

Technology Transfer and the National Laboratories

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ABSTRACT: TECHNOLOGY TRANSFER AT THE NATIONAL LABORATORIES

This thesis is a study of the effects of two laws passed in 1980 intended to increase technology transfer from the national laboratories. Technology transfer has emerged as an issue in technology policy because it suggests a solution to the problem of slow productivity growth and declining economic competitiveness. Utilizing the federal laboratories seems to hold much promise in this regard, because so much research money is spent there, yet so little commercially relevant technology has emerged.

The first two laws intended to increase technology transfer from the federal laboratory system were passed in 1980: the Stevenson-Wydler Technology Innovation Act and the Bayh-Dole Act. These laws mark the legislative points of departure in a long effort to make the federal labs more commercially relevant. However, no one has attempted to measure their effects.

A number of approaches to technology transfer point to two conclusions: First, patent licensing is not likely to be a very effective means of commercialization. Much more likely to succeed are transfer mechanisms that foster relationships between the laboratory and industry early in the technical development process. Second, technology transfer, as a goal, will be resisted by the labs. Their organizational mission, their organizational culture, their incentive systems were all structured against efforts to reorient their work toward commercial utility. Without changing any of these factors, Stevenson-Wydler and Bayh-Dole seemed doomed to fail.

This paper uses patents issued to lab inventors to measure any increase in transfer efforts from the lab. A statistical analysis is performed that shows a small jump in patent rates subsequent to the passage of these two laws. However, I do not conclude that this effect was a result of the 1980 legislation. Instead, two other causes are suggested: the maturing of alternate energy projects--mandated by prior legislation; and an increase in patent attorneys--an administrative change not driven by technology transfer concerns. Other measures of technology transfer are developed that indicate no change in activity at the labs after 1980.

The weakness of patent licensing, and the strength of organizational culture, together, made an increase in technology transfer unlikely. The laws of 1980, as written and implemented, did not provoke significant changes.

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CHAPTER ONE: INTRODUCTION

A. Precis

Technology transfer has emerged as an issue in technology policy because it suggests a solution to the problem of slow productivity growth and declining economic competitiveness. If the technology that we have already developed can be commercialized, the thinking goes, then our economy will be better off.

Utilizing the federal laboratories seems to hold much promise in this regard, because so much research money is spent there--about \$24 out of the total \$70 Billion in Federal R&D in FY 1992¹--yet, by all accounts, so little commercially relevant technology has emerged. Therefore, increasing technology transfer from the federal laboratories to the private sector seems to offer great rewards.

The first two laws intended to increase the transfer of technology from the federal labs were passed in 1980. One of them, Stevenson-Wydler, has become synonymous with the effort to utilize federal lab technology. The other, Bayh-Dole, targeted patents as the mechanism for increasing technology transfer of government funded inventions.

A number of theoretical perspectives on technology transfer suggest that these two laws would have little effect.² The reasons are two: the laws were likely to have little effect on technology transfer results because patent licensing, the transfer mechanism stressed by Bayh-Dole, is not a very effective way to move technology into commercialization. Much more likely to succeed are

¹ National Science Foundation, Federal Funds for Research and Development: Fiscal Years 1990, 1991, 1992, (1992), p.51.

² Discussed in Chapter 3.

transfer mechanisms that foster relationships between the laboratory and industry early in the technical development process.

Second, these laws were not likely to even increase technology transfer efforts. The organizational mission, organizational culture, and incentive systems of the labs were hostile, or at best, indifferent, to commercial interactions. Because these laws provided little reason for the labs to adopt this new and foreign mission, the status quo inside the labs was unlikely to change.

However, no one has attempted to measure their effects. This study does so. Patents are the primary measure used here as an indicator of technology transfer efforts. Measuring the results of technology transfer is much more difficult, hampered by lack of good measures and lack of data. Nevertheless, other measures are presented.

My analysis of patents from Department of Energy national laboratories shows a small rise in patenting after the passage of Stevenson-Wydler and Bayh-Dole, which seems to disconfirm the expectations. However, there are two more likely explanations for this rise, which will be discussed. One is the delayed effects of efforts to develop alternate energy sources in the Seventies. The other is an increase in patent attorneys in DOE regional offices and within the labs themselves--an administrative action not associated with these laws.

Another indicator of transfer efforts is presented which gives strong confirmation to the original hypothesis--that Stevenson-Wydler and Bayh-Dole had little effect on transfer efforts within the national laboratories. Two measures of technology transfer results

are presented that also indicate no reaction following the passage of these bills. And, two recent studies are reviewed that confirm, empirically that patent licensing is not effective.

Currently, the labs are becoming more amenable to technology transfer. More recent legislation has given the labs better transfer mechanisms to work with. And, subsequent changes in their environment have given the labs reasons to adopt technology transfer as a mission. But, implementation is still imperfect as incentive structures are not fully developed, and the cultures of the labs are still hostile in many ways to industrial interactions.

The lessons of this study confirm the theoretical expectations.

- 1) Patent licensing, the focus of much early technology transfer efforts, is not an effective way to promote utilization of national lab resources.
- 2) Without strong incentives or changes in their environment or both, even effective mechanisms will be resisted by the cultures of the labs, making significant efforts to transfer technology unlikely.

B. Technology Transfer

Technology transfer is the process of moving new technical ideas from one organization to another. The term has a number of common uses. It is sometimes used to refer to the cross-national exchange of technical knowledge or production facilities from one country to another. Most of this discussion is addressed to transfer from developed to developing nations--North/South technology transfer, although North/North transfer is also an issue. The term has also been used to refer to issues surrounding the acquisition of

militarily sensitive Western technology by the Soviet Bloc. This is East/West technology transfer, and is much less a topic of concern than it was ten or twenty years ago. The phrase can also refer to the movement of novel ideas from the R&D laboratory to the production floor within a single firm.

Technology transfer, as used in this paper, refers to the movement of technology from the Federal laboratories into commercial development and production. The adaptation of a technology developed for government use to a different area of application, called horizontal transfer,³ seems to be the dominant usage of the term today.⁴

The federal laboratories, for years, have been seen as a potential resource for commercial technological development. NASA, at its founding in 1958, included a provision for making the technical benefits of its research widely available.⁵ This indicated a recognition, in advance, that the research undertaken in pursuit of national goals in space, might be put to commercial use. Indeed, significant technology transfer has occurred from the Energy labs, as they have successfully moved civilian nuclear power from basic research to commercial use. However, this an example of vertical

³ Vertical transfer, utilizing a new technology for an intended use, is much less problematic. The distinction is developed in Harvey Brooks, "National Science Policy and Technology Transfer", pp. 256-259. In: Brooks, Government of Science, MIT Press, 1968.

⁴ No study of relative change in use of the term has been attempted, though it would make an interesting study. Noteworthy, also, is how technology transfer from one government agency to another fell out of the discussion during the Eighties.

⁵ Doctors, The NASA Technology Transfer Program, 1971.

transfer--application of a new technology for an intended use--which is judged to be easier than horizontal transfer.

Studies of ways to improve the federal technology transfer process have been common since at least the mid-Sixties.⁶ This issue was current then, as popular discontent with the utility of basic research drove a quest to make federal lab research more accessible.⁷ The rhetoric used in 1966 is the same as today: "The knowledge resulting from public investment in R&D constitutes a major, rapidly increasing, and insufficiently exploited national resource. Its effective use can increase the rate of economic growth, create new employment opportunities, help offset imbalances between regions and industries, aid the international competitive position of US. industry," ⁸

During the Eighties, technology transfer from the federal labs again became an issue of concern. This issue now has a prominent place in the discussion of technology policy options.⁹ President Clinton, in "Technology for America's Future", declared: "All federal R&D agencies (including the nation's 726 federal laboratories) will be encouraged to act as partners with industry wherever possible."¹⁰

⁶ See chapter 2 in Doctors, The NASA Technology Transfer Program, for a discussion of these early studies.

⁷ Mowery and Rosenberg "The Influence of Market Demand upon Innovation: A Critical Review of Some Recent Empirical Studies", Reprinted in Rosenberg, Inside the Black Box, (1982)

⁸ Leshner and Howick, Assessing Technology Transfer, 1966, p.5.

⁹ Office of Technology Assessment, Making Things Better, Competing in Manufacturing, (1990).

¹⁰ William Clinton and Albert Gore Jr., Technology for America's Future, Feb. 22, 1993.

C. Technology Policy and Technology Transfer

The problems of slow productivity growth and declining national competitiveness have been on the public agenda for about two decades. Since the stagflation of the 70's, there have been calls for the government to do something to help the economy grow. One possible solution has emphasized the contribution of novel technologies to economic growth.

A consensus among economic theorists has emerged that most of the economic growth in recent years is the result of technology taken broadly, improved skills, education, and new forms of work organization, as well as technical advancements.¹¹ Technology policy seeks to improve the likelihood that scientists, engineers, and entrepreneurs will create the new technical ideas that will lead to new products. Technology policy is, of course, not the only way to help the economy. Other factors involved in economic performance may be subject to legislative and other policy changes, such as the macroeconomic environment, the quality of managerial decision making, antagonistic labor relations, poor education and training, and the nature of interfirm relations. Also, as Ergas points out, there is more than one way to approach technology policy. He contrasts the mission oriented approach of the US, UK, and France with the diffusion approach of Germany and Sweden. Japan is described as

¹¹ See for instance, Nathan Rosenberg, Technology and American Economic Growth, (1972).

lying between these extremes with a policy that encourages rapid product development.¹²

The approach to commercial technical development traditionally taken by the US. government has been hands off. Basic scientific research, in contrast, has been generously supported. This results in an approach to technology policy that does not foster technology through government assistance to the commercial sector, but instead depends on basic research as the source of new technology. Technology is fostered, not directly, but as a natural result of basic scientific research. The other main source of novel technologies within this policy is the research that goes into large projects focused around a specific government mission, such as national defense, health, agriculture, or space. While warranted on their own terms, an important secondary justification is the "spinoff" of technology developed for these federally sanctioned uses to the civilian sector.

The prosperity of the 50's and 60's seemed to confirm the viability of the basic research and spinoff approach. The path to technology development that fueled American military superiority and the successful Apollo project was deemed sufficient to fuel the booming American economy. But the doldrums of the 70's are the all too familiar next chapter of the story. Energy crises and slow economic growth plagued the economy.

Executive branch support on this issue faded rapidly after Ronald Reagan's election. The supply side economics that he favored

¹² Ergas, Henry, "Does Technology Policy Matter?", In Bruce Guile and Harvey Brooks, eds., Technology and Global Industry, Washington, DC: National Academy Press, 1987.

offered a different solution to the problem of economic growth. This philosophy maintained that all the government had to do was to create the proper climate for business (lower taxes, fewer regulations, fewer government programs) and get out of the way of the economic growth that would result. Regardless of whether one agrees with this philosophy, the results were not unequivocally successful. Although the Eighties saw the "longest peacetime economic recovery" as President Reagan used to like to say, domestic economic growth was weak in comparison to historical trends, the economy lagged in comparison to international competitors, and the US lost the buffer of its trade surplus generated by high technology exports.¹³

While President Reagan disparaged direct involvement in technology policy, the executive branch has not been the sole source of new ideas. Throughout the Eighties, Congress struggled to create policy that would help the domestic economy grow at a faster rate, and thus regain competitive strength. One of the legislative solutions to the competitiveness and productivity problem has been to utilize more fully the ideas and technologies within the National Laboratories--to increase technology transfer. This approach has the virtue of exploiting research already paid for, and already justified. Research within the national labs was already justified as either basic or mission directed--the two acceptable rationales for R&D according to conventional views.

¹³ Baumol, et.al., Productivity and American Leadership, (1990).

D. The Legislation

The first two laws intended to increase the amount of technology being transferred from the federal laboratory system were passed in 1980: Stevenson-Wydler Technology Innovation Act [P.L. 96-480] (Stevenson-Wydler hereafter) and the Bayh-Dole Act [P.L. 96-517], an amendment to the Patent and Trademark Laws (Bayh-Dole hereafter). The legislative history of the two Acts, and the text of the legal code itself, is full of references to the issues of economic growth and international competitiveness. “Industrial and technological innovation in the United States may be lagging when compared to historical patterns and other industrialized nations.”¹⁴ “The crisis in US productivity and the governmental role in it has not gone unnoticed...”¹⁵

Stevenson-Wydler, focused attention on the federal labs and mandated the creation of Offices of Research and Technology Application--technology transfer offices--at all labs with yearly budgets of more than \$20 Million. Bayh-Dole allowed for small companies and non-profit organizations to take direct title to inventions developed at government expense, and created a procedure allowing exclusive licenses to be awarded to large companies.

Stevenson-Wydler and Bayh-Dole mark the legislative points of departure in a long effort to make the federal labs more commercially relevant. Stevenson-Wydler has become almost a generic term for this effort. Branscomb uses the term to mean any

¹⁴ Stevenson-Wydler [P.L.96-460]: 94 STAT. 2311.

¹⁵ Bayh-Dole legislative history, 94 STAT. 6461.

effort to increase technology transfer that does not disturb the status quo too greatly.¹⁶ The Commerce Department currently releases a “Biennial Report on Stevenson-Wydler” that describes all government technology transfer efforts.¹⁷ And in 1984, the Secretary of Commerce justified not implementing most of this law by describing other actions that, he asserted, accomplished the same goals. These other actions were referred to as “the administration’s Stevenson-Wydler initiative.”¹⁸

E. The Test

This thesis examines whether Stevenson-Wydler and Bayh-Dole improved technology transfer. There are two reasons to expect that this legislation would have little effect on technology transfer from the national laboratories. First, patent licensing, the means of transfer emphasized by the Bayh-Dole Act, is not the most effective means of doing technology transfer. Second, Stevenson-Wydler, as implemented, added almost nothing to the capacity of the labs to move technology out into the marketplace. Together, they gave the laboratories and the researchers within them little incentive to change their behavior.

To test whether these laws had any effect is difficult, for both practical and theoretical reasons. Practically, much data that might shed light on the question has not been systematically collected.

¹⁶ Branscomb, “National Laboratories: The Search for New Missions and New Structures”, (1993).

¹⁷ United States Department of Commerce. “Technology Transfer under the Stevenson-Wydler Technology Innovation Act: The Second Biennial Report.” (1993).

¹⁸ “The Stevenson-Wydler Technology Innovation Act of 1980”, Report to the President and Congress from the Secretary of Commerce. (February 1984).

Theoretically, the source of knowledge imbedded in most products is difficult to measure, as is measuring the end result of the transfer process. This paper uses patents as a metric and examines the number of patents issued to lab inventors. A statistical analysis is performed that shows a small jump in patent rates subsequent to the passage of these two laws. However, for reasons discussed below, I do not conclude that this effect was a result of the 1980 legislation. Instead, it is more probable that the jump in patent rates had two other causes: the maturing of alternate energy projects--mandated by prior legislation; and an increase in the numbers of lawyers at many of the labs and at DOE offices--an administrative change not driven by technology transfer concerns.

Other measures of changes driven by these laws are presented. None show any indication that Stevenson-Wydler and Bayh-Dole affected either technology transfer efforts, or technology transfer results. Then, two recent studies are examined that reinforce the conclusion that patent licensing is relatively ineffectual.

F. Outline

In the next section, chapter 2, the national laboratories are introduced, and their history, roles, and missions are discussed.

In chapter 3, a number of theoretical approaches to technology transfer are elaborated. All point to two conclusions: First, patent licensing is not likely to be a very effective way of moving technical ideas from the national labs into commercialization. Transfer mechanisms that foster relationships between the laboratory and industry early in the technical development process are much more

likely to succeed. Second, Stevenson-Wydler and Bayh-Dole were not likely to provoke any changes in technology transfer efforts from the labs. Their organizational mission, their organizational culture, their incentive systems were all structured to provoke hostility, or mere indifference, to efforts to reorient their work toward commercial utility. Without changing any of these factors, Stevenson-Wydler and Bayh-Dole seemed doomed to fail.

Chapter 4 is a review of the barriers that any effort to promote technology transfer faced in 1980. The barriers can be placed into context four ways: barriers internal to the labs, barriers between the labs and industry, barriers between the labs and the market, and barriers arising from public interest concerns.

Chapter 5, details the content of Stevenson-Wydler and Bayh-Dole--the rhetorical flourishes and the actual programs. Many of the more interesting programs outlined in Stevenson-Wydler were never implemented, as the Reagan administration refused to fund them.

Chapter 6 presents a discussion of measures of technology transfer. Four model have been proposed, and possible metrics within each are discussed. Patents are chosen for this study for two reasons. They provide an effective measure of technology transfer efforts because they were the focus of much of the early technology transfer discussion, and because they are a likely way for the labs to respond. Second, patent figures are accessible. This consideration is not trivial, as few other good metrics are available with sufficient historical reach to measure the effects of these two laws.

Since patents were the focus of Bayh-Dole and are the measures used here, Chapter 7 provides a discussion of patents and

their function as innovation measures. It also describes a debate over government patent policy. Bayh-Dole is significant because it represented a shift in traditional government policy, meant to increase utilization of federal technology.

Chapter 8 gives the details of the statistical test for effects of these laws on patent rates. It includes a discussion of the results of the patent tests, and why the result found--a rise in patents--does not disconfirm my hypothesis. The results of other studies, and other measures developed here are presented.

Conclusions are set out in Chapter 9.

An outline of the relevant legislation on this issue passed after 1980 is included in Appendix 1. And a list of the DOE laboratories is provided in Appendix 2

CHAPTER TWO: THE NATIONAL LABS

A. What are the National Laboratories?

Depending on how they are counted, there are up to 750 entities that can be called "federal laboratories". Any federal organization whose principle activity is the conduct of research and development (R&D) is defined as a federal laboratory. The largest in size, such as the Naval Research Lab, Goddard Space Flight Center, and Los Alamos, belong to the Department of Defense, NASA, and the Department of Energy (DOE). The greatest number are small facilities belonging to agencies other than the Department of Defense and the Department of Energy: Departments such as Agriculture, Health and Human Services, Commerce, the National Institutes of Health, and the Department of Veterans Affairs. The term "national lab" as opposed to "federal lab" is usually restricted to the Department of Energy laboratories, but has no official status. This paper concentrates primarily on the DOE national labs.

The federal labs consume almost a third of the total federal spending on R&D. In FY1992, the total bill for research conducted in all the Federal labs was \$24.8 billion.¹⁹ Most of this money is spent in nine DOE labs (approximately \$6 billion) and twenty four DoD labs (approximately \$9 billion). To understand the magnitude of the total bill, it should be noted that this is roughly equal to the total research

¹⁹ NSF, Federal Funds for Research and Development: Fiscal Years 1990, 1991, 1992, (1992), p.51.

money spent in all universities. The amount spent in the federal labs is about twice the federal R&D spent in the universities.

