all government-sponsored research and development (with the notable exception of classified research). Under Bayh-Dole, the government retained non-exclusive rights to patents developed with public funds, but universities could grant exclusive licenses to commercial interests. The framers of the policy imagined that Bayh-Dole would create an incentive system to facilitate technology transfer from university labs to the market. Like the Stevenson-Wydler Act, Bayh-Dole itself did nothing to fund research; instead it constituted a legal change that made university-industry collaboration much more feasible and attractive. David Mowery, who has studied the effects of Bayh-Dole at some length, has also pointed out that Bayh-Dole made nothing legal that was previously illegal – instead, it rationalized patenting rules across multiple agencies (Mowery 2002, p. 265).

Critical assessment of the Bayh-Dole Act has been mixed, but from a statistical point of view, the number of patents granted to university-performed research has exploded, as has the number of universities involved in patenting activity. The Association of University

Technology Managers reports that the number of patents granted to universities has increased from 500 in FY1980 to 3272 in 2000, with 3606 new licenses granted in FY2000 (AUTM 2000, p. 30). At the same time, membership in the AUTM has grown from 200 to 2,000 (COGR 1999, p. 3). But measuring Bayh-Dole's impact in other ways is more complicated and yields a more nuanced picture of the Act's success (Mowery 2002, pp. 263-5). Furthermore, there have been unintended consequences to Bayh-Dole. These include debates over the price of drugs developed from federally-sponsored research; disputes between collaborating institutions over intellectual property rights; and tense discussions about the unintended consequences of changes in universities' financial structures (Hardy 2002, pp. 10-12). Mowery and Ziedonis also note that the bulk of the products patented by universities for licensing are in the biotechnology/pharmaceutical/medical technology sphere, and the causes for the explosive development of this sector lie outside Bayh-Dole (Mowery & Ziedonis 2002, p. 415).

Several bills following Stevenson-Wydler and Bayh-Dole in the 1980s continued the Carter administration's emphasis on lubricating the process of technology transfer. During the first Reagan administration, the 1984 National Cooperative Research Act broke down more legal barriers in the commercial use of research findings by softening antitrust legislation. Prior to this change, independent firms that collaborated on any scientific or technical research could be charged with violating anticompetitive standards of corporate behavior. This act established a rule of reason for evaluating cooperative research undertakings and their potential antitrust implications.[6]

Stevenson-Wydler was amended in 1986 by the Federal Technology Transfer Act (FTTA). This law largely affected government-owned and -operated laboratories (so-called GOGOs). Lab employees were now allowed to share in the royalties their inventions generated, and their performance evaluations would consider their roles in technology transfer. GOGOs were, in fact, required to actively seek commercial uses for the research they undertook – scientists were to be the ambassadors and salespeople for their research. The FTTA also allowed GOGOs to create cooperative research and development agreements (CRADAs) with other agencies, universities, as well as private sector companies.[7] One of the more visible effects of FTTA has been the proliferation of mission-specific research centers, often located on university campuses.

In 1988 the Omnibus Trade and Competitiveness Act (OTCA) took the government's attention to technology transfer even further, by modifying the structure of National Bureau of Standards to spearhead technology transfer, and renaming it the National Institute for Standards and Technology (NIST). The Department of Education was also authorized to set up centers for training in technology transfer. Generally, however, the aims of the OTCA were directed at the private sector, by creating greater incentives for commercial cooperation in seeking out and sharing in federally sponsored research. Along these lines, the OTCA created the Advanced Technologies Program (ATP) in NIST as a structure to aid commercial interests in moving new cutting edge technologies from the laboratory to the production line. Projects in the ATP are jointly funded by government and private corporations.[8] On a smaller scale, the OTCA facilitated royalty payments to non-government employees of federal laboratories – creating innovation incentives on the individual level.