The amount of money involved indicates that the national labs are a key part of the U.S. science and technology system and might be considered as competitors, or as complementary to the universities regarding federal funds.²⁰ Like universities, federal labs are often seen as an important source of the new knowledge that leads to new technologies. Indeed, the federal labs are a key science and technology resource and a sometime source of new products, but their primary function is not to develop new product technologies. Historically, their research has always been defined by their support for the parent agencies' missions. In the case of the DoD labs, the mission is to develop new weapons, and other technologies that are militarily useful. The DOE labs have become more flexible in their research goals, but still are focused around a stated mission: energy research and development.

B. Types of National Laboratories

There are three types of DOE labs: weapons labs, large multifunction labs, and smaller, single function facilities. The weapons labs are Lawrence Livermore National Laboratory and Los Alamos National Laboratory whose primary mission has been the design of nuclear weapons; and Sandia National Laboratory which engineers and supervises the building of nuclear weapons. These three labs have diversified in recent years into non-nuclear research

²⁰ The competition for resources is usually quiet, but surfaces occasionally, see for instance the discussion in National Journal, "Federal Labs Come Under Scrutiny for Their Role in Science Research", Nov 13, 1982.

fields, and now are also considered "multifunction" labs.²¹ As the weapons labs have moved away from an overriding focus on weapons development towards civilian applications, they have come to be seen as a source of civilian technology. But, Alan Zucker, director of Oak Ridge National Laboratory in 1988, estimated that only 10 to 30% of the research in DOE's nonweapons labs--and a smaller percentage in weapons labs--involved technology that could be commercially useful.²²

The large, multifunction labs such as Brookhaven National Laboratory and Argonne National Laboratory have traditionally focused on long term, highly capital intensive, basic research in several areas in the energy field. Argonne has been the center for AEC civilian nuclear power reactor development. Lawrence Berkeley's mission has historically been fundamental physics--the first cyclotron was invented there in 1936. Brookhaven has taken on a wide range of non-military fundamental atomic research, much of which has depended historically on large, expensive, specialized machines.

The single function facilities range from the Fermi National Accelerator Laboratory and the Stanford Linear Accelerator Center which feature large, high energy research facilities, to the National Renewable Energy Laboratory which works on solar power and other

²¹ Indeed, the share of R&D devoted to nuclear weapons research at Lawrence Livermore has dropped from 48% in 1988 to 36% in 1991, according to John Nuckolls director of the Lab. And the head of Los Alamos, Siegfried Hecker, says that they have reduced weapons jobs by one-third in six years. Quoted in Science, 22 Nov. 1991.

²² Science, 13 May 1988.

alternative energy projects.²³ Of the multifunction labs, six are the focus of this paper: Lawrence Livermore and Lawrence Berkeley in California, Los Alamos and Sandia in New Mexico, Argonne in Illinois, and Brookhaven in New York.²⁴

C. The Future of the National Laboratories

The history of the DOE national laboratories dates back to the Manhattan Engineer District Project, the effort that developed the atom bomb in WWII.²⁵ Los Alamos, Sandia, Oak Ridge, Argonne, and Pacific Northwest all draw their origins directly from this effort. The purpose of the national labs' research has always been defined by their support for the parent agencies' missions.²⁶ The mission of the DOE labs--excluding nuclear weapons--has always been seen as supporting long term, basic energy research that the commercial sector is unwilling or unable to perform. But, they have also been involved in development projects--in the 50's and 60's civilian nuclear power was a lab mission, and in the 70's, research on alternate energy sources was added.

The future role and even the existence of the national labs is still a matter of debate.²⁷ This results from the triple pressures of the loss of traditional Cold War justification for the DoD and weapons

²³ A list of all DOE labs is given in Appendix I.

²⁴ The labs not treated here, such as Idaho National Engineering Laboratory and Oak Ridge National Laboratory, are left out because of the unavailability of some necessary time series data.

²⁵ The exception is the Lawrence Berkeley National Laboratory, which dates back to 1931.

²⁶ Argonne and Brookhaven also reflect a conscious effort to distribute geographically the energy research effort.

²⁷ "The Future of the National Laboratories", Hearings before the House Science and Technology Committee, (1991).

labs, the pressure on all federal programs exerted by the budget crisis, and the continuing pressure to address the problem of international competitiveness by developing new technology. But, controversy over their missions amid changing national circumstances is nothing new for the labs. And, studies to examine what should be done to adapt to these changes are not rare either. In 1983, the Packard report listed 39 prior studies on their role and their future, including at least seven in the previous six years.²⁸

The vision of the labs' proper role has ranged through the years from making the labs more commercially relevant, to emphasizing their long term, high risk focus. The Seventies saw the labs move toward becoming relevant to technology development, including a direct involvement in demonstration projects. The Reagan years saw a clear rejection of that philosophy, restricting their role to basic research, and emphasizing long term payoffs. The Bush administration showed some ambivalence on this issue, and, while not advocating a greater role for the national labs, did not challenge Congressional efforts to expand the lab's commercial relevance. Also, by the late Seventies, and increasingly through the Eighties, international competition and industrial innovation had become recognized as a factor in the discussion of the labs' future.

During the Eighties, no single, clear redirection or redefinition of the labs' mission was written, but what did emerge was a new function for the labs: technology transfer. At least nine laws were passed in the Eighties intended to increase the rate technological

²⁸ "Report of the White House Science Council Federal Laboratory Review Panel", Office of Science and Technology Policy, Washington, DC. (May 1983). Referred to as the "Packard Report".

innovation. Several were focussed directly on increasing utilization of technology developed within the federal laboratory system.²⁹

There were congressional hearings on the subject before each of these laws. These were followed by congressional hearings and GAO reports investigating why these laws were not working.

D. Why the Need for Technology Transfer Legislation?

Why, it might be asked, is or was, technology transfer a problem? Don't new technologies naturally find their way into commercial use? Why did Congress need to try to increase the movement of new technical ideas out of the Federal laboratories into commercial use?

The simple answer is that automatic spinoff is wrong, technology transfer does not happen by itself. Movement of any idea from the lab to market is a difficult process, and application of technology developed for one purpose is to a different one is extremely difficult. "By no stretch of the imagination can technology transfer be viewed simply as taking a piece of hardware, bought and paid for by some technology intensive government program, making it available to the world at large, and expecting the world to snap it up. Federal laboratory technology, no matter how useful, will remain on the shelf unless it is consciously moved and appropriately adapted by people and institutions with motivation, skill and access to resources."³⁰

The complicated answer is the subject of the next chapter.

²⁹ See Appendix 2.

³⁰ Teich and Lambright, "Federal Laboratories and Technology Transfer", p.428. (1977).

CHAPTER THREE: UNDERSTANDING TECHNOLOGY TRANSFER

If technological spinoff is not automatic, why not? Why don't technical ideas move freely from laboratory to developer to market? How does technology transfer take place? The answer to these questions seem to hold the key not only to understanding the technology development process, but to evaluating the success of policies intended to facilitate technology transfer. Descriptions of the technology transfer process seem sometimes like the descriptions of the elephant by the three blind men. They reflect different perspectives on the same thing. Almost every discussion of technology transfer is guided by some theoretical perspective, though rarely is this laid out explicitly. To understand these theories better, and to shed some light on the process generally, this section will review a number of approaches to understanding technology transfer.

To speak of theories of technology transfer implies more rigor than is present. Rather I should describe them as conceptual approaches. The conceptual approaches that I will discuss can be divided into seven categories. The first two are the most prominent in the literature: Technology Push and Market Pull. Next are two attempts to unite technology push and market pull by stressing the ways they are linked. The two ways of making this linkage are to see technology transfer as an information problem, and to see it as an issue of interorganizational relations. The fifth approach focuses on the characteristics of organizations, and sixth on characteristics of

the individuals involved in technology transfer. The last places technology transfer within two different, larger processes.

The result of this will not be a single comprehensive theory of technology transfer, but a survey of important conceptual tools. These tools will be used to examine the obstacles to technology transfer and the likelihood that Stevenson-Wydler and Bayh-Dole could have created any changes at the national laboratories. Taken together, the approaches point to two major kinds of obstacles to technology transfer: obstacles to increasing technology transfer results, and obstacles to increasing technology transfer efforts.

A. Technology Characteristics

Probably the most common theoretical starting point for technology transfer discussions is to talk of Technology Push versus Market Pull. This can be read as a debate over the question of which is more important, the generation of new technical ideas, or the demand of the user for these new ideas and products. It can be also be seen as a reflection of the historical sequence of thinking on science and technology policy. A Technology Push theory stresses the critical need to generate new technical ideas. A Market Pull focus counters that new technologies are irrelevant in the end, if no one adopts them. In the context of the national labs, Technology Push implies that the labs need only concern themselves with developing new technical ideas, these ideas will naturally find their way into commercialization. Market Pull implies that any technical developer needs close links to the market to be successful. (Market Pull ideas will be developed in the next section.)

Technology Push is not the only approach to technology transfer that focuses on the technology itself. Another group of theories does not postulate that the development of new technology is the most important factor *per se*, but does focus analytical power on the nature of the technology involved as a way of proceeding to further insights about the transfer process.

Technology Push will be dealt with because of its importance to the debate. Then perspectives that focus on technical characteristics will be examined.

1. Technology Push

Technology Push is the model that guided thinking on U.S. technology policy generally in the post-war era.³¹ Now used primarily as a whipping boy for failed policies, Technology Push reached its highest expression in Vannevar Bush's, Science: the Endless Frontier.³² Bush's ideas provided the intellectual basis for the strong growth in science support in the U.S. in the postwar period. Technology Push treats technical development as the result of a linear, stepwise progression from basic science, to applied science then to technology, then automatically on to product development. The process of generating new technology, in this view, automatically leads to a stream of new products in the

³¹ See: Bruce L.R. Smith, U.S. Science Policy since World War II (1990); and the discussion in Chapter 1 of Alic, et al, Beyond Spinoff (1992).

³² Vannevar Bush, Science: The Endless Frontier, Washington, DC: U.S. GPO, 1945. His theme was actually science push, which, when combined with a linear model of technology development, leads to technology push. This is not to imply that Bush was naive, only that the rhetoric he used to sell the postwar support of science was simplistic.

marketplace.³³ The development of new technology is sufficient to guarantee the utilization of the new technology--this leads to the conception of spinoff as automatic.

Technology Push is related to the pipeline model of innovation. This model depicts innovation as a linear, stepwise process in which ideas are transformed into new products as they move simply and inexorably from basic research to applied research, then from testing to product development, finally from manufacture to general use. This notion, now largely rejected, limits understanding of many of the interactions among functional groups in the innovation process. The interactions between marketing, for instance, and manufacturing, are key to most successful product innovations. The pipeline's linear perspective conceals these and other crucial linkages and feedback loops.³⁴

Technology Push as a technology policy assumes that "spinoff" works. As already mentioned, spinoff is the idea that the research and development that goes into achieving government missions, such as national security, space, or medicine, would benefit the civilian economy because the technological results will "spinoff" into usable products. Technology push rests on a notion that the pool of basic science and technology, regardless of origin, will necessarily lead to commercial products. Spinoff is one of the means by which technology push happens.

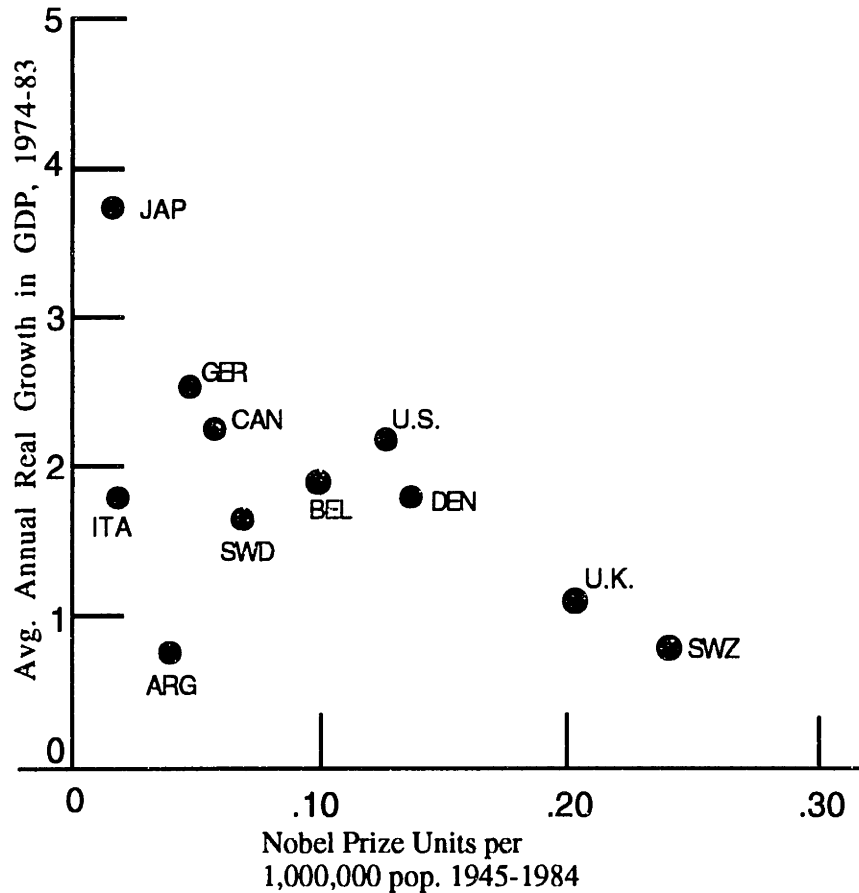
³³ Alic, et al, Beyond Spinoff, (1992) Chapter 1.

³⁴ For discussion of the importance of feedback loops, see, for instance, Rothwell, "Developments Toward the Fifth Generation Model of Innovation" (1992) and Klein, "Models of Innovation and Their Policy Consequences", (1989).

The whole body of economic and management literature that explores the relationship between R&D and innovativeness can be taken as an exploration and ultimately a critique of Technology Push. Management scholars investigate issues of innovation promotion and facilitation. This stands against technology push because if technical development was automatic, then there would be little need to facilitate it. In the Economics discipline, the questions studied include what levels of R&D are necessary for innovativeness on a firm level and at the national level. Here the research results form a critique of technology push when levels of R&D or basic science spending are not positively correlated with innovativeness--as they are often not. Hill has put together a thought provoking graph of the relationship of Nobel prizes in Chemistry and Physics to economic performance in the years 1974-83.³⁵ The relationship is largely an inverse one! The more Nobel prizes won in the post-war period, the worse the economic performance in these years.

³⁵ "Science Policy Study Background Report No. 3: The Nobel-Prize Awards in Science as a Measure of National Strength in Science", Report for the Task Force on Science Policy, House Committee on Science and Technology, prepared by the Congressional Research Service. (September 1986).

FIGURE 1
 Relationship between Nobel Prize-Winning
 in Physics and Chemistry and Growth in GDP



Source: Congressional Research Service, "The Nobel-Prize Awards in Science as a Measure of National Strength in Science".

The implication then is that good science does not lead necessarily to economic health. There must be other factors that determine how efficiently R&D resources are put to use. To set out to explore these factors is to leave Technology Push behind.

Technology push, the pipeline model of innovation, and spinoff have become straw men for advocates of greater technology policy efforts. But it is important to remember that they contain a grain of truth. Spinoffs from military spending in the post-war period, while not directly resulting in many consumer products, have helped create the environment for civilian as well as military innovation: a generously supported system of higher education, a large body of trained engineers, a market for novel technologies, and a huge number of newly emergent high tech companies willing to innovate to supply military and civilian needs.

The innovation pipeline, too, has its uses. Not all industries do technology development in the same way. The pipeline model is still a moderately accurate model of innovation in some industrial sectors--for instance the chemical industry. Research and development in this industry does often flow from the lab to production to market.

Technology push should not be rejected out of hand, either. Continued technology development does depend upon addition to a pool of technical ideas. Many commercial innovations are developed from technology that has existed for years.³⁶ Thus, addition to the technical idea base is essential for continued innovation.

More importantly, technology push is the means by which breakthrough ideas are developed. Since, the market can only "pull" what it desires, and it only desires what it is familiar with, any really new product can not accurately be said to result from market pull.³⁷

³⁶ Utterback, "Innovation in Industry and the Diffusion of Technology", (1974).

³⁷ Carr, "Doing Technology Transfer in Federal Laboratories." (1992).

Many new technological systems not only expand the market, but create new markets. The copy machine and the computer have overwhelmed early market projections. And, integrated circuits and semiconductors were the result of technology push, not market pull.

Nevertheless, by stressing the primacy of the technology, and envisioning the process of developing new technical ideas as unproblematic, Technology Push ignores innumerable other factors. It leaves out the role of the developing organization, the market reception, the legal and regulatory environment, just to name a few.

The positive policy implication of technology push ideas is simple: "do science, and technology and economic benefits will follow". Policy attention is focused on inputs into the lab, e.g. money for lab supplies, numbers of scientists, availability of specialized equipment. Barriers to technology transfer then, are conceived only in terms of undersupply of inputs. As a means of insight into technology transfer problems, technology push provides no policy advice, because the transfer of ideas is not perceived to be a problem.

Stevenson-Wydler and Bayh-Dole represented a rejection of Technology Push ideas. They were deliberately premised upon the need to utilize more fully the technological resources already extant as a result of government R&D spending. "There is a need for ... a strong national policy supporting utilization of the science and technological resources of the Federal Government."³⁸ "It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally

³⁸ Stevenson-Wydler code: 94 STAT. 2311. Emphasis added.

supported research and development; ...³⁹ These laws, or any move to facilitate utilization of federally developed technology, are a rejection of Technology Push.

The simplest notion of Technology Push innovation might be summarized: 'technology will create its own market'. In the case of the national laboratories, policy guided by Technology Push has clearly been insufficient, as there is a widespread feeling that the labs' technology is underutilized.⁴⁰ Indeed, it is true almost by definition, that if the labs had more of a market focus, then less of their technology would remain unexploited. Though it is unclear whether they could have had much more of a market focus, given their historical missions of defense and basic science. (The crucial point that moving the focus toward the market requires first changing the national labs' mission will be discussed below.)

2. Characteristics of the Technology

One does not have to believe in Technology Push to use the characteristics of the technology as the point of entry in analyzing the technology transfer problem. A number of authors focus their analysis of technology transfer on the technology involved in the transfer. This is not Technology Push because the claim is not that development of new technology is the most important factor overall, but only, the nature of the technology involved in technology transfer can influence the outcome of the transfer process.⁴¹ This

³⁹ Bayh-Dole legislative history, 94 STAT. 3019. Emphasis added.

⁴⁰ This sentiment is expressed explicitly in the Legislative history of Stevenson-Wydler, for example.

⁴¹ For interesting work that uses the notion of 'technology paradigms' to explore the constraints on technical change, see Dosi, "Technological

body of literature, concerned directly with technology transfer, gains insight into the process through examining the technology itself.