The FTTA was further buttressed in 1989 by the National Competitive Technology Transfer Act, which established technology transfer as one of the *primary* missions of the federal laboratories, including the nuclear weapons laboratories. This act also allowed the creation of CRADAs between government-owned, contractor-operated laboratories (GO-COs). In addition, the products of CRADAs could also be protected from disclosure by this legislation – making these agreements even more attractive to the private sector. The result of this array of policies in the 1980s was to change the mission of scientific and technological research in the federal government, moving from a relatively laissez-faire stance to first facilitating technology transfer, then eventually requiring it as a chief research objective.

## 4. Science and Technology Policy in the 1990s

The end of the Cold War in 1990 accelerated changes that the policy shifts of the 1980s had already begun. Most importantly, the ending of the Cold War fundamentally altered the common military justification for supporting a wide range of science and technology research projects. Yet, as we have seen, another justification was already in place, even before the demise of military necessity – an economic necessity focused on global competitiveness. Naturally, this newly important justification would affect the kinds of science seen to deserve federal support.[9] In an effort to ease the transition from a largely military to a generally civilian basis for scientific and technological research and development, George Bush Sr. created the President's Council of Advisors on Science and Technology (PCAST) in 1990. However, even with a more serious and better organized conduit for advice from non-governmental research practitioners, the transition from a focus on military technology to an integrated vision of military and civilian technology promised to be, and has proven to be, complicated. Writing in 1993, Lewis Branscomb even claimed that the US manufacturing economy consisted of two cultures – military and civilian. According to Branscomb, government institutions were more in touch with military innovation than with civilian (Branscomb 1993, p. 13). Branscomb then argued that US technology policy faced three challenges in the post-Cold War world: First, to recognize "that defense priorities will no longer dominate the U.S. federal government's technology policy"; second, to create a "publicly supported technology base, supporting industry's capability to create technologies for all three areas [military, commercial, and environmental] of national need"; third, to emphasize the "diffusion of technical skills and knowledge", since "economic performance in a competitive world economy rests primarily on how well the society uses the existing base of technology, skills, and scientific understanding" (*ibid.*, p. 16). These issues represented the foci of science and technology efforts during the 1990s, and were principally shepherded by the Clinton-Gore administration, who shared these priorities.

In the first month of the Clinton presidency, Bill Clinton introduced his technology policy initiative called "Technology for America's Economic Growth". This document outlined the Clinton administration's commitment to the new model of economically justified science:

> Since World War II, the federal government's de facto technology policy has consisted of support for basic science and mission-oriented R&D – largely defense technology. Compared to Japan and out other competitors, support for commercial technology has been minimal in the U.S. Instead the U.S. government has relied on its investments in defense and space to trickle down to civilian industry. Although that approach to commercial technology may have made sense in an earlier era, when U.S. firms dominated world markets, it is no longer adequate. The nation urgently needs improved strategies for government/industry cooperation in support of industrial technology. […] This new policy will result in significantly more federal R&D resources going to (pre-competitive) projects of commercial relevance. It will also result in federal programs that go beyond R&D, where appropriate, to promote the broad application of new technology and know-how. (Clinton 1993, p. 8)

The paper then lays out the 6 particular areas where new initiatives would be made: extending the research tax credit; investing in a national information superhighway; advanced manufacturing technology; the next generation of automobiles; technology for education and training; and investment in energy-efficient federal buildings (Clinton 1993, p. 24).

Clinton also emphasized the need to redirect federal research funding from 59% toward military aims to an equal split between civilian and military objectives.