This approach usually ends up dividing the technical development process into stages, then examining how technology gets (or does not get) transferred at each stage. Bozeman and Fellows developed a framework for use in the national laboratory setting that describes three categories of technology characteristics: proximity to commercial application; directness of commercial application; and, potential breadth of application.⁴² (They do not elaborate on this framework further.) Robinson, in a discussion of international technology transfer, identified twelve factors concerned with the developmental stage of the technology involved in transfer.⁴³ These characteristics include maturity--the newness of the technology; dynamism--the rate of expected change of the technology; relative importance--is the technology a radical, incremental, or branching innovation; and, environmental specificity, --which describes the scope of the possible applications. Robinson's concern is with the receptivity of other cultures to transfer projects. His analysis proceeds descriptively, rather than analytically, so is not that useful here.

Paradigms and Technological Trajectories." (1982). Related is Sahal's notion of the natural constraints inherent in any technology, see: Patterns of Technological Innovation, (1981).

⁴² Bozeman and Fellows, "Technology Transfer at the U.S. National Labs", (1988) p.74.

⁴³ Robinson, R.D., The International Transfer of Technology, Cambridge, MA: Ballinger, (1988) p.11.

One of the best of these studies is that of Winebrake.⁴⁴ He examines case studies of technology transfer and seeks to determine a relationship between the stages of technical development and different types of transfer. The question is whether some methods of transfer work better than others for different stages of development. He finds this to be so. Specifically, he finds that approaches using patent licensing are less likely to succeed when the developmental stage is either basic/experimental or market penetration. His results, while not deeply theoretical, are directly applicable to technology transfer policy, and will be discussed in detail in chapter 8.

With only the most distant relationship to technology push, the approaches to understanding technology transfer that examine the characteristics of the technology are much more useful. They give empirical reinforcement to a conclusion that will come up again and again, that collaborative forms of research are most likely to result in commercially relevant technologies. By emphasizing patent licensing and horizontal transfer as the way to remedy their labs' historic inattention to the market, the first steps of Stevenson-Wydler and Bayh-Dole seemed likely to fail.

B. MARKET CHARACTERISTICS

Perhaps the most obvious weakness of the technology push approach is brought out by those who point to the importance of market pull. Indeed, the ability to make a profit by selling a new

⁴⁴ JamesJ. Winebrake, "A Study of Technology Transfer Mechanisms for Federally Funded R&D" (1992) pp. 54-61.

technical product depends at least as much on non-technical factors--not limited to market considerations. Left out are the role of the inventor, the organizations involved in technology transfer, and the legal and regulatory environment, to name just a few. But, theories of Market Pull were the first response to Technology Push. The customer demand is given primacy here as innovation is seen to be a response to needs, explicit or latent, within the market.

For the purpose of understanding technology transfer, theories of market pull can be separated into are four types, only two of which will be explored in depth. The first version surrounds the claim that forces in the economy call forth inventions. This idea is associated with the work of Schmookler, and will not be explored here.⁴⁵ The second version is von Hippel's insight that the customer or user of a technology is often an important source of innovation--the market as a source of technical ideas.⁴⁶ Von Hippel's insight on the user as the source is not that relevant for our purposes, except as a specific example of the importance of feedback loops in the innovation process, and the limits of the linear model of innovation.

The third version is the claim that recognition of market demand is more important for innovative success than technical novelty--that is market potential is more important than technical potential. This is the position of Myers and Marquis, and

⁴⁵ Schmookler's work centered around the questions of patterns of inventive activity as opposed to innovation. He concluded that inventive effort, as measured by patents is responsive to economic pressures and opportunities. This means that patenting should not be thought of as totally serendipitous and unpredictable, but as driven by the same general forces that drive the economy as a whole. This suggests more than anything that patents should be seen as an outcome of applied research, not as the results of basic research.

⁴⁶ Von Hippel, The Sources of Innovation (1987).

Utterback.⁴⁷ The final version is the normative assertion that more attention should be focused on the market if innovations are to succeed-- more attention should be paid to customers wants and needs.⁴⁸ The relevance of these final two points for the federal labs is clear: attention to market demand and marketing expertise are skills that the labs generally do not have. To succeed at technology transfer, they must develop them, or have ready access to them.

1. Market Pull

Market Pull is embodied in the assertion that "Market factors appear to be the primary influence on innovation."⁴⁹ Myers and Marquis' paper was one of the first to assert that market demand was the prime determinant of innovation. Surveying a number of innovations they found consumer demand was the source of 45% of successful innovations, while technical feasibility was the source of only 21%. The other major category was production need at 30%. From this, others have concluded that 75% of innovations are "need driven". Utterback reviewing this and a number of other studies, concluded that "from 60 to 80% of important innovations in a large number of fields have been in response to market demands and needs."⁵⁰

⁴⁷ Myers, S. and D.G. Marquis, "Successful Industrial Innovations," NSF Report 69-17, Washington, DC, (1969); Utterback, "Innovation in Industry and the Diffusion of Technology", (1974).

⁴⁸ Roberts, Entrepreneurs in High Technology (1991).

⁴⁹ Utterback, "Innovation in Industry and the Diffusion of Technology", (1974), p.659.

⁵⁰ Utterback, "Innovation in Industry and the Diffusion of Technology", (1974), p.659.

Historically, this focus emerged in the late 60's and early 70's. Rosenberg and Mowery suggest that this challenge to technology push came from two sources. First was a general dissatisfaction with the utility of basic research. Second was the specific effect of several studies that purported to show the crucial role played by market forces in successful technical innovations and the lesser significance of pure forces of technology push.⁵¹

As Rosenberg and Mowery point out, the idea of Market Pull as a description of the innovative process is extremely diffuse.⁵² The definition used is "so broad as to embrace virtually all determinants of the innovative process..."⁵³ And, enthusiasm for this idea in the early seventies tended to go a bit overboard. An example: "Everything that we know about technological innovation points to the fact that user or market demand is the primary determinant of successful innovation. What is important is what consumers or producers need or want rather than the availability of technological options."⁵⁴ While the point is rarely made so baldly anymore, Market Pull still exerts its effect, as 'greater attention to the market' is a staple prescription for innovation maladies.

⁵¹ Exaxmples of these studies were Myers and Marquis (1969), DOD's Project HINDSIGHT, and Utterback's review article in Science in 1974.

⁵² Mowery, David C. and Nathan Rosenberg, "The Influence of Market Demand upon Innovation: A Critical Review of Some Recent Empirical Studies", Research Policy, 8:103-153 (1979). Reprinted in Rosenberg, Inside the Black Box, (1982).

⁵³ Mowery and Rosenberg, "The Influence of Market Demand upon Innovation", p.194.

⁵⁴ Gilpin R., "Technology, Economic Growth and International Competitiveness", Study presented to the Congressional Joint Economic Committee, (1975), p.65; quoted in Mowery and Rosenberg.

Rosenberg and Mowery conclude that conflation of a number of different variables makes the assertion of the primacy of market demand unreliable. "The uncritical appeal to market demand as the governing influence simply does not yield useful insights into the complexities of that process."⁵⁵ According to Rosenberg and Mowery, over reliance on this point of view may lead to faulty policy prescriptions. Government R&D should not try to focus directly on the market. Private companies can respond to market demand, that is what they do. Government's role, they argue, should be to advance research in areas where the market is not yet well defined or where market demand is non-existent, such as environmental technologies. Government should lead the market, not try to follow it.

Since both the knowledge base of science and technology and the structure of market demand play central roles in innovation, neither can be neglected. They argue for an linkage of market with research, both functionally and organizationally. They conclude that policies directed toward increasing both the frequency and the intimacy of interactions among basic research institutions and private firms and labs, and users and producers may prove to be particularly rewarding.⁵⁶ The barrier to development does not arise because government R&D is not focused on the market, but because institutional forms linking government labs to industry users of research are non-existent or underdeveloped.

⁵⁵ Mowery and Rosenberg, "The Influence of Market Demand upon Innovation", p.228

⁵⁶ Mowery and Rosenberg, "The Influence of Market Demand upon Innovation", p. 238.

2. Marketing

Another way of focusing on innovation through the lens of the market is not to see 'market pull' in opposition to 'technology push', but by stressing the need for 'marketing'. Though recognizing the importance of understanding customer wants and needs does not require a belief in the primacy of the market, the need for marketing might be seen as the policy implication of Market Pull. Indeed, Marquis makes this transition. "Recognition of demand is a more frequent factor in successful innovation than recognition of technical potential. It seems to me, therefore, that management ought to concentrate on any and all ways of analyzing such demands and needs."⁵⁷

Any number of studies have come to this conclusion. Banting found a frequent cause of failure in new product development was the lack of a customer orientation.⁵⁸ Cooper and Kleinschmidt examining both successes and failures, found that a strong marketing orientation was frequently absent, especially in the case of failures.⁵⁹ Roberts in a number of studies has stressed the need to be sensitive to marketing details and that this is one of the prime failings of high tech start ups--not the technology, but the lack of marketing experience among technically trained and oriented personnel.⁶⁰ A related explanation for innovation failures is that markets are not

⁵⁷ Marquis Donald G., "Anatomy of Successful Innovations", Innovation, (1969) p.47. Reprinted in Tushman and Moore, (1988) .

⁵⁸ Banting, Peter M. "Unsuccessful Innovation in the Industrial Market", Journal of Marketing, 42(1):99-100 (1978).

⁵⁹ Cooper, R. G. and E. J. Kleinschmidt, "Resource Allocation in the New Product Process," Industrial Marketing Management, 7:249-262. (1988).

⁶⁰ Roberts (1991, 1992).

prepared to accept innovations. This, too, can be seen as a failure of "marketing". And, in either case, the lesson is the same: successful innovation depends on attention to the market. Insofar as technology transfer is one step in the innovation process, attention to the market is critical to its success.

Indeed, this is one conclusion that has been made explicitly in the case of national lab technology transfer efforts. "The national labs are hindered in their ability to successfully complete the innovation process because of a lack of access to the necessary business and marketing skills and resources."⁶¹ Steele et al. specifically address the need for marketing expertise in national lab technology transfer. They conclude that "there is little resistance to the notion of technology transfer on the part of lab personnel, but rather an absence of appreciation of market philosophy. This could be taught. In summary, marketing fundamentals are probably the key to effective technology transfer."⁶² While I think this over represents the simplicity of a solution, the lack of market awareness is a significant obstacle to a well developed technology transfer policy.

Technology transfer theories that focus on the characteristics of the 'market' stress that a good technical idea is not enough. The policy implications are clear: marketing skills in the broadest sense, must be added to the national labs' repertoire to increase transfer results. In practical terms, this means pushing information about the

⁶¹ Soderstrom et al. "Improving Technological Innovation through Laboratory/ Industry Cooperative R&D." (1985) p. 138.

⁶² Steele et al, "The Technology Innovation Act of 1980, Ancillary Legislation, Public Policy, and Marketing: The Interfaces." (1990) p.179.

available technology selectively toward potential developers, pulling knowledge of what the market needs into the technical development process, and accessing the skills of marketers when necessary.

Stevenson-Wydler showed awareness of this market barrier, and declared an intent to promote interaction of personnel between the labs and private industry, and to encourage cooperative research programs. "Many new discoveries and advances in science occur in universities and Federal Laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon action by business and labor. Cooperation among academia, Federal Laboratories, labor and industry, in such forms as technology transfer, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened."⁶³ However, the plans within Stevenson-Wydler to achieve this interaction of federal, university, and industry researchers were never implemented. What was left from Stevenson-Wydler provided only passive means for linking the federal lab research to the market.

C. Linkage Theories

In a way, the 'market pull' theories are just as limited as the 'technology push' theories. By stressing only half of what seems obviously two sides of a coin, they ignore the ways in which the two halves are made whole. This leads (once again it seems obvious) to theories that stress the linkage between technical development and

⁶³ From Stevenson-Wydler legal code: 94 STAT. 2311

the ultimate user of the innovative product. Any analysis of technology transfer or the future of the national labs, shallow or deep, academic or journalistic, that concludes that closer links between R&D and the market is 'the key', is calling forth a linkage theory of technology transfer. Linkage theories come in many shapes and sizes, but will here be separated into theories that focus on the nature of the communication involved, and theories that focus on the way organizations involved in the process come together. Although there is some overlap, these two approaches to technology transfer will be treated in separate sections.

1. Information Linkages

Perspectives that focus on the importance of information in the technology transfer process can be broken down into two types. The first is a somewhat simple view of technology transfer as a straightforward information exchange. Here the technology is seen as discrete and well defined. And, the transfer is unproblematic, once a potential user is made aware of the existence of the technology. The problems are in getting the parties together. The second, more sophisticated view sees technology not as a thing, but as information. To transfer technology, then, requires communication skills, sensitivity to the other party's interests, and the ability to present information in a way in which it can be absorbed.⁶⁴

⁶⁴ A third view, information exchange as social construction is presented in Doheny-Farina. Innovation, Rhetoric and Technology Transfer. Using insights from the social construction of knowledge perspective, he describes technology transfer as reconstruction of knowledge. Any transmission of information requires a process of translation and reconceptualization. "There is no clearly objective fact or physical entity that proceeds uninterrupted

The effect of these two views on policy recommendations are different. The first perspective has resulted in increased efforts to spread information about the technology available within the federal lab system. These programs, started subsequent to Stevenson-Wydler and Bayh-Dole are likely to have limited impact on technology transfer results. The second perspective leads to policies that get potential industry users involved inside the federal labs. Only here can they fully understand the potential uses of otherwise inchoate new technologies.

a. Technology Transfer as an Information Dissemination Problem

A simple view of technology transfer as information exchange does not see the description of the technology itself as a problem. The linkage issue arises as the labs try to find a users for their technology. This approach operates within the spinoff or horizontal transfer paradigm: a technology is developed for one purpose, and a second, commercial use is then found for it. This communication approach can lead to recognition of some of the procedural difficulties that must be addressed. These include the development of legal or administrative procedures involved in transfer, and the need for an appreciation of the difficulties of the negotiation process.

Perhaps the most obvious consequence of viewing technology transfer as information exchange is to emphasize the opportunities presented by information technology. Publicizing technology transfer opportunities via computers and telecommunications has

from the lab to the market." This can be taken as an extreme statement of the second view presented here.

been offered by Williams and Brackenridge as a way to speed the interactions involved.⁶⁵ They are aware that "the actual technology transfer process is often very circuitous," but suggest that telecommunication networks can assist by keeping a myriad of participants up to date, organize a vast amount of overwhelming data, provide instantaneous communication regardless of geographic location, and provide access to advanced services such as supercomputing and parallel processing.

Once the communication gap is bridged, the issue moves to the licensing of technology. Any organization using licensing must develop some formal and informal mechanisms to move the process forward. The barrier presented by these procedural hurdles must be overcome if technology transfer is to succeed.

One study that describes the development of transfer rules is Eberlein's study of the Technology Licensing Office at MIT. He describes the steps in the licensing process.⁶⁶ The first step in the procedure is formal, that is the inventor fills out a form. By filling out the form, the inventor has created a 'case' within the licensing office, which triggers a standard reaction for identifying and tracking the invention. The next step is a quick technical and market evaluation, which is informal. A formal patent filing is the next step, which is handled by an outside patent lawyer. After the patent filing, the license officer seeks to market the invention and negotiate a license. Once a potential licensee is located, the negotiation starts,

⁶⁵ Williams and Brackenridge, "Transfer via Telecommunications: Networking Scientists and Industry" , Chapter 8 in Williams and Gibson, (1990).

⁶⁶ John A. Eberlein, Technology Transfer at M I T: An Analysis of the Technology Licensing Office, (1989).

using a standard license form, which may be customized to meet individual requirements. This quick sketch shows that the license process is a combination of formal and informal procedures.

One of the points made by Eberlein is that some procedures work better than others. He describes the restructuring of the MIT Technology Licensing Office in 1985. Improved functioning has been achieved by abandoning an overly legal approach for a more flexible one that blends some formal procedures with a focus on the ultimate goal of commercialization.

The next logical step is to recognize that mere procedures are not enough, people must execute them. An example is Hittle's work that stresses the problems of negotiation involved in technology transfer.⁶⁷ He uses a body of literature specific to negotiation to examine some of the problems--not limited to legal ones--in forming Cooperative R&D Agreements (CRADAs). He describes three phases, initial contact; coordination and negotiation; and review and approval. The first step can be seen as an effort by involved parties to convince others to see his viewpoint and share his enthusiasm. The second stage involves iterative meeting to convey understanding of the technology; laying of legal groundwork; and drafting of the CRADA. The final process requires getting all parties to come to a final agreement. Included on the lab side at the final stage are: the researcher, lab division manager; the director of plans and programs, the laboratory director, lab-level and headquarters legal counsel, and even the agency head. On the commercial side, the list may be

⁶⁷ Audie Hittle, Technology Transfer through Cooperative Research and Development, (1991).

slightly smaller. The need for subtleties of negotiation is apparent from the number of people involved here.

The communication approach presented here stresses barriers that are mostly procedural. The issues are how to spread information, how to get people together, and how to get them to an agreement. These considerations point to factors that would limit technology transfer results. The absence of these things would not prevent the labs from adopting technology transfer as a goal, but would limit their effectiveness until the requisite skills and programs were developed.

Stevenson-Wydler and Bayh-Dole, were premised in part on the view of technology transfer as an information problem. Stevenson-Wydler sought to create a Center for the Utilization of Federal Technology. This organization was to act as coordinating body for technology transfer efforts, providing information resources and developing and sharing necessary expertise. The intention of Stevenson-Wydler in mandating ORTA's was, of course, that the staff of this office would develop this legal and negotiating expertise, and develop the procedures for implementing technology transfer.

Further steps using this perspective have been taken since 1980. The concrete results have included giving legislative imprimatur to the Federal Laboratory Consortium for Technology Transfer (FLC).⁶⁸ The FLC originated in 1971 as an association for technology transfer professionals. Its purpose is to assist labs in their technology transfer efforts, and it now also electronically distributes information about technology transfer opportunities and

⁶⁸ Federal Technology Transfer Act of 1986.

technology transfer problems. The second result of this approach has been the Department-wide effort to create information packets describing patents, devices, and processes available for licensing. Third, there has been a move to take advantage of the information revolution and create a database of available patents, experts, and facilities. The FLC, National Technical Information Service, and the newly created National Technology Transfer Center are all developing databases that will facilitate access to information on federal lab technologies. The fourth result has been the active participation of many labs in trade fairs and open houses meant to get the word out on their projects to potential users or developers or licensees. The National Technology Initiative was a traveling road show run by the DOE in 1992 to get the word out about the opportunities available in the Federal labs.⁶⁹

These are all worthy steps to enhance the dissemination of information about pre-existing technologies. Two points need to be made: all these came after Stevenson-Wydler or Bayh-Dole, and all are limited by their fundamental perspective.

Framing technology transfer as a problem in communication about technology oversimplifies things greatly. By seeing technology transfer as an information problem, the labs and others have spent much effort on facilitating licensing of preexisting devices and processes. That is, it conceives of the mission of technology transfer

⁶⁹ A procedural impediment still on the legislative agenda is legal protection for software code developed within the national labs that parallels the protection afforded to patented ideas. This is the primary legal barrier remaining according to a GAO report "Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness," (1993)

as taking already developed products and processes and finding a new use for them. The benefits of this approach are limited, since most writers no longer see the technology development process moving in this 'develop--find a match--license the device' manner.⁷⁰ Only when there exists a pre-existing product prototype does this model help. This is not very common.⁷¹

More sophisticated views of technology transfer show that the developer of the technology, the receiver of the transfer, must be involved early in the development process. (See below). Stevenson-Wydler seemed to show some realization of this, as it called for many new forms of collaborative research between the labs, industries, and universities. Development of these new cooperative research institutions was killed in the implementation stage. (See chapter 5). Bayh-Dole, on the other hand, clearly was premised on developing opportunities for technical licensing. The next section points to some of the limits of this thinking.

b. Technology Transfer as a Communication Problem

The second information perspective sees technology itself as information (not as a device) and focuses on the deeper problems of communication. Since technology is never self evident, conveying an understanding of new technologies is a crucial step to having another organization adopt them. The solution to these problems is to not let them develop. That is, having the lab inventor and the industry

⁷⁰ See discussion following.

⁷¹ Teich and Lambright, "Federal Laboratories and Technology Transfer: An Interorganizational Perspective" (1977).

developer together at the outset of a project is the best way to avoid communication problems.

As opposed to information dissemination, this approach stresses that two way communication is necessary to link technology push and market pull. "To make technology transfer successful requires overcoming the many barriers to communication encountered when individuals use different vocabularies, have different motives, represent organizations of widely differing cultures, and when the referents of the transactions may vary from highly abstract concepts to concrete products."⁷² Williams and Gibson note that "many of the exchanges needed for successful technology transfer take place in situations not particularly opportune for effective communication."⁷³

(Here, Williams and Gibson start to recognize that industry and the federal labs have different cultures. These cultural obstacles are one of the most significant impediments to technology transfer, and will be discussed more fully in a following section.)

An important point is that technology transfer should not be seen as the transfer of things, but as transfer of ideas about new things. Williams and Gibson recognize that "the technology to be transferred often is not a fully formed idea and has no definitive meaning or value: meaning is in the mind of the participants, researchers, developers, or users are likely to have different

⁷² Williams and Gibson, Technology Transfer: A Communication Perspective (1990).

⁷³ Williams and Gibson, Technology Transfer, (1990) p. 10, 12.

perceptions about the technology, which affects how they perceive the information.”⁷⁴

One way to overcome communication problems is if developers and users are involved together early. As Leonard-Barton points out, the benefits of user involvement are twofold: the user transmits information that is "needed in the development process to create value and ensure usability"; and it "promotes user "buy-in", acceptance of the innovation and commitment to use it".⁷⁵

Since, technology does not explain itself, approaches to technology transfer that seek to boost information dissemination are likely to be underappreciated by the intended audience. The clear suggestion is that the labs should downplay the licensing approach and develop policies that involve users and developers with researchers at early stages of the process. The barrier to technology transfer that is highlighted here is the persistence of an "over the wall" approach to technical development, where one organization hands the research project over to the next organization. To reduce these barriers, new collaborative institutions needed to be created. As mentioned already, Bayh-Dole was confined to a licensing approach, while Stevenson-Wydler did include a stunted attempt to develop some new institutions.

Later legislation showed more appreciation for the opportunities in collaborative work. This realization led, in 1986 and 1989, to the development of Cooperative R&D Agreements (CRADAs).

⁷⁴ Williams and Gibson, Technology Transfer, (1990) p. 16.

⁷⁵ Leonard-Barton, "The Intraorganizational Environment: Point-to-Point versus Diffusion", in Williams and Gibson (1990).

CRADAs put those who will elaborate the technical idea into the lab to work with the inventors from the earliest stages of the innovation process. Other forms of cooperation can increase communication, too. An idea taking hold is a wider role for industry advisory boards overseeing lab R&D.⁷⁶ These advisory boards can act to transfer knowledge of the market into the lab, where researchers lack this kind of perspective. The labs are now also acting as catalysts for industry consortia, which break down information barriers among firms, as well as between firms and the labs. Sandia has helped form the Specialty Metals Processing Consortium, where collaborative research is performed at the lab for the benefit of a number of firms.⁷⁷

The communication approach emphasizes boundary spanning as a key function. This perspective points to barriers to increasing transfer results. In most simple terms, publicizing information about national lab technology is a first step. But, the barriers to technology transfer are not merely information dispersal. There is a need for a deep understanding of new technical ideas if they are to be adopted and developed within another organization. Technology from the national laboratories will not be fully developed unless the developing organization is in a position to recognize the worth of the idea, then adapt the idea into a product, ready it for economical production, market it, and get people to buy it. This occurs most

⁷⁶ Winebrake's study (1991) of factors that are linked to successful technology transfer makes this point, as does Leonard-Barton.

⁷⁷ "A Day at Sandia", Technology Transfer Business (Spring 1993) pp. 12-18.

easily when there are no boundaries to span--when the lab and developer are co-innovators.

2. Interorganizational Linkages

The communication approach developed by Williams and Gibson easily evolves into studies of how different organizations interact. The interaction of unlike organizations is at the heart of the technology transfer problem. As the national laboratories seek to increase their commercial relevance they are forced into contact with large consumer product firms, small technology-based startups, industrial manufacturers, even marketing and retail organizations. One of the best discussions of technology transfer in the national laboratory is Teich and Lambright's treatment of these interactions. They describe technology transfer as a three stage process, and stress the interorganizational linkages that must be formed at each stage.⁷⁸

Teich and Lambright describe the technology transfer process in terms of three basic functions, innovation, production, and utilization.⁷⁹ In commercial technical development these roles may be contained within one organization, but in the process of technology transfer from the national labs, different organizations fill the three different roles--the innovator, the developer, and the user. The successful interaction of these different organizations is the key to technology transfer. A dynamic equilibrium must be created by linkages between all three roles in the process, not merely between

⁷⁸ Teich and Lambright, "Federal Laboratories and Technology Transfer: An Interorganizational Perspective" (1977).

⁷⁹ Teich and Lambright, (1977) p.425.

the sequential steps. It is the linkages between the three actors that is the key to technology transfer.

The first linkage necessary is between the innovator and the consumer. "In order for the dynamic equilibrium between 'technology push' and 'market pull' to exist, an early informational linkage between the innovator and the user is necessary. The function of this early linkage is to provide the innovator with an understanding of the real needs of the potential consumers of his innovation."⁸⁰ This knowledge of user needs may be known to the innovator directly through experience with the market. But when an innovator attempts to match his technical capability with a problem far afield from his background or the mission of his institution, "genuine purposeful linkages" with representative users are critical. They must be consciously sought out, and the earlier they are achieved the better.

The innovator-manufacturer linkage is the next stage in the process. The traditional linear process of innovation envisions an innovator developing a prototype, then contacting a manufacturer to add it to his line of products. Teich and Lambright report that empirically, this is not the way technology transfer happens. "It appears that the early establishment of a strong innovator-manufacturer linkage--strong enough so that the manufacturer becomes a co-innovator--is one of the keys to successful transfer of federal laboratory technology."⁸¹

⁸⁰ Teich and Lambright, (1977) p.429.

⁸¹ Teich and Lambright, (1977) p.431.

In examining the process of adopting national lab technology, Steele had asked where the money for a market appraisal of lab inventions would come from.⁸² The suggested solution was that it be included in each project's funding. The linkage approach of Teich and Lambright suggests that the manufacturer should be involved early enough in the process to be willing and able to make this appraisal himself. Without this level of involvement there is little hope for transfer, since an essential link in the chain has not been forged.

Three ways are suggested to form the innovator-manufacturer linkage: 1) By the innovating institution or a broker consciously seeking out a potential manufacturer to work as a co-innovator. 2) By the innovating institution utilizing a potential manufacturer as a supplier of prototypes. 3) By a 'people transfer' in which one of the innovators establishes or joins the manufacturing firm.⁸³

The third linkage necessary in the technology transfer process is the one between manufacturer and user. Such linkages are necessary to provide the manufacturer with a view of the potential market for the innovation. Manufacturer-user links, leading to early orders, could help to guarantee a sufficient market to encourage the manufacturer to move forward. They might also supply feedback and guidance on refinement of the innovation and for a marketing strategy. User-manufacturer linkages can serve an important

⁸² Steele et al, "The Technology Innovation Act of 1980, Ancillary Legislation, Public Policy, and Marketing: The Interfaces." (1990)

⁸³ Teich and Lambright, (1977) p.431.

function developing the initial market by providing a demonstration effect--which may attract other early adopters.⁸⁴

Teich and Lambright's approach goes beyond simple market pull and technology push views in a number of ways. Worth noting is that two kinds of relationships are embodied in the "market pull" idea. There must be a link between the market and the inventor--to make the research relevant from the outset. And, there must be a link between the market and the developer--to shape the final product form. Since these functions are performed by two different organizations, one conception of "market pull" is not enough. Different organizations, with different goals, performing different functions have to come together successfully.

Barriers arise at each stage. The need to form developer-producer linkages early in the research process argues for the enhancement of collaborative activity at the national labs. The need to form producer-user linkages highlights the need to link marketing and R&D within the firm--a message that is now commonplace in the management literature. The last relationship may be the most difficult to implement: The need to form developer-customer linkages means that the lab researchers will have to become more aware of the possible applications of their work. This message highlights the need for change in the organizational culture of the national lab, making them more open to commercial influences, as discussed below.

⁸⁴ Teich and Lambright, (1977) p.432.

Once again, the (unrealized) approach of Stevenson-Wydler indicated a sensitivity to the need for interorganizational linkages, while Bayh-Dole did not.

D. Intraorganizational Factors

The perspective on technology transfer that examines interorganizational relations and the interactions of organizations, leads naturally to intraorganizational characteristics. Organization theory as an academic field has a huge literature which I will not try to summarize here. Instead, I will focus on a few features of organizations which are often mentioned in technology transfer discussions (without always being explored deeply). I will again try to highlight the barriers to technology transfer, both the barriers to the task being adopted, and the barriers to the task succeeding once adopted. Some comments will be made about how Stevenson-Wydler and Bayh-Dole failed to address these issues, and what organizational change requires.

First, I will discuss organizational procedures and rules as they facilitate or impede technology transfer. Studies critical of technology transfer implementation often target rules and procedures, or the lack thereof. This kind of criticism is somewhat naive, in that it assumes that the labs have adopted technology transfer as a goal and the lack of guidelines is what is blocking implementation of the laws. A subtler understanding of organizations points to the key role of the organizational mission. The strength of the preexisting organizational mission in the national laboratories is one of the greatest barriers to technology transfer. Organizational

mission determines not only the specific organizational goals, but the culture of the organization, as well. The 'culture of the national laboratories' is frequently cited as an obstacle to technology transfer. Indeed it is, and the reasons why will be examined.

1. Organizational Rules and Procedures

An early strain of institutional inquiry examined organizations in terms of procedures, rules, and structures (such as might be found on an organizational chart). Organizations need procedures, and new tasks need new procedures. So, in simplest view, adding a task to an organization requires only providing new rules and procedures. This rational view of organizations is no longer in favor academically, but is evidently still around in practice.

In 1980, Congress was trying not to change the labs, but to utilize the technology they had already developed. The task of technology transfer was seen as a simple addition to the labs' existing goals or mission that required a few new procedures and structures. Seen this way, one of the barriers to transfer is the lack of administrative action to create these procedures. Much of the criticism of the national labs has focused around their slowness in establishing the administrative practices and rules that would lead to CRADAs and other commercialization links. Congressional hearings and GAO reports stress this lack of responsiveness. A recent example of this kind of criticism is from a subcommittee report of the of the House Small Business Committee.⁸⁵

⁸⁵ House of Representatives. Committee on Small Business. "Technology Transfer Obstacles in Federal Laboratories: Key Agencies Respond to Subcommittee Survey". (March 1990). pp. 12-13. Highlights in original.

"Ineffective management from the White House. The White House Science Advisor--the nation's chief technology officer--has not taken the lead on tech transfer, overseeing the efforts of the executive departments and agencies.

"Unclear and sometimes conflicting directives on transfer from top-level agency and lab officials. No agency's transfer efforts can be taken seriously unless the cabinet-level (or equivalent) official makes an authoritative statement affirming the priority of transfer activities. As a result there are few detailed policies handed down from cabinet-level officials dictating aggressive transfer efforts.

"Vacancies in many technology posts in the federal departments. Currently, several important technology posts--including the Undersecretary for Technology in the Department of Commerce are vacant.⁸⁶

"Micromanagement of laboratories' activities. Although agencies must emphasize the importance of transfer, the labs should have authority over their own technology. In many cases, technology transfers--case by case--are decided by headquarters officials in Washington, D.C. causing delay, frustration, and ultimately failure for commercialization efforts.

"Lack of preference to federal contractors who promise to commercialize technology. Although the spirit of the Bayh-Dole Act requires that agencies--particularly the Department of Defense--encourage contractors which work for the government to keep and use the resulting inventions, federal contract administrators often give preference to companies which promise not to commercialize their inventions."

"The non exclusive nature of federal technology offerings. When labs do offer inventions, the method is often public disclosure--a means that necessarily cheapens the value of the technology to individual businesses.

More than proving the stubbornness of the national laboratory management, the difficulty of making administrative changes

⁸⁶ This was also true for more than six months into the Clinton administration.

through legislative fiat demonstrates the weakness of this procedural approach to organizational change. Formal rules are no longer the primary research approach in organizational theory as other, informal, determinants of organizational behaviors have been seen to be more pertinent. Researchers have discovered that changing an organization requires more than just changing rules. The people in the organization must act upon the announcement, and this does not always happen.

Stevenson-Wydler, itself, was guilty of this approach. To increase technology transfer, the law mandated the creation of Offices of Research and Technology Applications (ORTAs) at all labs (with total budget greater than \$20 million). But, when eventually created, these were often just a relabeling of patent offices, or a merger of patent with public information functions, and did not represent an adoption of a new goal. Similarly, Stevenson-Wydler mandated that each lab spend a certain percent of its total budget on technology transfer. This overhead charge was meant to fund various technology transfer activities. But this provision clearly failed. There was a provision in the law for a waiver of this, all labs requested the waiver, and eventually the requirement was dropped.

2. Organizational Mission and Goals

If procedures and rules are not the keys to understanding organizations, then what is? One way of understanding organizations is to start with their mission. The mission of the labs is frequently cited as a barrier to technology transfer. It will turn out that the organizational mission and the linked phenomenon of organizational

culture impeded both the adoption and the successful execution of technology transfer.

Mission is the overarching purpose that defines why an organization exists. According to Etzioni, serving its mission is the *raison d'être* of an organization.⁸⁷ While the mission is rarely written down, every organization must have one as a internal guide, or it will not survive the inevitable unexpected shocks from outside.

Schein suggests that there is a cycle that every organization goes through as it copes with its external environment, that in some sense flows from its mission. First, a core mission and strategy is developed. Second, goals derived from this mission are determined. Third, means to attain the goals must be arrived at, such as procedures, rewards and authority systems. Then, measurement to assess goal fulfillment is necessary. And, finally, there must be correction through repair or remedial strategies when goals are not being met. Though in an existing organization these go on simultaneously, there is clearly a hierarchy to these processes.⁸⁸

In any organization the mission is usually defined by the leader. Indeed, as Schien points out, this is something that the leader must do. In governmental organizations, though, the mission is often more a product of compromise between conflicting political impulses.

For the national labs, their mission has always been clearly articulated: to provide research into long term energy needs, or in the case of the weapons labs, to provide practical nuclear research for national security. The goals that derive from that mission are to

⁸⁷ Amitai Etzioni, Modern Organizations, 1964. p.5.

⁸⁸ Schein, Organizational Culture and Leadership, (1985) ch. 3.

achieve excellence in the research projects that the lab takes on to support the mission. The means of achieving the goals are reflected in the rules and procedures, rewards and incentives of the labs.

Not only do specific goals flow from the mission, but an organizational culture develops that reinforces the mission and supports the goals. One of the ways organizations resist change is by having this common sense of purpose or mission. Wilson points out that all organizations resist change because, at root, that is their function.⁸⁹ They are intended to create stability in an environment of change and confusion. They provide a structure within which people can work together to get things done. Only by fighting off the impacts of chance and uncertainty from the environment can they survive. Since the ultimate mission of the organization provides the group not only with guidance, but is one of the means of maintaining cohesion, attempts to force internal changes that conflict with the mission will be rejected.

3. Organizational Culture

One of the barriers to pursuing technology transfer, certainly in 1980, was that this new mission had difficulty being integrated into the labs' culture. It was not merely a problem of inertia that prevented technology transfer from being added to the labs mission. Conflicts were apparent between technology transfer and the old accepted way of doing things and seeing things. Researchers in both kinds of labs, basic research and weapons, were used to certain

⁸⁹ Wilson, Bureaucracy, (1989).

procedures, and responsive to certain kinds of incentives that were threatened by technology transfer.

In the national labs focused on basic research, the culture promoted generating knowledge for its own sake, it stressed the values of openness, and rewarded scientific progress. An emphasis on technology transfer would require more applied research, and stress awareness of the applications of projects. Stressing market applications conflicts with the scientific ideal of free choice of topic. Furthermore, patenting and licensing is almost the opposite of open communication, as the patent process requires secrecy and the licensing process also requires discretion. The rewards that reinforce the pure science approach are oriented around publications and peer acclaim. One of the problems with Stevenson-Wydler and Bayh-Dole is that they provided no alternative rewards to the researcher.

In the weapons labs the culture is different, but the results are the same. Technology Transfer initiatives, especially Stevenson-Wydler and Bayh-Dole, made little headway because of the accepted practices of these labs. Chief among them is the imperative for secrecy. The researchers are used to shunning any discussion of their work with outsiders--while this behavior is the key to building transfer linkages. Until 1989, national security concerns kept the weapons labs from being included in many technology transfer provisions. The provision of Bayh-Dole that allowed non-profit contractors to take title to patents did not apply to the non-profits operating the labs, because of security concerns over Los Alamos and Lawrence Livermore which are operated by the University of California.

Wilson makes three generalizations about the effects of organizational cultures that clearly apply to this case. "Organizations will resist taking on new tasks that seem incompatible with its dominant culture." This clearly describes the first reaction of the labs to technology transfer--resistance to the new task. "Tasks that are not part of the culture will not be attended to with the same energy and resources as tasks that are part of the culture." Insofar as technology transfer was grudgingly adopted, marginalization was the next organizational response. "Organizations with two or more cultures will experience serious conflict as the each culture seeks to become dominant."⁹⁰ Since technology transfer is only now becoming an accepted goal, with an attendant culture, this stage has yet to be played out. But this kind of conflict should be expected to occur.