Clinton's commitment to the economic goals for scientific research was extended in 1994 with his science policy statement "Science in the National Interest". This was the first executive statement on science since Carter's in 1979. Ironically, Clinton cast back to Vannevar Bush's famous 1945 policy recommendation, *Science the Endless Frontier*, for inspiration, echoing Bush's emphasis on the need for government support of scientific training.[10] But Clinton's policy was fundamentally different from Bush's in many ways, since Clinton's policies would increase government involvement in and control of scientific research, a position Bush fought against. Similar in structure to his 1993 statement on technology policy, Clinton's 1994 science policy pointed toward 5 specific goals: "maintaining leadership across the frontiers of scientific knowledge"; "enhancing connections between fundamental research and national goals"; "stimulate partnerships that promote investments in fundamental science and engineering and effective use of physical, human, and financial resources"; "produce the finest scientists and engineers for the 21st century"; "raise the scientific and technological literacy of all Americans". Vice-President Gore described the White House's view of science and technology as "more like an ecosystem than a production line. Technology is the engine of economic growth; science fuels technology's engine."[11] To accomplish this wide variety of initiatives, Clinton set up a new cabinet-level group, the National Science and Technology Council (NSTC), to help coordinate research policy across numerous agencies. The NSTC would work in concert with Clinton's new PCAST.[12] Clearly, by the second term of Clinton's presidency, science and technology policy had successfully moved from the Cold War mentality of military needs to a global economy paradigm of economic justification. Still, in the slow economy of the first half of the 1990s many of Clinton's promises fell victim to budgetary concerns. In this sense, Clinton's policies played a more important role in changing attitudes about what government intervention in science and technology was supposed to accomplish than in actually accomplishing these goals.

## 5. Nanotechnology Initiatives

Nanotechnology policy initiatives began to appear near the beginning of Clinton's second term, initially coming through the Advanced Technology Program of NIST.[13] The ATP made nearly $57 million in grants to nanotechnology projects prior to the year 2000, with an equal amount of matching funds guaranteed by the private sector.[14] However, by the end of the decade, the National Science Foundation, Department of Defense, and Department of Energy had taken the lead in funding nanotechnology projects. But the most important development in nanotechnology policy was not its funding within agencies; it was its migration outside standard funding avenues into the position of being the jewel in the crown of Clinton's science and technology policy. This process took several years, building on the developing imperative that science and technology needed to be managed for the economic health of the nation.

The visibility of nanotechnology in science policy took an important step in 1998 when the National Science and Technology Council established the Interagency Working Group on Nanotechnology (IWGN). The IWGN was a small group of practitioners who could explain and advocate for nanotechnology. The IWGN funded workshops on nanotechnology, many of which were focused on forecasting the future. This emphasis on what could be was enormously helpful in selling nanotechnology to the NSTC and the President – the 1999 publication *Nanostructure Science and Technology: A Worldwide Study* contains a chart of 5 nanotechnology areas showing both their present and potential impacts. While reports of the IWGN are highly technical, they still contain numerous politically useful statements. For example, "Nanostructure science and technology is a broad and interdisciplinary area of research and development that has been growing explosively worldwide in the past few years. It has the potential for revolutionizing the ways in which materials are produced and products are created" (Siegel *et al.* 1999, p. xvii). Through the workshops the IWGN created a draft plan for a national nanotechnology initiative. PCAST responded to the draft in November of 1999, and a nanotechnology panel, headed by Charles Vest, endorsed the 5-year initiative suggested by the IWGN. The PCAST statement was far less technical than the IWGN report and championed the potential, long-term economic benefits of a commitment to nanotechnology. However, dealing with long-term consequences and benefits was more challenging in the paradigm of economic justification. Statements had to be carefully constructed to emphasize the considerable economic payoffs of such research, while also justifying government action by showing that the work to be supported contained disincentives for industry – but these disincentives were based on a dynamic of time and risk and not on serious doubts about the efficacy of the research. PCAST constructed the following statement with an eye to these concerns:

> Most foreseeable applications are still 10 or 20 years away from a commercially significant market; however, industry generally invests only in developing cost-competitive products in the 3 to 5 year timeframe. It is difficult for industry management to justify to their shareholders the large investments in long-term, fundamental research needed to make nanotechnology-based products possible. […] There is a clear need for Federal support at this time. […] we strongly believe that the United States must lead in this area to ensure economic and national security leadership. (PCAST 1999b, p. 3)

In a letter to the President accompanying the review quoted above, PCAST urged Clinton to "make the NNI a top priority" (PCAST 1999a, p. 1). This letter also makes the strongest claim for the economic importance of nanotechnology, arguing, "We believe that nanotechnology will have a profound impact on our economy and society in the early 21$^{st}$ century, perhaps comparable to that of information technology or of cellular, genetic, and molecular biology" (*ibid.*, p. 2). Similar support came from Neal Lane, the President's science advisor, who rated nanotechnology one of the government's 11 R&D priorities. The National Nanotechnology Initiative officially came into existence in the spring of 2000, and was first funded for fiscal year 2001, beginning in the summer of 2000. Clinton's budget request for the NNI in its first year included a doubling of the federal investment in nanotechnology, for a total of $497 million to be spread across 6 agencies (NSF, NASA, NIH, and the Departments of Defense, Energy, and Commerce).[15] In the Congressional responses to Clinton's request, the economic justification for the nanotechnology bill proved to be compelling. Senator Evan Bayh said,

> Research in nanotechnology is extremely important to future rates of innovation in the country. Innovation is the key to our comparative advantage in the global economy, yet federal investment in the physical sciences that help drive innovation – math, chemistry, geology, physics, and chemical, mechanical, and electrical engineering – are all declining, as are the number of college and advanced degrees in these areas. [...] It is vitally important that we increase our investment in the physical sciences, including nanotechnology, if we are to see increases in productivity and incomes in the years ahead. (quoted in Leath 2000, p. 2)

From these statements about the NNI it is clear it fits into the regime of science justified by its role in global economic competitiveness.

## 6. Effects of the New Regime of Science and Technology Policy

In his 2000 book *Real Science*, John Ziman argues for the emergence of a new way of doing science. His model of Post-Academic science develops along a parallel timeline to the policy changes and changes in the U.S. federal government's vision of science, which I have described here. Although Ziman grants the importance of science policy, he writes very little about science policy and its role in the scientific culture that he details. When Ziman does focus on government-science interactions, he is interested in the effects of the 'soft-money' system and the competition for grants, but this is rarely related to what policy-makers thought they were accomplishing when funding protocols were changed. In this sense, Ziman largely ignores the details of the effect of policy on science, although he does admit "the emergence of science and technology policy as a major factor in the transition to a new regime for science" (Ziman 2000, p. 75).[16]

Ziman claims that a new regime of science began to emerge in the 1960s; many of these changes were evident by the end of the 1970s. There was no single underlying cause for the emergence of this new culture. Rather, a series of changes, both inside of and external to the scientific enterprise, occurred which in sum net a socio-cultural shift. This new regime had several distinct qualities.[17] First of all, there was a change in the social arrangement of work. In the Post-Academic regime, work is collective and trans-disciplinary (*ibid.*, p. 69). Teams of scientists and technicians are not arranged by discipline – the kinds of problems they work on require specialists from numerous fields. This fundamentally challenges the social structure of scientific work.

Second, this new regime has to work in a steady-state of funding. Science is no longer an expanding activity. R&D, as a percentage of national income, hovers around 2-3%. Whereas during the Cold War there had been as escalation of funding (in the US this occurred after Sputnik), in the world of Post-Academic science, there is no assumption of overall increase in the size of the research enterprise. This promises to amplify the language already central to science policy about the productivity of research. However, while the overall size of the research landscape is not expected to expand, allocations will shift and explosive growth in particular sectors will occur (*ibid.*, p. 71).

These changes in allocation are driven by a new stress on the utility of the science – Ziman's third criterion. Research is targeted at recognizable practical problems – regardless of their field of the research (*ibid.*, p. 72). Commercial evaluations of discoveries precede and become more important than scientific validation (*ibid.*, p. 74). The new emphasis on utility also makes scientists accountable to institutions outside the scientific community – from businesses to government overseers. It also has explicitly ethical consequences – if science is done with applications in sight, then scientists can no longer remain neutral about the potential uses of their work.