Using, Schein's description of missions and goals, the same conclusion is clear: the reason why Congressional efforts to append technology transfer to the labs' goals failed, was that neither the ultimate mission nor the practical goals of the labs had changed. And without a prior change in these, adoption of technology transfer as a new goal was resisted because it conflicted with existing culture.

Stevenson-Wydler and Bayh-Dole also provided no incentives to the administrators of the institutions, indeed the opposite. Most important perhaps, no money was provided for technology transfer. There was no line item for technology transfer in the labs budget: the ORTA required by Stevenson-Wydler was to be funded out of an overhead charge on all research funds. Arranged this way,

⁹⁰ Wilson, Bureaucracy, (1989) p.101.

technology transfer actually costs the institution money. As late as October of 1993, as the labs were struggling to respond positively to technology transfer directives, the technology transfer function was not a line item. Most technology transfer in the weapons labs is funded out of an overhead charge on the defense research portion of their budget.⁹¹ As this amount decreases, the availability of money for technology transfer does also.

Given the foregoing discussion, organizational change seems very problematic. But, organizations do change their missions. Some may achieve their goal and rather than go out of business, seek a new goal. The March of Dimes is the most common example of this process. As polio was conquered, fighting birth defects was consciously chosen as the replacement mission.

Most private organizations adjust their missions only through strong leadership.⁹² But, the discussion in Wilson suggests that governmental organizations are subject to change in mission in a number of ways. Organized political forces can provoke institutional responses, as can other less well defined changes in their environment. I am arguing that the attention given to technology transfer by Stevenson-Wydler was not sufficiently strong an environmental impact to cause the labs to adopt technology transfer as an organizational goal.

The labs have slowly moved to adopt technology transfer, as three forces have converged: the radical reduction in the Soviet

⁹¹ Personal communication with John Russel in the technology transfer office at Los Alamos.

⁹² Schein, Organizational Culture. (1985).

threat in 1991, the increasing budget deficit and increasing public concern about it, and ongoing economic competitiveness concerns. The end of the Cold War seems crucial in the case of the weapons labs. Clearly, in 1980, this convergence of factors was not present, as President Reagan increased the Cold War rhetoric, as well as the lab funding. Competitiveness concerns and the early legislative efforts were insufficient to provoke a change in lab mission or goals.

4. Cultural Differences between National Labs and Industry

Even as they have become motivated to accept technology transfer as a new institutional goal, the labs have had difficulty doing technology transfer. Organizational Culture still looms as an obstacle to the interaction between the national laboratories and industry--one of the key linkages that Teich and Lambright described. Here the problem is the difference in organizational cultures of the labs and industry.

Organizational culture has been defined as "the pattern of basic assumptions developed by an organization as it learns to cope with problems of external adaptation and internal integration. These assumptions are taught to new members as the correct way to perceive, think and feel in order to be successful. They cover a wide range of issues: how to dress, how much to argue, how far to defer to the boss's authority, what to reward and what to punish."⁹³ These norms are enforced by a system of rewards and punishments. Organizational cultures can be identified by determining behavioral regularities, norms, and rules. Less concrete, but equally important

⁹³ Pugh, Hickson, and Hinings, (1985), p. 197.

are the dominant values, the climate of interaction, and the corporate philosophy.⁹⁴

Problems for technology transfer occur as the different cultures of the national labs and corporate R&D try to interact.⁹⁵ The prevailing culture at most federal laboratories emphasizes basic research, independence, and open exchange of ideas. Rewards are given for performance judged by other scientists, such as publications and conference talks. Science for its own sake is valued greater than any resulting applications. The culture of the weapons labs emphasizes secrecy, and execution at any price. As described by Carr, the usual procedure there is to accomplish the mission, figure out the cost, bill the government.⁹⁶

The culture of the industrial lab differs from both. It emphasizes practical applications of research, commercialization, and cost effectiveness. Time and money are always emphasized. When these organizations meet, they rarely understand each other. The businessman often reacts negatively to governmental bureaucratic procedures, not seeing the rationale for them. The lab researcher may not appreciate business's need to move quickly (and quietly). While by no means highly developed, the industry researcher has a greater sense of market needs and tastes than his national lab counterpart.

⁹⁴ Schein, Organizational Culture. (1985).

⁹⁵ This point is made in many places, for two examples see: DeBruin, "Innovation, the Economy, and the Federal Laboratories" (Dec. 1991) p.13; GAO Report, "Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness". (1993) pp.36-7.

⁹⁶ Carr, "Doing Technology Transfer in the Federal Laboratories", (1992) p.10.

The differences in these cultures create impediments to technology transfer from the national lab to industry. Overcoming cultural differences is never easy. Every group is convinced of the merit of its ways. In general, the two ways of bridging the gulf are to make one organization more like the other, or to create intermediary institutions whose mission is to bridge the cultural divide.

In practice, the first choice means changing the national labs, specifically by changing or adding to their mission. The difficulty here has already been mentioned. Organizations seeking to change themselves must be aware of the sensitivity of employees to their existing cultures. Lab researchers report that one of the reasons they sought employment within the federal laboratories was that the culture was different from industry.⁹⁷ The difficulty of changing organizational culture will probably persist for years. Even if a new mission is adopted, implementing it fully will require change in attitudes at all levels, down to the bench scientists.

The other choice is to create new institutions. It is suggested that new infrastructures, such as university-industry-government consortia, show promise in bridging this culture gap.⁹⁸ The ARCH organization developed by Argonne and the University of Chicago is an example of an institutional innovation intended to create lab-

⁹⁷ GAO report, "Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness". (1993).

⁹⁸ Feller, "Recent Theoretical and Organizational Approaches to U.S. Technology Policy." (1992); Subcommittee report to the House Science, Space, and Technology Committee, "Transfer of Technology from Federal Laboratories and Universities", (July 1991) p. 15.

industry linkage without deleteriously affecting the lab culture.⁹⁹ ARCH is committed to setting up new companies as the way to commercialize inventions from these two labs. Experimentation with new institutions, it has been suggested, is necessary to form the interconnections between the different units of the technology system. This will require a long term perspective, willingness to replace organizational arrangements that do not work, and a patient long term perspective.¹⁰⁰

Stevenson-Wydler was clearly intended to create new forms of interactions and new organizations to house them. The Centers for Industrial Technology were meant to include individuals from industries, universities, and the labs in research useful to industrial firms. These Centers were also meant to disseminate technical information among universities and industry and aid small company startups. The Center for the Utilization of Federal Technology was intended to be an active coordinator for information and expertise across all technology transfer and technology development efforts.

While Stevenson-Wydler was not fully implemented, calls for adding technology transfer as a goal for the national labs increased throughout the Eighties. Buffeted by external political and social changes, the national labs have recently shown some willingness to add technology transfer to their mission. The development of new institutions that might overcome the gap in organizational cultures is

⁹⁹ ARCH described at AAAS meeting by Steven Lazarus, Feb. 13, 1993.

¹⁰⁰ See the discussion in Feller, "Recent Theoretical Approaches" (1992).

now slowly proceeding, the (non) implementation Stevenson-Wydler delayed these experiments for about a decade.

E. The Individual and Technology Transfer

Perspectives that focus on organizations can lose sight of the individual. While, the individual has been mentioned in passing in terms of incentives provided by organizations, attention has not yet been focused directly there. What role does the individual play in transfer? While Stevenson-Wydler nor Bayh-Dole directed attention specifically at the individual researcher, subsequent legislation has. However, the results are not yet clear.

It is often said that technology transfer is a 'person to person activity'.¹⁰¹ If this is true, then perhaps it is the characteristics of the individuals involved that determine technology transfer success. According to John Preston, Director of the MIT Technology Licensing office, the key agent in the technology licensing process is the "motivated inventor".¹⁰² The real question is can an interest in commercialization be encouraged that will increase technology transfer. While more outgoing personalities might be better at the interpersonal aspects of technology transfer, it is unclear how much these characteristics of lab researchers can be manipulated. It was suggested by one of patent attorneys that I interviewed that the best way to increase technology transfer would be to "get the inventor

¹⁰¹ Hittle provides seven citations for this, I am sure there are hundreds more. Hittle, Technology Transfer through Cooperative Research and Development (1991).

¹⁰² Eberlein, Technology Transfer at MIT : an Analysis of the Technology Licensing Office. (1989) p. 65.

involved through financial incentives."¹⁰³ Though the Stevenson-Wydler did little in this regard, later legislation did seek to create direct and indirect incentives for the researcher.

The 1986 Federal Technology Transfer Act law mandated that technology transfer be included in job performance evaluations of federal laboratory workers. And, perhaps more significantly, a provision in the same act directed the labs to give not less than 15% of any net licensing revenue to the researcher responsible for the invention.¹⁰⁴ The assumption is that people, attracted by financial rewards, can change their behavior--specifically, they would patent licensable ideas and work toward their transfer.

However, it is unclear whether this is true. A recent GAO report interviewed a number of lab scientists and found that only a few of them said that "royalties of more than a nominal sum would encourage them to report and patent inventions." On the contrary, a number of non-monetary rewards were described. Many said that the recognition of their peers and personal pride were more rewarding than money. Indeed, researchers in the national labs who have engaged in development often cite their pride in seeing their project used by others as motivating them. Others said that receiving a patent validates their feeling that they have accomplished something totally new.¹⁰⁵ Given these reactions, it is uncertain whether financial incentives would increase patenting.

¹⁰³ Personal communication with Vale Myles, patent attorney at Brookhaven.

¹⁰⁴ Brookhaven National Laboratory has instituted an aggressive reward policy. Fifty percent of the first \$100,000 in net license fees go to the inventor, 25% of the next \$400,000, and on a sliding scale to 10%. (The practical problem here being the determination of "net licensing fees".)

¹⁰⁵ GAO report "Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness," (Dec. 1992). p.35,36.

Though this legislation was passed in 1986, its implementation has been slow. According to the same GAO report, most federal labs had not effectively implemented reward systems--and patenting behavior had not changed measurably in the labs of 17 out of 21 departments and agencies. Because of implementation problems, there is no evidence that monetary rewards are sufficient to alter behavior.

Policies that focus on individual incentives for measures beyond patent licensing have not yet been part of the technology transfer discussion. The incentive mentioned above is rather narrowly directed at increasing patent licensing. It does nothing to increase contacts between the lab researcher and his industry counterparts. It does nothing to encourage individual entrepreneurship, nor to foster personnel movement to new or existing companies. It has been suggested that perhaps a policy could be developed that allows lab researchers to move to the private sector, while preserving their pension and other rights at the labs, if the start-up fails.¹⁰⁶

Indeed, insofar as the culture of the labs is built upon creativity and independence, it may be unlikely that monetary rewards will have any effect.

F. Technology Transfer As Part Of A Larger Process

This chapter will close with two ways of viewing technology transfer as part of a larger process. These are the new product

¹⁰⁶ Branscomb, "National Laboratories: The Search for New Missions and New Structures," in Branscomb, ed: Empowering Technology. (1993).

development process, and innovation. The lessons from new product development are two, some conception of market needs is necessary as early as possible, even as early as the definition stage. And, there is often a 'development gap' perceived by industry in regard to lab-developed technologies. This gap refers to a technical idea that has not proceeded far enough for a market or financial evaluation to be performed. The lesson from innovation theories is that the most innovative organizations are self-consciously located in a web of buyers, sellers, and competitors, all of whom can be constantly on the lookout for new ideas. And if the national labs are to be most useful, then they must integrate themselves into this system.

The danger of roaming far afield is great here, as each of these subjects has a large, well developed academic literature, so I will try to make only a few points about each field.

1. New Product Development

Perhaps because it is so obvious, the point is rarely made, but technology transfer can be seen as one step in the new product development process. There is a large body of management literature that tries to understand the new product development process. Most of these models are characterized by a step approach, although many emphasize the limitations of a 'ladder model'.¹⁰⁷

Following Callantone and di Benneto, the steps of the new product development process are: idea generation, screening, concept

¹⁰⁷ See: Gomory, "From the Ladder of Science to the New Product Development Cycle" Harvard Business Review, Nov/Dec., 1989 Gomory strongly advocates a recursive approach to commercialization of technology which links the refinement of existing products to research and development.

testing, pre-test marketing, financial analysis and risk reduction, product development and testing, test marketing, and product launch.¹⁰⁸

The idea generation stage consists of “analyzing or synthesizing information about markets, technologies, approaches, or procedures, from which is generated an idea for a new or improved product or service, a new technical approach or procedure, or a solution to a challenging technical problem.”¹⁰⁹ For our purposes the idea generation stage is clearly pre-transfer, but nonetheless there is an important lesson contained in this definition. Seen as the first step in product development, as opposed to the first step in “R&D”, idea generation necessarily includes some market focus. This indicates, once again, that technology transfer from the national labs will face a hurdle if a market orientation has to be patched onto a new technical idea.

The next stage is screening. “Concepts and ideas for new products must be evaluated on a number of key dimensions: feasibility of manufacture, likely cost of further development, expected production and marketing costs, fit with company goals, and likelihood of acceptance in the marketplace.”¹¹⁰ Since, the ability to make these judgments does not reside in the national labs,

¹⁰⁸ Callantone and di Bennetto, Successful Industrial Product Innovation, (1990).

¹⁰⁹ Roberts and Fusfeld, “Staffing the Innovative Technology Based Organization,” Sloan Management Review, Spring 1981, pp.19-34. Rreprinted in Tushman and Moore (1988), p.313.

¹¹⁰ Callantone and di Bennetto, Successful Industrial Product Innovation, (1990) p.24.

idea evaluation must take place after a technology transfer contact is made, but before the transfer is completed.

Next is concept testing and pre-test marketing. The literature here is replete with talk of focus groups, employee panels, use testing, product characteristics, psycho social cues, perceptions, and preferences. Clearly, most of this discussion is directed toward consumer products introduced by large corporations, and clearly this skill does not lie within the national laboratory. But asking for this expertise from an intermediary organization, such as a business incubator or a venture capitalist, that could be associated with a national laboratory, is not absurd.

Financial analysis and risk reduction is a key stage in the new product development, and often a key stumbling block for technology transfer. Within a large innovative corporation, the product manager must assess the risk of new product development at many stages. In the process of technology transfer., the receiving company will usually want to evaluate the risk before committing to the transfer. This may be difficult if the innovator has not performed some preliminary market testing. Then, the problem may become a Catch-22, without a financial analysis the transfer is not made, and without some transfer interest, the financial analysis is not made. Steele et al suggested that the projects at the national laboratories budget money for this kind of financial analysis. Though I have suggested above that in the best case the industry partner, already involved in the project, will be willing to make this investment.

The final stages--product development and testing, test marketing or sales forecasting, and product launch--are all clearly post-transfer functions of the developing organization, so the discussion will end here.

The most obvious benefit of seeing technology transfer as part of new product development is that it makes clear that technology transfer is not a national laboratory problem, but a mutual problem of the national labs and whomever tries to commercialize the technical idea. And, ultimate success is judged by economic performance. The most obvious drawback of this approach is the tendency to see the process as both discrete and linear. This can reinforce an over-the-wall attitude to technical development, where each functional group is isolated from the next. This stepwise conception can hide the critical need for interactions by people with ostensibly different tasks.

The barriers to technology transfer are the lack of necessary market awareness early in the process, the lack of marketing skills later, and the difficulty in interesting a developer without some level of financial risk analysis. Stevenson-Wydler took direct aim at this problem. The activities of the Centers for Innovative Technology were to include: "assistance to individuals and small businesses in the generation, evaluation, and development of technological ideas supportive of industrial innovation and new business ventures; technical assistance and advisory services to industry, particularly small business; and curriculum development, training, and

instruction in invention, entrepreneurship, and industrial innovation."¹¹¹

This never happened. (See chapter 5.)

2. Innovation

Another process into which technology transfer can be fit is innovation. Unfortunately, this does not narrow the scope of the discussion, rather this widens it dramatically.¹¹² An ever growing body of literature seeks to understand innovation.¹¹³ The many models range from very simple linear ones to very complex, feedback models.¹¹⁴ Like all models, the more realistic ones tend to be more complicated.

Forrest, in a review of numerous models of the innovation process, finds them all more or less lacking for having left out one or another factor. For our purposes, it is interesting to note that "the all important idea generation and screening or pre-innovation process stage is overlooked in the majority of models."¹¹⁵ This is significant because this is the realm of national laboratory technology transfer--the movement of ideas between idea generation and idea development. The message here is that many managers or management thinkers limit their concerns to the development process. They take the idea generation stage for granted, and

¹¹¹ Section 6, (b), 2,3,4. 94 Stat 2314.

¹¹² A good, single volume reader in innovation is Tushman and Moore, Readings in the Management of Innovation, Harper, 1988.

¹¹³ One of the best treatments of basic issues is Tornatzky, The Process of Technological Innovation. (1990).

¹¹⁴ See for instance Klein and Rosenberg's "Chain Linked Model" described in Kline, "Models of Innovation and Their Policy Consequences." (1989).

¹¹⁵ Forrest, "Models of the Process of Technological Innovation." (1992) p. 447.

therefore are not alive to the opportunities presented by technology transfer of ideas generated elsewhere.¹¹⁶ This supports the point that part of the effort of the national labs must be simply to educate business people about what they have to offer.¹¹⁷

One model that is fairly simple yet helpful has been developed by Roy Rothwell. His model of innovation stresses the need for organizational interconnectedness and interdependence. The innovation process as Rothwell describes it is not only interfunctionally integrated within the firm (marketing, engineering and R&D working together), but the firm is integrated in a network of other firms, both vertically and horizontally (suppliers and competitors). "Innovation includes fully integrated parallel development; strong linkages with leading edge suppliers; strategic integration with primary suppliers, including co-development; strategic alliances where appropriate; an emphasis on corporate flexibility and on development speed; and focus on quality and other non-price features." One of the most significant features of the fifth generation model is the use of the new electronic toolkit. This includes linked CAD/CAM systems, linked supplier-assembler CAD; simulation modeling replacing physical prototyping; and use of expert systems.¹¹⁸

¹¹⁶ This problem has been described as the N-I-H syndrome, "not invented here." Since this is never discussed systematically, and is probably a sensible reaction to limited organizational time and effort, I have chosen not to discuss this notion here.

¹¹⁷ Carr, "Doing Technology Transfer in Federal Laboratories", (1992) p.22; Steele et al, "The Technology Innovation Act of 1980, Ancillary Legislation, Public Policy, and Marketing: The Interfaces." (1990).

¹¹⁸ Rothwell, "Developments Toward the Fifth Generation Model of Innovation." (1992) p. 74.

Rothwell's model is normative as well as positive. It is intended to goad firms to integrate, innovate, and celebrate. He seeks to expand thinking about R&D beyond the pipeline model, to a more accurate vision of innovation as a complicated process with many feedback loops and simultaneous functions. In the context of the national laboratory technology transfer., this model can serve to remind companies to seek out innovative ideas from external sources such as the national laboratories.