Taken in concert, the changes described by Ziman yield a picture of science that obscures traditional distinctions between basic and applied work.[18] Because science is valued chiefly for its applicability in the Post-Academic regime, even research with extremely long term goals is cast as having potential for use (*ibid.*, p. 173). Furthermore the history of science is rife with cases of science performed without an eye to application, which has subsequently become enormously important economically. These cases often give support to research which seems to have little direct application. Like my earlier argument about the economic justification for research, what is important to see about Ziman's claims about the basic/applied distinction, is that it represents a cultural shift in how science is perceived and discussed. Science may be important to scientists for exposing fundamental knowledge about the world, but it is important to politicians and the public for generating products and jobs. In reality, there is no reason not to claim that science does all three, but the latter two justify public spending in a more concrete, and frankly, popular way than the first. The picture of science that Ziman paints in *Real Science* is summed up in the sentence, "Science is being pressed into service as the driving force in a national R&D system, a wealth-creating technoscientific motor for the whole economy" (*ibid.*, p. 73). From both this statement and from his general description, it is quite clear that Ziman's Post-Academic mode of science agrees quite well with the science for global competitiveness model espoused by policy makers in the 1990s.

## 7. Nanotechnology as a Moment in Science

If we accept Charles Vest's and others' claims that science and technology policy in the 1990s shows a visible shift in both function and rhetoric and John Ziman's and others' claims that science is being done differently, we arrive at a coherent picture of a new regime in science. Both of these dimensions revolve around claims that the economics of science is changing. But there are two perspectives on the economics of science: the input of both public and private funds necessary to support science; and the potential economic impact generated by the products of scientific research. These two aspects are linked by science policy – both governmental and corporate – which uses the products of science to justify and allocate the funds to actually perform scientific and technological R&D.

Given the coherence of the politics, economics, and culture of science in this new regime, would it be fair to characterize the emergence of nanotechnology as a crystallizing moment in science? While it may be too early to tell, examining the context of science, politics, economy, and culture into which nanotechnology was introduced in the 1990s seems like a fruitful avenue for investigation. Cultural historians of science often seek historical episodes where changes in actual scientific practices can be related to socio-economic, political, and cultural contexts. Peter Dear explains that the cultural history of science often operates by showing "people doing things that look somewhat unexpected – or, crucially, can be *presented* as looking odd – and makes sense of their behavior by appropriate contextualization: finding out what made particular behaviors or ways of doing things look normal" (Dear 1995, p. 151, emphasis in the original). Often these works look at the emergence of new disciplines and fields of inquiry and show how these developments happened in light of particular circumstances outside of the science itself.[19] The emergence, and particularly the hype, of nanotechnology and the government's attention to it are just such a case of an odd-looking event that can be made to look expected through attention to its political and economic context. Nanotechnology, in particular, seems to require, or at least benefits from, such a multidimensional explanation.

These cultural arguments are not to claim that nanotechnology would not have developed without this particular environment. However, it is to claim that because of the socio-economic environment of the 1990s, nanotechnology has developed in a particular way.[20] Embracing this type of contingency helps to explain the positioning of nanotechnology as the jewel in the crown of current publicly supported science. Nanotechnology is a nearly perfect fit for what both companies and the government expect from science. It also conforms to the new Post-Academic regime within science, so that the development of the field is less stymied by the challenges it presents to traditional modes of doing science – *e.g.*, transdisciplinarity, focus towards applications, ties to proprietary industrial research, blurring of science and engineering.[21] Nanotechnology corresponds to the current regime of science so well because it grew up in this regime – no crippling modification of it had to occur, as happened in particle physics after the budget axe fell on the superconducting supercollider.

Nanotechnology hardly represents the end of pure science as I provocatively titled this paper. However, it does stand as an exemplar for a new relationship between science, politics, and economy, where seeking the fundamental truths lacks political punch. With an eye to history, it is worth restating the origin of the rhetoric of pure science. The ultimate statement in support of an elevation of pure science is Henry Rowland's 1883 "Plea for Pure Science" Address given to the AAAS. Rowland complained that,

> it is not an uncommon thing, especially in the American newspapers, to have the applications of science confounded with pure science; and some obscure American who steals the ideas of some great mind of the past, and enriches himself by the application of the same to domestic uses, is often lauded above the great originator of the idea, who might have worked out hundreds of such applications, had his mind possessed the necessary element of vulgarity. (Rowland 1901, p. 594)