Barriers highlighted by this approach to technology transfer are the inability of the national laboratory, by its nature as a government R&D center, to become fully integrated into a network of suppliers and customers. The best way to address this is to increase the participation of sections and groups of researchers at the national labs in industry research groups and consortia. This is indeed happening.

Sandia, for instance, now sees the best way to leverage its technical capabilities is to act as a catalyst for local and national industry consortia.¹¹⁹ These kinds of groups may perform the function of integrating the national labs into a network of scientists and engineers working on similar projects, thereby increasing commercial contacts with the national labs, increasing the relevance of national laboratory research, and increasing the resources of the civilian industrial sector as a whole. Theories that emphasize the recursive nature of the innovation process, make clear the need to

¹¹⁹ Olen Thompson, head of technology transfer office Sandia. Personal communication.

develop numerous links with the industrial and commercial sectors to most fully transfer technology.¹²⁰

Stevenson-Wydler's authors had this kind of fuller integration into commercial practice in mind. Industry-lab personnel exchanges were planned, advisory boards that would direct lab research into areas relevant to industry were described, active information exchange would be facilitated, diffusion of best most current technology to industry users was mentioned. Alas. (See chapter 5)

G. CONCLUSION

This section has detailed seven ways of understanding technology transfer. Only Technology Push suggests that there should be no problems ahead of technology transfer in this context. All other perspectives point to either the difficulty of getting the labs to adopt technology transfer as a goal, or the difficulty of succeeding at transfer through patent licensing.

The limits of a patent licensing approach are highlighted by the communication, interorganizational and the individual perspectives. Focusing on the individual highlights the lack of monetary reward for helping to transfer technology. The interorganizational perspective and the communication perspective point to the same conclusion, that the barriers to development are reduced when potential developers are involved early in the development process. The serious limitations of the patent licensing approach are also made

¹²⁰ CRADA's are not the only way to accomplish this, the kind of industrial review board that Winebrake advocates would help make relevant even work that is not being done cooperatively with industry.

clear by seeing technology transfer as part of innovation or new product development. Here, the complexity of the task contradicts the simplicity of the licensing approach. Also impeding successful transfer through licensing is the lack of familiarity with the market and the lack of publicity for transfer opportunities.

While these difficulties are important, they are in a way tactical problems. The strategic issue involves getting the labs to want to succeed. Crucial to the eventual success of national laboratory technology transfer is to get the labs to embrace this new function as an organizational goal. Organization theory perspectives shows that the existing mission, goals, and culture of the national labs all worked against the adoption of technology transfer. Without strong incentives or deep changes from their environments, no real changes should be expected from the labs.

Stevenson-Wydler set out to redefine the role of the national labs in technology development. The non-implementation of this part of the law meant that the status quo would prevail. Pending a decision within the labs to truly take up technology transfer as a goal, a multitude of problems awaited any legislative approach that saw its task as merely assisting spinoff.

CHAPTER FOUR: BARRIERS TO TECHNOLOGY TRANSFER

This section is intended to be a short review of the preceding chapter.¹²¹ It is especially concerned with delineating all the barriers to technology transfer that existed in 1980. Those who sought to add technology transfer to the organizational repertoire of the national laboratories faced a monumental task. For Stevenson-Wydler and Bayh-Dole to have caused significant changes would have been near miraculous.

The following discussion uses Lambright and Teich's framework by grouping a number of barriers under the heading of obstacles to linking the labs and the market, and obstacles to linking the labs and the would-be developer. But, first I will integrate a number of problems under the heading of barriers internal to the lab. The discussion will conclude with a section on the barriers that result from overriding public considerations, barriers outside the process of technology transfer itself.

(Past tense will be used to emphasize that these are the barriers that existed in 1980. Some of them have been addressed, either by Stevenson-Wydler and Bayh-Dole, or by subsequent legislation.)

A. Barriers Internal To The Lab

The barriers to technology transfer that arose within the lab were procedural, legal, and financial. Also significant were the lack

¹²¹ Most discussions of technology transfer mention barriers. The citations in this chapter are taken from a limited number of works. Fuller references can be found in the discussion in the preceding chapter.

of leadership and guidance, the lack incentives to researchers, and conflicts with the traditional mission of the labs.

By procedural barriers, I refer to the observation that any new activity within an organization needs new procedures. Even in the case of a sanctioned reform, there will be a natural institutional inertia and resistance to change.¹²² Stressing the lack of guidelines to follow presumes that the labs were inclined to accept new procedures had they been given--which is most likely untrue. Nevertheless, well into the Eighties, complaints were raised that technology transfer was being held up through lack of guidelines.¹²³ Indeed, until the early 90's, labs had to get department-level approval for patent waivers and exclusive licenses, the reforms at the core of the 1980 legislation.

Beyond the need for concrete procedures, subsidiary organizations need guidance and direction to make substantial changes. Complaints have been lodged against DOE headquarters, as well as against the White House, for this failing.¹²⁴

Of primary concern all along have been legal barriers to technology transfer, particularly patent policy. The specific complaint regarding patents was the disinclination of the federal government to grant exclusive licenses to federal patents. This was seen as the prime barrier to the effective use of federally developed technology.

¹²² Carr, "Doing Technology Transfer in Federal Laboratories", p. 17.

¹²³ House of Representatives. Committee on Small Business. "Technology Transfer Obstacles in Federal Laboratories," (Mar. 1990).

¹²⁴ Committee on Small Business. "Technology Transfer Obstacles in Federal Laboratories," (Mar. 1990), pp. 12-3.

This was addressed by Bayh-Dole, which created a procedure for large business to follow to gain exclusive licenses. Bayh-Dole went beyond allowing exclusive licenses to give presumption of title to small businesses and non-profits for inventions funded by the federal government. Addressed by later legislation was need to grant title waiver to large firms and to all operators of the labs, including the operators of the weapons labs. Legal barriers not addressed by Bayh-Dole were the need for proprietary rights to data, and the disposition of software rights resulting from joint projects.

Financial limitations on technology transfer are of at least two types: the lab organization received no separate money for technology transfer, and the lab inventor had no financial incentive to get involved in transfer activities. While it is common for the Congress to require agencies to take on new tasks without allocating new money, this dilemma is usually solved by focusing only on those tasks perceived to be at the core of the agencies mission.¹²⁵ Until the national labs felt a change in mission, they gave mostly lip service to technology transfer.

Direct financial incentives to lab employees were instituted in 1986, though their effects have been equivocal. Implementation has been incomplete, and the lab researchers themselves report that financial rewards might not override the less intangible rewards of scientific pursuit.¹²⁶

The incentive and reward system of the national labs and of the scientific professions were not set up to encourage technology

¹²⁵ Fesler, Public Administration (1980).

¹²⁶ GAO, Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness. (1993).

transfer oriented inventors. Not only were there no financial rewards, but the existing intangible rewards worked against the behaviors required for technology transfer. The openness rewarded by pure science conflicted with the requirements of patent licensing. And, the secrecy necessitated by weapons work conflicted with industrial collaboration. In fact, it has been suggested that one result of successfully moving technology to industry is to put the labs out of a job--an obvious institutional disincentive.¹²⁷

The fundamental mission of labs, how the organizations define themselves, was an obstacle because the existing mission did not include commercialization. The mission was instead to explore fundamental research in the energy field, or to develop the basis for a sophisticated weapons program. Interacting with corporations was rarely considered an end in itself. Many have made the point that technology transfer must be integrated into basic mission of labs, in order to change the many organizational assumptions that work against adopting technology transfer procedures.¹²⁸

B. Barriers Between The Laboratory and Industry

Moving next to barriers between the national laboratories and private industry. One of the most obvious barriers to this relationship was that there was no relationship! That is, there was little information held by one side about the other. Private industry

¹²⁷ Teich and Lambricht, "Federal Laboratories and Technology Transfer: An Interorganizational Perspective", (1977).

¹²⁸ For just three recent examples: OTA Report "Making Things Better", pp.192-5; Carr, "Doing Technology transfer in Federal Laboratories (Part 1)"; Subcommittee on Technology and Competitiveness of the Committee on Science, Space, and Technology Committee. "Technology Transfer from Federal Laboratories and Universities.", July 1992, p.10.

did not know what kind of technologies the labs had to offer, or what services they could provide. Industry can't be the developer of what they don't know. And the labs had no knowledge of what business needed or whom to contact if they did want to make connections.¹²⁹

Another problem here is the development gap. When the lab did make contact with a company, offering a new technology, often the complaint was that the technology was not scaled up to where the firm could evaluate it.¹³⁰ Many interactions left firms with the conviction that the labs didn't understand their requirements.

Even if these knowledge or technical development issues did not exist, there were the problems that arose as two different types of organizations interacted. Business, who value speedy development, especially in high technology, have been frustrated by the slow pace of negotiation or implementation of agreements. They may not appreciate the public concerns that force bureaucracies to work the way they do. On the other hand the labs may fail to see business's need to act quickly.¹³¹

The less concrete value clashes of the two types of organizations can be just as abrasive. Open communication versus

¹²⁹ Carr, "Doing Technology Transfer", (1992) p. 17. Marone and Ivins, "Problems and Opportunities in Technology Transfer from the National Laboratories to Industry", (1982) p. 39.

¹³⁰ Committee on Small Business. "Technology Transfer Obstacles in Federal Laboratories," (Mar. 1990), p.13; and Subcommittee on Technology and Competitiveness of the Committee on Science, Space, and Technology Committee. "Technology Transfer from Federal Laboratories and Universities", p.11.

¹³¹ Carr, "Doing Technology Transfer".

secrecy, patenting versus publishing, different attitudes towards cost, and the not-invented-here syndrome all kept the two cultures apart.

Possible solutions to bridging this gap may lie in creating new institutions.¹³² Research consortia, industry advisory boards, electronic networks that did not exist then, are all possible forms now being suggested and developed.¹³³

C. Barriers Between The Laboratory and the Market

Teich and Lambright also stress the need to link the lab and the market. There were three barriers here, the lack of market knowledge, the lack of marketing skill, and lack of support for spinoff companies that do move an idea toward the market.

The lack of market knowledge was an overriding problem for the labs. Lab researchers were often unfamiliar with the potential applications of their projects and had little contact with potential developers. Potential users were even more remote. If the transfer involved an area far afield of the researcher's expertise, then early links to the potential user are essential.¹³⁴ The lack of market experience points to a problem for technology transfer that is rarely mentioned. Technology transfers can fail because the technical idea is not viable. The market will demonstrate this soon enough, but the

¹³² Feller, "Recent Theoretical and Organizational Approaches to U.S. Technology Policy"; Carr, "Doing Technology Transfer".

¹³³ Rothwell, "Developments towards the Fifth Generation Model of Innovation".

¹³⁴ Teich and Lambright, "Federal Laboratories and Technology Transfer".

sooner the better.¹³⁵ Familiarity with user constraints would help the labs reduce this kind of failure.

Similar, but not identical was the lack of marketing skill and resources at lab. To license new technology, applications must be identified, then information must be targeted and interactions promoted.¹³⁶ Since all organizations are resistant to change, not just federal labs, the labs need to sell industry on what they have to offer. They can not simply wait for industry to come to them.¹³⁷

Finally, the labs needed to conceive of technology transfer as complete process. An out-the-door approach was often taken to commercialization, where moving the idea out of the lab was the end of the transfer. One of the manifestations of this myopia was a lack of support for spinoff companies.¹³⁸ Most labs in 1980 had no links with new business incubators, nor could they give management support, marketing assistance, or financial assistance. This limited vision impeded the ultimate success of technology transfer.¹³⁹

D. Barriers Arising From Public Interest Concerns

Finally, moving outside the range of Teich and Lambright's scheme, and outside the process of technology transfer itself, there are barriers that arise from concern for the public interest. These

¹³⁵ Marone and Ivins, "Problems and Opportunities in Technology Transfer", (1982).

¹³⁶ Steele, et al.

¹³⁷ Marone and Ivins, "Problems and Opportunities in Technology Transfer", (1982).

¹³⁸ Marone and Ivins, "Problems and Opportunities in Technology Transfer", (1982); Soderstrom et al. "Improving Technological Innovation through Laboratory/Industry Cooperative R&D". Oak Ridge may have been an exception at that time.

¹³⁹ OTA Report "Making Things Better", (1990).

are not the kind of barriers that can be 'solved'. They are: Anti-trust concerns, desires to protect against unfair competition, issues of private gain at public expense, conflict of interest concerns, and last but not least, national security issues.

Anti-trust concerns have traditionally been a strong constraint against inter industry collaboration in the U.S. Yet, some of the most promising opportunities for increasing research productivity lie in this area. Insofar as the labs have sought to transfer technology by getting involved in research consortia, this has been a problem.¹⁴⁰ The 1984 National Cooperative Research Act permitted private firms to perform collaborative research (in a non-profit environment). Though on the Congressional agenda recently, as yet unrealized are calls to legalize collaborative manufacturing links. Anti-trust feelings may prevent this from kind of law from passing.

Concerns over unfair competition are another restriction on the labs' ability of expand into the private sector. For instance, in doing 'work for others', the labs are prohibited from performing any service, like consulting, that is offered commercially.¹⁴¹ This reflects a concern over unfair competition, since the labs do not have to price these services to make a profit. Undercutting commercial services can be an unintended consequence of labs' efforts to be more commercially relevant.

¹⁴⁰ Committee on Small Business. "Technology Transfer Obstacles in Federal Laboratories," (Mar. 1990), p.12-13; and Subcommittee on Technology and Competitiveness of the Committee on Science, Space, and Technology Committee. "Technology Transfer from Federal Laboratories and Universities", p.10.

¹⁴¹ OTA Report "Making Things Better", (1990) pp. 192-5; Marone and Ivins, "Problems and Opportunities in Technology Transfer".

An issue that has not been dealt with fully is the problem of private gain at public expense. Since national lab technology transfer means putting publicly developed ideas at the disposal of private companies, there is a concern for fairness. Do the companies that use the national labs' resources get an unfair advantage over those who do not. If so, is it a problem or is it just tough luck. Is equality of opportunity enough to address this problem, or is it even possible. Small companies, for instance, are less able to access national lab technology through CRADAs since they have small or nonexistent research budgets with which to cost share. Forcing the labs into danger is the corporate desire for speedy action on proposals to develop a hot technical idea from within the lab. Balanced against this pressure must be a concern for fair access to the profitable ideas within the labs.

Another conflict of interest issue is whether it is fair for lab researchers to form start-ups to develop ideas originating within the labs? Balanced against the pressure to commercialize or help existing companies must be a concern for equal opportunity at the profitable ideas within the labs. This issue will continue to nip at the heels of those who push for aggressive technology transfer policies.

The conflict of interest of researchers who take positions in two organizations that may do business with each other is another concern that slows the rush to bring the labs and the market closer together. This is a concern especially in the biotech field, but surfaces elsewhere as well.¹⁴² University and lab researchers in

¹⁴² Carr, "Doing Technology Transfer", (1992) p.18; Soderstrom et al. "Improving Technological Innovation", p.142.

basic health sciences are often called upon to perform the public service of analyzing scientific claims. As these researchers become linked to the commercial world, the possibility of conflict of interest arises.

Legitimate national security concerns obviously take precedence over the desire to facilitate technology transfer. National security is an obstacle to technology transfer when the risks are that nuclear secrets or sensitive materials or processes might fall into enemy hands, or when nuclear proliferation is at stake.¹⁴³ Since the dissolution of the Soviet Union in 1991, this is less on people's minds, but it is still a real concern. This was more of an obstacle in 1980, when the desire to maintain the secrecy of the weapons labs was much greater than it seems now.

Not only did this limit the ways researchers interacted with others outside the labs, it impacted the ways technology transfer advocates saw the weapons labs. What are now seen as opportunities to be developed, were then strictly off limits. Only later in the decade did the sophisticated manufacturing expertise that is required for bomb assembly come to be seen as a source of competitive advantage for the metal working industry.¹⁴⁴ For instance, the Kansas City Plant, which assembles the non-nuclear components of nuclear weapons, is now a center of diffusion for the most sophisticated machining technology. Early in the decade it was seen as top secret. This way of thinking kept the weapons labs out of the realm of early technology transfer legislation.

¹⁴³ Carr, "Doing Technology Transfer", (1992) p.18

¹⁴⁴ DOE publication, Technology Transfer 92/93 (1993).

E. Conclusion

In 1980 there were many roadblocks to creating an effective technology transfer policy in the national Laboratories. These obstacles lay within the labs, between the labs and industry, between the labs and the market, and arose from overarching societal considerations. Together, these barriers seem to create an impenetrable front facing the adoption of technology transfer. But this does not necessarily mean that Stevenson-Wydler and Bayh-Dole could not succeed. First, the precise content of these laws must be examined to see what ammunition they provided to attack this array of barriers.

CHAPTER FIVE: DETAILS OF STEVENSON-WYDLER AND BAYH-DOLE

What follows are the details of the Stevenson-Wydler Technology Innovation Act of 1980 (PL 96-460) and the Amendment to the Patent and Trademark Act. (PL 96-517) known as the Bayh-Dole Act. Understanding the provisions of the laws is, of course, essential to predicting whether they would have any effects or not. What makes the laws significant is that both represent legislative responses to the economic conditions of the late Seventies. Both were intended to spur innovativeness by facilitating access to federal technology. But in the end, neither could deliver the goods. Bayh-Dole was limited because its radical changes were applied too narrowly, effectively leaving out the national labs. Stevenson-Wydler was limited not in its conception--its conception was right on target--but by its implementation.

A. Bayh-Dole

The legislative history indicates that Bayh-Dole was not a mere patent reform bill, but part of a larger attack on this innovation problem. It declared that "the effective commercialization of government financed research is becoming an ever more important issue for those who are concerned with industrial innovation." "The patent policies governing the utilization of government funded research will become even more important" when alternate energy research begins to produce usable new technologies. The law declared that "it is the policy and objective of the Congress to use the

patent system to promote the utilization of inventions arising from federally supported research or development".

The Bayh-Dole Act addressed three principal issues.

First, it provided for a system of administrative reexamination of patents within the patent office. Second, it provided a new fee structure for the patent office. Third, and most relevant for this study, it provided for a new policy governing the disposition of patent rights in government funded research.

The new, uniform, policy replaced the differing policies of 26 agencies then in effect. The new policy was bifurcated; small businesses and non-profit institutions, including universities were treated one way, and large businesses another. The legislation establishes a presumption that ownership of all patent rights from government funded research will belong to the contractor if they are a small business or not for profit corporation. A crucial exception against this right is for contractors of government owned research labs--they were not covered. Large businesses were allowed to receive exclusive licenses for specific, stated uses they intend to commercialize, with departmental approval. A procedure was provided that was intended to guarantee swift action--within 90 days--on requests for exclusive licenses.