As David Hounshell points out in his investigation of "Edison and the Pure Science Ideal in 19th Century America", Rowland was reacting to Edison, who had aggravated Rowland and other academic scientists a decade before by using the press to publicize his science, behavior Rowland considered inappropriate for a scientist (Hounshell 1980, p. 613). Furthermore, Rowland was also upset with his scientific colleagues for their adulation of Edison and their championing of him as a scientist – Rowland believed that credit should be going to the academic physicists. Rowland wanted to distinguish his own work in the laboratory from Edison's inventions and industrial laboratory, and to do so he attempted to hold them up to a higher moral standard. Making money off scientific research was, as David Hounshell puts it, "vulgar, opportunistic, and even cutthroat, and had somehow been confused with the work of pure science" (*ibid.*, p. 616). Of course, as Hounshell points out, this was ironic, since it was Edison's inventions that fueled public support for science. Apparently, science justified by industrial transformation sold as well at the turn of the 20th century as it does at the turn of the 21st. But Rowland's own credentials were themselves conflicted, with a civil engineering degree from Rensselaer Polytechnic Institute, and a short stint as a railroad surveyor. Furthermore, his employer, the Johns Hopkins University, did not shy away from close industry-academy relationships. The Rowland-Edison debate demonstrates once more the complexity of the pure-applied divide, even at one of its most crystallized moments.

In *The Landscape of History*, his recent apologia for history, Cold War historian John Lewis Gaddis tackles the difficult problem of whether history gives us any insight into the future. While it would be folly to claim that it does so in a narrow fortune-telling sense, Gaddis also points out that "we know the future only by the past we project onto it. History is, in this sense, all we have" (Gaddis 2002, p. 3). But then in explaining why this approach might be useful, Gaddis explains that history depends on the recognition of patterns, "the realization that something is 'like' something else" (*ibid.*, p. 2). Seeing the recurrence of the debate between Rowland and Edison over the nature of real science bears Gaddis out. Edison's tactics, for all of Rowland's attacks won out – therefore, his are the lessons to bear in mind. Edison's science produced what he said it would – lights, among other things, and the public cared. Nanotechnology promises to be many things, but in the current environment of policy, it is best to be an economic engine. Still, it is even smarter to claim to be tomorrow's engine, since this provides protection from immediate demands for productivity.

## Notes

1. The notion of room for maneuver ("Handlungsspielraum") as I use it here is best developed in Knut Borchardt's study of German economic policy during the interwar crisis (Borchardt).
2. Since 1980, there have been many legislative and executive attempts to pull together all of the various agencies and institutions involved in science and technology policy. Several of these attempts will be detailed in this paper. Still, no one body has gained overriding control over all scientific and technological affairs.

3 This was clearly not the only problem in the US economy of the late 1970s, and no policy maker from the period argued it was. However, the notion that science was an untapped resource was a common sentiment and there was hope that a number of the major problems plaguing the economy had technological fixes (*e.g.*, the oil crisis, the quality crisis in manufacturing, productivity).

4 The notion of research productivity fits into a nearly obsessive concern with productivity in general. This issue was ubiquitous in industrial policy during the 1960s and 70s. However, the notion of research productivity posed special problems in how to relate money spent on research to long-term economic goals.

5 In *Forged Consensus*, David Hart sees the renewed economic emphasis on technological innovation in the 1980s as part of a new, explicitly civilian industrial policy, advanced as an alternative to "Reaganomics" (see Hart 1998, p. 227).

6 The Rule of Reason requires that both harmful and beneficial effects of the cooperative effort be examined. Antitrust proceedings will begin only if the analysis shows that the potential harm outpaces the benefits to the industry and market.

7 Despite the orientation of these policies, it is important to realize that private-public research partnerships predate this legislation by at least a century – perhaps much longer than that. Universities and private companies were doing collaborative research in the 19th century in the US and in Europe. There are countless incidences of other private public research partnerships before the 1980s (such as DuPont's work with Oak Ridge during the Manhattan Project). However, FTTA looked to encourage these partnerships with a renewed vigor. For earlier examples of private-public research partnerships, see Nathan Rosenberg & David Mowery's *Paths of Innovation*.

8 Nanotechnology projects have been a part of the ATP from its inception.

9 Nowhere in this paper do I want to imply that an economic justification for science and technology was a new idea in the 1990s – clearly it is one of the oldest justifications. However, I do argue that, in the 1990s, the economic justification of science became much more direct and public. Furthermore, my argument here is about *perceptions* of what science could and should be doing, not some objective, philosophical claim about what science was "really" about. I also am wary of claiming (naively) that there are clear distinctions in the kinds of science supportable by the new regime of science for economic benefit. In fact, claiming that a particular body of research would play an important economic role was often a rhetorical choice more than an issue of what was happening in the lab. Still, there were real effects to what kind of work scientists chose to do.

10 However, Clinton specifically points out differences between his vision and Bush's, claiming to "acknowledge an intimate relationship between basic research, applied research, and technology, appreciate that progress in any one depends on advances in the others and indeed recognize that it is often misleading to label a particular activity as belonging uniquely to one category" (Clinton 1994, p. 5).

11 This quote is notable for the directness with which it addresses the economic motives for science. Still, it is a peculiar claim. Although Gore refers to an ecosystem, the engine analogy seems linear in the Vannevar Bush sense. This seems to point out the complicated project of justifying non-targeted research in terms of economic goals.

12 PCAST is a non-governmental advisory group that does not require Congressional approval – therefore it operates at a less formal level than the cabinet. Each President must set up and renew the existence of this group – it is not a standing committee. As a result, each administration can rename the organization (calling it variously a council or committee) and then claim to set the group up as though it were new. On the other hand, the NSTC is a standing committee made up of cabinet members with responsibility in science and technology policy matters. These conflicting arrangements add to the multidimensional complexity of US Science and Technology policy.

13 NIST claims that it made nanotechnology grants as early as 1991, however the bulk of funds have been paid out closer to the end of the decade.

14 ATP has made another $85.5 million in grants since 2000, an amount that has been matched by industry, as is the guiding principle of the ATP.

15 $464 Million was actually allocated. Additional agencies have since joined the NNI: EPA, Justice, Transportation, Agriculture, State, Treasury, CIA, and the NRC.

16 Ziman's reference to the "emergence" of science policy in the Post-Academic regime is troubling, since it implies there was no science policy prior to the 1960s. However, I think he's trying to emphasize the real partisan political work that science policy does once it moves into the realm of economic justification. Science policy as politics is what emerges, not just science policy. When science was justified militarily, or in the Bush paradigm when it was never directly justified, science policy remained non-partisan and out of the political spotlight.

17 One of the places to quibble with Ziman's model, and Ziman admits this, is in the comparison of the new Post-Academic model with the older Academic one. Ziman makes a number of generalizations about how science works in the pre-1960 period that many historians of science would disagree with. In his defense, whenever an aggregate model like his is constructed, one of the consequences is to lose touch with the ac-

tual details of any of the case studies. It is only natural that the model of Academic science (and Post-Academic science, too) doesn't exactly map onto any real example. However to dismiss his model because of these quibbles invites "throwing the baby out with the bathwater".

[18] There is a massive historical and philosophical literature about this distinction, which has always been slippery. Many works focus on the labels of "pure" and "applied" as rhetorical tools and as normative rather than accurately descriptive labels. It is in this sense, as well, that Ziman uses the terms. I will discuss this distinction further in the conclusion to this paper.

[19] The best recent example is Galison 2003.

[20] John Gaddis explains, "while context does not directly cause what happens, it can certainly determine consequences" (Gaddis 2002, p. 97).

[21] Of course, I do not imply that nanotechnology alone has these attributes; these are the characteristics Ziman claims for Post-Academic science that cover a much broader array of sciences. But without a new acceptance of these qualities and new social structures for science, these attributes would be disincentives and handicaps.

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