Specifically, the law states:

The ability of non profits or small business to take patent title is presumed, but it may be provided for otherwise in the funding agreement in three scenarios: if the agreement is for the operation of a government owned research or production facility; or if it is determined that exceptional circumstances mean that the policies of this bill will be better promoted by not giving title; or if national

security concerns, especially regarding intelligence activities, take precedence.

The non-profit or small business must file a disclosure of the invention to the agency, actively elect to retain title, and file for a patent within a reasonable time, or the federal agency may receive title to the invention. The Federal agency always receives a nonexclusive, royalty-free license for its use of the invention. The contractor must report periodically on its commercialization progress, though such information is not subject to inquiries under section 552 of title 5, (Freedom of Information Act). The contractor must specify that the invention was federally supported and the government retains certain rights in the invention.

A non profit organization may not assign rights to the invention without federal approval. It cannot grant exclusive license to large business for more than five years. The law requires the nonprofit to share royalties with the inventor, and the balance of royalties, above administrative expenses, must be used for research or education.

If the contractor does not want the rights to the invention, the inventor himself may be granted them. The contractor may not be forced to license this or any patent by the sponsoring agency, without the written authorization of the agency head, subject to judicial review.

In all cases, the government retains 'march in' rights. The government may retake control of the patent rights, if it is determined that the patentee has not taken steps toward practical application of the invention, or if health or safety needs are not satisfied by the contractor, or if public use requirements are not being met, or if the licensee is violating requirements for domestic manufacture. The requirements for domestic manufacture are that products embodying the invention be produced substantially in the U.S. This may be waived by the agency if reasonable but unsuccessful efforts to manufacture in the U.S. have been made, or that domestic manufacture is not commercially feasible.

Agencies of the federal government are authorized to file for patents on which the government owns a right, title or interest. They are authorized to grant nonexclusive, partially exclusive or exclusive licenses to government owned inventions, as determined appropriate to the public interest. They may protect and administer

rights to their patents, and may transfer control of them to another federal agency.

The policy for licensing to large businesses: No federal agency may grant any license under a patent unless the person requesting a license has supplied the agency with a plan for the development and marketing of the invention--these plans may be treated as privileged and not subject of disclosure under sec. 552 of title 5. Licensing rights are to be granted only if the licensee agrees that any product embodying the invention will be produced substantially in the U.S. Exclusive or partially exclusive licenses may be granted only after it is determined that: 1 best interests of the fed government and the public will be served by the proposed licensee's intended plans and he has the ability to bring the invention to practical application, 2 the desired practical application has not been achieved under any non exclusive license to be granted or already granted, 3 exclusive or partially exclusive licensing is a reasonable and necessary incentive to call forth the investment of capital to bring about the invention's practical application, 4 the proposed terms and scope of exclusivity are not greater than necessary to achieve these ends.

Exclusive or partially exclusive licenses may not be granted if they lessen competition or result in undue concentration or maintain any other situations inconsistent with anti-trust laws. First preferences for licenses shall go to small businesses. Government inventions covered by foreign patents may also be licensed. A record of these licenses must be kept. Any license will contain provisions for: 1 periodic reporting on utilization efforts, 2 termination upon non execution of plan, 3 termination for violation of the domestic manufacturing clause, 4 to facilitate a necessary public use of the invention.¹⁴⁵

The Bayh-Dole Act's bifurcated approach to title and licensing, reflects a compromise in the traditional debate over patents to government sponsored research. It gives the contractor the patent title--acknowledged to be the best way to facilitate commercialization--but only when the contractor is a small business

¹⁴⁵ 94 STAT. 3019-25.

or non-profit organization. It allows large businesses to take exclusive licenses of government inventions--but only for declared uses. Though a compromise, this legislation represents a large shift away from the status quo, which was government retention of title to all DOE patents.

The public's traditional rights are addressed through various features of the legislation: The government, not the large business contractor, will obtain ownership of the patents. Exclusive rights to patents are granted only for specified fields of intended commercialization. The government retains the right to deny the ~~transfer of exclusive rights within 90 days.~~ Public interest, antitrust, and national security standards are to be applied by the government in the approval process. The developer is required to manufacture the invention domestically. Also, the requirements of the bill are intended to prevent the licensee from sitting on the invention. By retaining 'march-in' rights, the government holds the ultimate sanction over abuse--the ability to revoke legal possession of the patent.

The bill rationalized government patents by creating one single policy for all agencies. This meant that large defense contractors lost rights that they previously had--under DOD procedures they had been granted full title. But the legislation was intended to make life easier for contractors by reducing the number of different policies across agencies from more than twenty to only one, and by easing administrative delays. Delays were to be reduced by mandating government action within 90 days of the contractor filing an intended commercialization plan.

Bayh Dole was enacted Dec. 12, 1980 and its provisions regarding licensing went into effect then.

B. Stevenson Wydler

The Stevenson-Wydler Technology Innovation Act of 1980 (PL 96-480) is now seen as the first legislative attempt to promote technology transfer in the national lab setting. However the bill as passed was much broader in intention and approach. Like Bayh-Dole, Stevenson-Wydler was framed as part of a long term solution to the innovativeness problem. It attempted to create a new, more cooperative environment for government R&D in general. Stevenson-Wydler "provides for a multi-faceted approach to improving the environment in which industrial innovation occurs."¹⁴⁶ But its effects were diminished as most of its provisions went unfunded and ignored after the change in administrations in 1981. (This will be discussed below.)

1. Content of Stevenson-Wydler

The language in the preamble is worth quoting in full, as it shows the broad intentions of the writers.

"The Congress finds and declares that:

- 1 Technology and industrial innovation are central to the economic, environmental, and social well being of citizens of the United States.
- 2 Technology and industrial innovation offer an improved standard of living, increased public and private sector productivity, creation of new industries and employment opportunities, improved public

¹⁴⁶ Stevenson-Wydler legislative history, 94 STAT. 4893.

services and enhanced competitiveness of United States products in world markets.

3 Many new discoveries and advances in science occur in universities and Federal Laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon action by business and labor. Cooperation among academia, Federal Laboratories, labor and industry, in such forms as tt, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened.

4 Small businesses have performed an important role in advancing industrial and technological innovation

5 Industrial and technological innovation in the United States may be lagging when compared to historical patterns and other industrialized nations.

6 Increased industrial and technological innovation would reduce trade deficits, stabilize the dollar, increase productivity gains, increase employment, and stabilize prices.

7 Government antitrust, economic, trade, patent, procurement, regulatory, research and development, and tax policies have significant impacts upon industrial innovation and development of technology, but there is insufficient knowledge of their effects in particular sectors of the economy.

8 No comprehensive national policy exists to enhance technological innovation for commercial and public purposes. There is a need for such a policy, including a strong national policy supporting domestic technology transfer and utilization of the science and technological resources of the Federal Govt.

9 It is in the national interest to promote the adaptation of technological innovations to State and local government uses. Technological innovations can improve services, reduce their costs, and increase productivity in State and local governments.

10 The Federal laboratories and other performers of federally funded research and development frequently provide scientific and technological developments of potential use to State and local governments and private industry. These developments should be

made accessible to those governments and industry. There is a need to provide means of access and to give adequate personnel and funding support to these means.

11 The Nation should give fuller recognition to individuals and companies which have made outstanding contributions to the promotion of technology or technological manpower for the improvement of the economic, environmental, or social well-being of the United States.”¹⁴⁷

The bill's intent was to develop the links between government, industry and academia that are necessary to facilitate the innovation process, and to enhance the interaction of these institutions. It acknowledged the information and resources in the Federal laboratories and made an effort to improve the access and utilization to the technical resources within them.

The bill was intended to do five things:

I Establish organizations in the executive branch to study and stimulate technology. The bill directs the Secretary of Commerce to establish an Office of Industrial Technology. This Office would undertake policy studies on all aspects of technology innovation and public policy. It would also be in charge of the Centers of Industrial Technology.

II Promote technology development through the establishment of Centers for Industrial Technology.

The Department of Commerce and NSF were authorized to mutually support Centers for Industrial Technology. The objective of these Centers was multiple: 1) to stimulate and coordinate cooperative activities of individuals from industry and universities;

¹⁴⁷ 94 STAT. 2311-2.

2) to develop the generic research base, in which firms have little incentive to invest, but which may have economic or strategic importance; 3) to educate Individuals in the innovation process; 4) to improve dissemination of science, technological and engineering information among universities and industry; 5) to utilize the capability and expertise of Federal lab staff; 6) to become self supporting through generation of fees.

The activities of the Centers were to include: 1) research supportive of technological and industrial innovation, including cooperative industry-university basic and applied research; 2) assistance to individuals and small businesses in the generation, evaluation, and development of technological ideas supportive of industrial innovation; 3) technical assistance and advisory services to industry, particularly small businesses; 4) curriculum development training, instruction in invention, entrepreneurship, and industrial innovation.

The bill provided for the establishment of a National Industrial Technology Board, which was to review the activities of, and to give policy advice regarding the Office of Industrial Technology and the Centers for Industrial Technology.

III Stimulate improved utilization of federally funded technology developments by State and local governments and the private sector.

The bill declares it a policy that Federal technology should be fully used. "To this end the Federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector."

It mandated the establishment of an Office of Research and Technology Applications (ORTA) at each Federal lab, to be manned by at least one full time staffer (if the lab research budget was over \$20,000,000). It set funding levels for technology transfer activity at 0.5% of the research budget for each agency that runs a lab.

It specified four functions for these ORTAs. They were: 1) to prepare an assessment of each project that has potential for successful application; 2) to provide and disseminate information on federally owned or originated products, processes and services having potential application; 3) cooperate with and assist organizations which link that laboratory to potential users in State and local governments and private industry; 4) to provide technical assistance to requests from State and local government officials.

Also, it legislated the creation of the Center for the Utilization of Federal Technology in the Department of Commerce. This body was to serve as a clearinghouse for information on federal technologies, coordinate activities of ORTAs, and help state and local government find expertise,

IV Provide encouragement for the development of technology through the recognition of individuals and companies which have made outstanding contributions in technology or technological manpower. The National Technology Medal was created by this legislation to recognize individuals who have made significant contributions to technology development or to technical personnel development.

V Encourage the exchange of scientific and technical personnel among academia, industry and Federal laboratories. The law

declared that the Secretary of Commerce and the NSF jointly shall establish a program to foster the exchange of scientific and technical personnel among academia, industry, and Federal Laboratories. Such program shall include both federally supported exchanges and efforts to stimulate exchanges without Federal funding.

The bill also included a section authorizing the Secretary of Commerce to enter into cooperative agreements in order to assist "any activity consistent with the act". Total amount of the government contribution to any cooperative program was not to exceed 75% of the cost. Curiously, this section is almost never mentioned in the literature on Stevenson-Wydler. Never utilized, it may be seen as a precursor to CRADA's, legalized in 1986 and 1989.

2. Implementation of Stevenson-Wydler

Most of the new ways of increasing competitiveness embodied in the Stevenson-Wydler 'multi faceted' approach were never tried. Ronald Reagan was elected espousing a radically different diagnosis of the nation's economic ills. His cure did not include new government programs. Rather than an inherent economic malaise, Reagan saw government induced lassitude. The Reagan solution to problems of innovation was threefold: create tax incentives for technology development, reduce the burden of federal regulations, and generally remove government from the marketplace.

The new administration saw Stevenson-Wydler as antithetical to an approach that called for less government in the market. Given the excuse of an atmosphere of budget austerity, Joseph Wright, Deputy Secretary of Commerce could tell the House Science and

Technology Committee that "programs in Stevenson-Wydler requiring outlays of appropriations of federal funds will not be implemented."¹⁴⁸ This, of course, meant that most of Stevenson-Wydler was stillborn.

The Office of Industrial Technology was not created in the Commerce Department. The Office of Productivity, Technology and Innovation, a recently formed office in Commerce with a mandate similar to the Office of Industrial Technology, was slated for elimination.

No Centers for Industrial Technology were ever created. In addition to budget constraints, Wright declared that this program was essentially infinite, therefore its goal was absurd. "The Cooperative Generic Technology Center is specifically directed toward individual industries of applications, we will never have enough funding to spread across the board of American Industry, all of the specific applications that are needed in order to improve technology and productivity." He concluded that the Reagan policy to create tax cuts was preferable because it would allow business to interact, in research endeavors, with whomever they choose. The NSF representative at the hearing, justified his institution's refusal to create these centers by pointing to its preexisting programs to create University-Industry Cooperative Technology Centers.

The Center for the Utilization of Federal Technology (CUFT) never appeared, either. Some of the information dissemination functions planned for CUFT were shifted to The National Technical

¹⁴⁸ "Hearings on the Implementation Status of the Stevenson-Wydler Technology Innovation Act." House Science and Technology Committee. (1982)

Information Service (NTIS). But, NTIS is strictly a passive information service, and was in no position to coordinate the (now nonexistent) activities. Moreover, NTIS did not gain administrative control of patents, it only provided information; and, the NTIS did not have any information about Department of Energy patents. What is more, the early Reagan administration had plans to eliminate NTIS and privatize its functions.¹⁴⁹

No systematic program of exchange of industry, university and national lab personnel was ever formed. The requirement that the parent agencies of all labs allot 0.5% of their research budget turned out to be difficult to calculate, most agencies yearly took advantage of the waiver provision, and the requirement was eventually dropped. The Department of Commerce had not yet decided what to do about the National Technology Medal and the National Industrial Technology Board as of Summer 1981. Eventually, the first Technology Medal was awarded in 1985. And the Industrial Technology Board idea was never established.

A number of other programs within NSF in the spirit of Stevenson-Wydler also were canceled. The Intergovernmental Science and Technology Program, which promoted public sector technology transfer was eliminated in 1982. Also canceled were the Innovation Centers, where entrepreneurial advice was given and skills were taught. The small amount of money and coordination that the NSF supplied to the Federal Laboratory Consortium for Technology Transfer was also zeroed out at this time. These actions

¹⁴⁹ It must be noted that a close reading of the CUFT provisions did not create a source of 'adaptive assistance' for would-be technological innovators, as some witnesses at the oversight hearing in 1982 seemed to believe.

were justified by NSF spokesmen by reference to the budget cuts that forced it to concentrate on its basic mission of high quality science and engineering research.

What was left was two things. The bill declared that it was Federal Government policy "to strive to transfer federally owned or originated technology to State and local governments and to the private sector". And, it mandated ORTA's at all labs with R&D budgets over \$20 million. Only by this process of elimination did Stevenson-Wydler become a bill about technology transfer rhetoric and technology transfer offices.

3. Summary Of Implementation Of Stevenson-Wydler

The concrete proposals were listed in sections 5 through 13 of the bill. This section lays out the implementation of the various provisions.

Section 5: Office of Industrial Technology to be created within the Commerce Department.

Result: Implemented by the creation of Office of Assistant Secretary for Productivity, Technology, and Innovation.

Section 6: Centers for Industrial Technology to be created by Department of Commerce jointly with the National Science Foundation.

Result: Not established.

Section 7: Grants and Cooperative Agreements to be awarded by Secretary of Commerce to assist any activity consistent with this act.

Result: None awarded.

Section 8: National Science Foundation Centers for Industrial Technology. (Same as Section 6.)

Result: NSF funding for pre-existing program of University/Industry Centers continued on a reduced level.

Section 9: Provided for Department level coordination of affected agencies.

Result: None made.

Section 10: National Industrial Technology Board to be created to oversee Centers for Industrial Technology.

Result: Not established

Section 11: Center for the Utilization of Federal Technology intended to be an active clearinghouse for federally owned technologies, and coordinator of ORTAs.

Result: Passive clearinghouse established within the National Technical Information Service (NTIS), not involved in coordinating ORTAs, and not including all federal patents.

Section 11: Offices of Research and Technology Applications to be created in all federal laboratories.

Result: ORTAs eventually created at most labs.

Section 12: National Technology Medal to be awarded yearly.

Result: First medals awarded in 1985.

Section 13: Personnel exchange program to be established among academia, industry, and federal laboratories.

Result: Not established.

CHAPTER SIX: HOW TO MEASURE TECHNOLOGY TRANSFER?

Any study of changes in technology transfer policy is faced with a difficult problem: How to measure technology transfer? This question can be separated into two parts: How to measure changes in technology transfer efforts? And, how to measure changes in technology transfer results? The issues are interrelated, but separable. It is possible to imagine the labs actually increasing their attempts to transfer technology, but having no success. It is also possible to imagine an increase in technology transfer results without any real change in the level of technology transfer efforts. Nevertheless, this study treats these possible as distinct.

A. Measurement Models

The next point is that the measures will reflect a model. Bozeman and Fellows suggest that there are four models of technology transfer measurement: the out-the-door model, the political model, the opportunity cost model, and the market-impact model.¹⁵⁰ Lying behind these models of measurement are different ways of viewing technology transfer. The out-the-door model focuses on technology transfer simply as a function carried on within the national lab. The political model sees technology transfer as a part of a political strategy played out in a political environment. The opportunity cost model sees technology transfer as a competitor for institutional funds and attention. The market model sees technology transfer as an effort to generate economic activity.

¹⁵⁰ Bozeman and Fellows, "Technology Transfer at the U.S. National Laboratories: A Framework for Evaluation", (1988).

Using the out-the-door (of the technology transfer office) model usually leads to measuring some countable thing, such as licenses, CRADA's, information brochures, industry visits to the lab, lab visits to industry, or personnel exchanges. These measures have problems. Admittedly, they do not attempt to measure the results of the transfer. Most important, they do not take into consideration the differences, sometimes great, between items in the same category. Not all patents are equal, neither are all lab visits. For instance, a single patent license may lead to a revolutionary development, or it may be a modest increment to an accepted practice.

Recently, the Department of Energy has publicized its success in forming Cooperative Research and Development Agreements (CRADAs).¹⁵¹ The numbers and value of CRADAs are displayed as evidence of technology transfer success. Using this metric also has a number of problems. CRADA's are not the only means of transfer, so reliance on this measure excludes other means. More substantially, simple counts of CRADAs do not reflect results--however measured--only the anticipation of results, since most CRADAs have yet to begin research operation.

Carr describes a variant to the out-the-door model, the in-the-door (to the technology transfer office) model. He refers to resources that the technology transfer office has to offer, such as invention disclosures and patents. An increase in this kind of measure may reflect an increase in incentives or rewards within the lab. A recent GAO study of the effects of 1986 legislation measured the effects of

¹⁵¹ For example, Roger Lewis, Director of DOE Office of Technology Utilization, talk at AAAS meeting, Feb.13 1993.

legislated changes in terms of changes in 'invention disclosure' per research employee.¹⁵² While this does have some drawbacks--incentives might draw lower quality disclosures--this is an intriguing measure of changes in technology transfer efforts.¹⁵³

The political model focuses on the political origins of these programs, and the actions needed to retain political support. Possible measures mentioned are reports to Congress, testimony before Congress, levels of authorized funds. From a policy standpoint, the only drawback to seeing technology transfer this way is that it has nothing to do with technology transfer, only with the politics surrounding it.

The opportunity cost model examine technology transfer programs as institutional competitors to other programs, such as research, administration, capital spending. The question driving this approach is what could have been done with the same funds within the lab. That is, without measuring the effects on the economy external to the national lab, are the effects internal to the lab positive? Clearly this has relevance to the administration of the lab itself. The most interesting result of this approach is to look at the licensing income compared with the cost of running the technology transfer office. If the costs are greater than the benefits, then institutional resistance may be anticipated. If the returns from licensing are greater than costs, than the offices have some intraorganizational claim to permanence, if not legitimacy.

¹⁵² GAO, "Technology Transfer:Barriers Limit Royalties' Effectiveness", (May, 1993). This kind of data was unavailable for my analysis.

¹⁵³ More intriguing, perhaps, because it is not systematically available.

Indeed, the head of the Patent Office at Brookhaven suggested, in 1991, that the net patent licensing income is the proper way to measure technology transfer activity at the National Labs. He pointed out that Brookhaven now has achieved a stream of income from licenses that is greater than the cost of the transfer activities--and that this was the only national lab that has gone into the black on transfer activities.¹⁵⁴ The Technology Licensing Office at MIT which, too, is running a positive balance, also says that this is the most significant metric.

On a nuts and bolts level, the problem with this approach is that patent licenses often do not begin to pay off for a number of years, so license income may lag licenses by many years. A deeper problem is that, like the political model, the opportunity cost model has no real bearing on what technology transfer is usually seen to be all about--getting technology utilized commercially.

The market model seems to have a strong claim to legitimacy. As DeBruin points out, the concern for technology transfer is driven by concerns for economic development and economic competition. "The whole point of is to get federal technology into practical applications where it will have a positive impact on the national economy."¹⁵⁵ For this reason he argues, technology transfer studies should focus on the real world impact of the transfer. This conclusion is also reached by those who argue that technology transfer should be seen in terms of a new product development.

¹⁵⁴ Vale Myles, personal communication.

¹⁵⁵ Jeffrey DeBruin, "Innovation, the Economy, and the Federal Laboratories", (1991) p.71.

However, this perspective does not lead to just one metric. Possible choices are many: increased profits or the number of new jobs arising from transferred technologies, the increase in income of the firms workers, the sales of the new product., the valuation of spinoff companies. License income is also relevant here, often it is assumed that license income is *prima facie* indication of economic success.¹⁵⁶

But there are a few problems with this approach. One, it is often difficult to trace the exact origin of new ideas that go into innovations. Even if the contribution of national lab technology could be traced, it may be only one of several novel technical ideas embodied in a new product. Second, not all transfers result in products, a successful transfer might be one that prevents a company from 'wasting' time and effort on a dead end, or informs it about the state of the art. How would this be measured?

The largest problem with this approach is that so much of the success or failure of the transfer depends on efforts down the line. Studies have estimated that cost of research is only one-tenth of the total required to move an idea into production. Once the transfer takes place, the national lab has little control over the innovation's ultimate success. Start up companies are notoriously unstable, and even established companies are subject to the effects of human frailty. A worthy idea can meet an unworthy end, even after a perfect transfer effort.

¹⁵⁶ The assumption is, if companies are willing to pay for licenses, then they must be putting the technology into use and earning money from them. Griliches, "Patent Statistics as Economic Indicators: A Survey, " (1990).

Furthermore, measuring the resultant profits or jobs presents the problem of the counterfactual. What would have been the result of no action? That is, what is the baseline for evaluation of profits? Should we assume no change, decline of profits without any action? What about healthy industries, perhaps they would have increased profit levels without intervention? Another problem is what is the proper time frame to measure the effects? If the long term health of the industry is at stake, then only a long term evaluation is adequate. Clearly, metrics within the market model have problems.

B. Patents as the Metric

In the end, all possible measures have one weakness or another. What is most regrettable is that most measures mentioned here are not even available. Number of patents licensed and amount of license revenue have been collected recently, as have the number of CRADA's and amount of money committed to CRADA's. (Since CRADA's were created in 1986 and 1989, they are not germane to this study.) But more telling measures have not been assembled. New jobs created, new companies formed, number of new products introduced, sales of new or improved products, utilization of new processes or materials, improved quality of products, amount of profits generated as a result of national lab interaction are all potential measures that are impossible to find. Even asking the companies involved if they found the interaction useful has not been done systematically (if at all). Because technology transfer, as pictured today, was little concern of the labs, they have kept no long term records or long term measures.

As Carr points out there has been no constituency supporting technology transfer measurement and evaluation.¹⁵⁷ Those who support the process are happy with anecdotal reports, and those who might oppose it are not yet mobilized. This is bound to change. The labs will need measures to determine how to focus their efforts, now that they have decided to do technology transfer and have run up against financial constraints. And, inevitably, politicians will start to ask harder questions, once significant money finally starts to get spent on technology transfer.

Patents were chosen for this study primarily because they are available. But beyond that, they are legitimate measures of the labs' reaction to technology transfer imperatives. Because they are created by a familiar procedure already in place, they would not require any new procedures, or institutional innovations. Also, any reaction of the labs to Stevenson-Wydler and Bayh-Dole through an increase in patenting would be noticeable and measurable.

There are admittedly drawbacks to patents as measures of technology transfer success: not all patents are utilized, not all utilized patents are equal, and once again, patents are just the first step in the process of technology utilization and so are distant from any economic success. But, as measures of technology transfer efforts, they are more than acceptable.

¹⁵⁷ Carr, "Doing Technology Transfer in Federal Laboratories", (1992).

CHAPTER SEVEN: PATENTS

As mentioned earlier, patents were chosen as the metric for this study partly by default. No other potential measures of technology transfer have been collected. Having said that, patents do have some relevance to innovation. This chapter will explore that relevance: the role of patents in technology development.

Also explored will be a long running debate on government patent policy. Bayh-Dole is significant because it represents a shift in thinking on this question. The debate pits concerns for public access to public funded inventions against claims that government patent policy is actually impeding development of federally funded inventions by not offering exclusive rights. In a nutshell: Should the federal government offer exclusive license or even title to government funded inventions, or should the government retain title to its patents and continue to offer non-exclusive licenses to all comers. Bayh-Dole was a significant move toward policies that, it had long been argued would facilitate development of government funded technology.

A. What is a Patent?

A patent is a document issued by a government agency.¹⁵⁸ Patents are granted for inventions that are judged to be novel,

¹⁵⁸ Griliches, "Patent Statistics as Economic Indicators: A Survey." (1990), p.1662.

useful, and non-obvious to practitioners in the relevant art.¹⁵⁹ A patent confers the right to exclude others from making, using, and selling an invention or a new contribution to the arts. That is, it is the right to maintain a monopoly on the use of the subject matter of the patented invention (limited to seventeen years in the US, and subject to other limitations imposed by law). The patent rights can be assigned by the inventor to somebody else, usually his employer; and it can be sold or licensed for use by others. Patents were considered so important to technical and economic development in the early republic that power to grant them was explicitly given to Congress in the U.S. Constitution.¹⁶⁰

Patents are meant to encourage technical progress in two ways. By giving a temporary monopoly to the inventor, patents provide an incentive for the development of novel ideas. At the same time, by disclosing the information necessary for the production of the item, patents promote the dissemination of technical information. In practice, they also promote technical activity by motivating those excluded by the patent. Attempts to invent around a patent may lead to other significant inventions.

Not all inventions are patented. In practical terms, an invention that is economically useful will be protected in one of two ways: through patenting or through secrecy. Inventions will not be

¹⁵⁹ The percent of applications for patents that are granted in the U.S. is around 65%. Griliches, "Patent Statistics as Economic Indicators: A Survey." (1990).

¹⁶⁰ Article 1, Section 8: "Congress shall have the power to promote the progress of science and the arts by securing for limited times to authors and inventors exclusive right to their respective writings and discoveries."

patented if: 1) The invention is not patentable by law--in some industries, such as bio-technology or microelectronics what is and what is not patentable may be unclear. Secrecy may therefore be chosen. 2) The economic expectations do not justify the cost. Patents will not be filed in industries where technologies evolve rapidly because the useful life of the patent would be very short. For example, in the microelectronics industry, patents may be obsolete before they are granted.¹⁶¹ There are also practical economic reasons for not patenting. If the inventor can not afford a patent or if the expected gain is less than the cost of the patent, patents will not be sought. If the idea is judged to be easy to invent around, then the time and effort of a patent filing will not be made. 3) There may be strategic reasons for not patenting. If, through the public disclosure of filing for a patent, a company believes that it will divulge too much information about its research to competitors, then secrecy may be the chosen route for protection.

B. Patents as a Measure in the Innovation Process

Patents clearly have a role in the innovation process. As mentioned, they secure the inventors rights to profit from his creative work. But, they are also used as indicators of progress when talking about the process of innovation. In stage models of innovation, they are often seen as the final, capstone event in the development stage, before the production stage begins. Seen this way, patenting can be used as an output indicator of work at the

¹⁶¹ Basberg lists the opposite reason for not patenting: if the patent life is expected to be much greater than seventeen years, patenting may not provide sufficient protection. I suspect that this consideration is purely theoretical.

development stage. Freeman, uses it this way to indicate output of "inventive work", which is his second stage of innovation.¹⁶² The licensing of patents can be used as a measure, not of innovation but of technology transfer efforts, as for instance in Arnow's model.¹⁶³

Patents will be used in this study as measure of the labs reaction to Stevenson-Wydler and Bayh-Dole. An increase in patenting would show an increase in attention paid to it. While the national labs have not traditionally been oriented toward creating patents, they do have measurable record of patents. Also, the labs already possessed the institutional structures to create patents: patent offices, patent attorneys, patent procedures.

Furthermore, the relative lack of attention to patenting prior to 1980 within the labs makes patents an attractive measure. The rate of patenting per R&D dollar in the national labs in 1980 was more than very low in comparison to patenting at large companies.¹⁶⁴ If the effects of Stevenson-Wydler and Bayh-Dole were to increase patents because they drew attention to patent licensing, then any growth in patents should be immediately apparent against the background of the previous low level of activity.

¹⁶² His five stages are: basic research, inventive work, development work, new type plant construction, are the stages in his model. Freeman, Economics of Industrial Innovation. (1982) p.8.

¹⁶³ She uses patents in one form or another as a measure of three of her five stages. Patent application and grant mark stage two activity, "results of knowledge production", the purchase of patents are involved in stage 3, "the use of results of new knowledge in improving technology; and stage 5 "diffusion of new technology" may be marked by the licensing of patents. K.S. Arnow, A Proposed Conceptual Framework for Indicators of R&D Inputs, Outputs and Industrial Innovation, (1980). Cited in Basberg (1987).

¹⁶⁴ The rate of patenting at the labs averages about 1 per \$25 million in R&D, (my calculation) while the rate in large R&D intensive business is about 1 per \$600,000, according to Pakes and Griliches, "Patents and R&D at the Firm Level: A First Look", in Griliches, R & D, Patents, and Productivity. (1984).

C. Debate over Government Patent Policy

Behind the treatment of patents as a practical or legal problem, lies a philosophical debate about the proper policy towards government patents. Understanding this debate is important, because Bayh-Dole represented a fundamental shift which was thought to be the key to unlocking the underutilized trove of government patents. The debate divides on whether the contractor--or anyone--should be able to gain exclusive license to patents resulting from work funded by the government, or whether ideas patented as a result of government funding should remain freely accessible to anyone. A policy where the government takes title, then offers licenses is called a title policy. In the alternative, license policy, the government gives up title to the developer of the invention, retaining only a full license to the invention. Until 1974, the government policy toward inventions originating from the national labs was determined by the Atomic Energy Act of 1954. This law established a title policy for the national labs. The rationale was clearly to protect national secrets surrounding work on atomic weapons, and to control the eventual transition of nuclear power to civilian uses.

Congressman Emilio Daddario (D. Conn), writing in 1965, explained the debate as involving a balance in four issues: "the needs of the government, the equities of the contractor, facilitating commercialization, the public interest".¹⁶⁵

¹⁶⁵ Daddario "Legislative Problems in the Field of Patents and Patent Policy (1965)." p.90

Traditionally, the direct "needs of the government" are served by the research itself, which is performed to further an agency mission. The disposition of the patent rights are not an immediate government concern. While the patent may be pragmatically important for horizontal spinoffs, this has clearly been a secondary concern of the agency performing the research. Only when technology commercialization is moved from secondary to primary concern will the government have a direct stake in the way the patent is disposed.

Second, Daddario suggests that it is necessary to recognize the 'equities of the contractor'. His point here is that since the contractor did the R&D, it may be unfair to restrict him from the fruits of his labor. This point of view is countered by the claim that the contractor did what he was paid for, and the resulting invention therefore belongs to whomever paid for the work--the people.¹⁶⁶ Further reward--preferential rights to the patent--would be unnecessary and unfair.

The third consideration is facilitating the commercialization of research. If the "public interest in a dynamic and efficient economy requires that efforts be made to encourage the expeditious development and civilian use of inventions in scientific and technological fields resulting from work performed under government contracts, then it is suggested that the contractor is in the best position to do the commercializing" (for the reasons explored

¹⁶⁶ The rationale for the lack of additional reward for breakthrough inventions in many industrial research labs is that this is what the researcher is paid for in the first place.

in Chapter 3).¹⁶⁷ This is, of course, the sentiment driving government policy away from a title policy.

This point is further justified by the argument, as corporate patent lawyers have long maintained, that open licensing discourages development.¹⁶⁸ By giving access to government patents to all, the government gives incentive to none. The reasoning here is that the developer must spend more time and effort to turn the invention into a commercial product. Without any protection, this effort will not be made. Since the resulting product could be copied by industrial competitors, the initial developer will be unable to recoup his development costs. Knowing this, government patents are never taken advantage of by potential investors.

The argument against nonexclusivity is not so ironclad as often made to appear for several reasons: First, reverse engineering of others' work is not always simple and straightforward. Second, the first mover may be able to establish marketing advantages beyond the reach of the fast follower. Third, industry development times are frequently so fast as to make patent protection not a relevant part of product strategy, so patent protection is not a factor anyway.

In practice this point turns upon how much additional effort is needed: the less effort needed, the more willing a company will be to take a nonexclusive license. This effect is apparent in high royalty generators like the AIDS test kit (NIH) and the Cohen/Boyer gene splicing patent (Stanford). These two inventions have been eagerly exploited through non-exclusive licenses, because they required little

¹⁶⁷ Daddario, "Legislative Problems in the Field of Patents and Patent Policy." (1965) p.91.

¹⁶⁸ See testimony in 1978 and 1979 "Hearings on Federal Patent Policy".

additional development work to utilize. But when a great deal more development work is needed, patent protection is required to protect the investment of the developer.

The final consideration laid out by Daddario is "equity of treatment". It seems unfair to the contractor's competitors, if the fruits of government research are kept from them by exclusive licenses. Further, it is argued that it is not a proper treatment of the body politic for the government to give away what it purchased in the name of the people. The populist argument is that government bought the research, and the fruits of the research belong to all the people. To assign exclusive license would be unfair to those excluded, and the process could lead to corrupt practices. In a letter appended to the legislative history of Bayh-Dole, Jack Brooks (D. Tx) argued: "The major problem I have with [Bayh-Dole] is that it violates a basic provision of the unwritten contract between the citizens of this country and their government; namely that what the government acquires through the expenditure of its citizens' taxes, the government owns. Assigning automatic patent rights and exclusive licenses to companies or organizations for inventions developed at government expense is a pure giveaway of rights that properly belong to the people."¹⁶⁹

Those who are in favor of allowing exclusive licensing of government patents, argue that the people's ability to use the fruits of their research is protected sufficiently when the government retains the right to a royalty free license of the patented idea--which it does in Bayh-Dole and all other recent patent legislation. An

¹⁶⁹ Bayh-Dole legislative history, 94 STAT. 6487.

alternative proposed by Senator Russell Long (D La.) in the early sixties, was for the government to retain title to all its inventions, while establishing a central government agency to manage and exploit the government's patent portfolio. This New Deal style proposal for active government involvement in development never got very far, but the opposition from populist politicians was sufficient to stall movement in the 60's and 70's toward granting direct title or giving exclusive licensing of government patents. Similarly, the Center for the Utilization of Federal Technology, outlined in the Stevenson-Wydler law was a move toward the active management of the government patent portfolio, though as mentioned, it was never implemented in this manner.

The Federal Non-Nuclear R&D Act of 1974 was actually the first step away from a title policy regarding National Lab patents. It allowed the waiver of the government's claim to patents resulting from government funded work. This new policy was used for the research surrounding the large alternate energy projects of the 70's. Bayh-Dole of 1980 was significant because it specifically granted title (without need for waiver) for DOE work done by small business and non-profit contractors. The lingering populist opposition to this policy shift was indicated as this presumption to title was extended only to small business, nonprofits, and universities, not to large businesses.¹⁷⁰

¹⁷⁰ It should be noted, that by automatically granting title to small businesses and non-profits, Bayh-Dole removed some technology transfer flexibility from the DOE. Elements in the department argued that often small contractors and universities might not be the best situated to take commercial advantage of the

With the passage of the Federal Non-Nuclear Act of 1974 and then the Bayh-Dole Act of 1980, the center of the debate on the proper government policy toward patent licensing had clearly changed. No longer was the assumption made that exclusive licenses were harmful, and that a license policy was undemocratic. Instead, the focus was turning toward facilitating the commercialization of government work.

A crucial caveat is that the power conferred by Bayh-Dole to take direct title did not extend to national labs run by non profits or universities. Though the law was intended to “promote the commercialization and public availability of inventions”, as it was written, its strongest provision did not apply to the DOE national labs. Whatever the law’s stated intention, the practical effect on the labs technology transfer efforts in 1980 was very small.¹⁷¹

discovery. By automatically giving these organizations patent rights, Bayh-Dole might have the effect of restricting commercialization efforts.

¹⁷¹ It is now DOE policy for all labs to take title to all inventions. DOE no longer takes title to any inventions unless the labs do not think they can utilize them.

CHAPTER 8: THE EFFECTS OF THE LEGISLATION

Passing a law is not the same thing as solving a problem. Just because Stevenson-Wydler and Bayh-Dole drew some attention to the technical resources within the federal laboratories, and just because they were oriented to increasing patent licensing as a means of transfer does not mean that they had this effect. In fact, I have reviewed several theoretical perspectives on technology transfer that suggest that little effect should be expected. Again, there are two separate lines of reasoning supporting this claim.

Patenting as a means of transfer is not likely to generate much in the way of technology transfer results. Emphasizing patents reflects a number of ideas about technical development that are simply not useful or not realistic: technology push, the pipeline model of innovation, the conception of spinoff as automatic and free, and an over-the-wall approach to the interaction between research and development and manufacturing. A patent licensing approach also presumes that there are discrete technological entities that are just waiting to be adopted within the walls of the federal laboratories. All these ideas have been examined in Chapter 3, and are extremely limited.

Even if the patent emphasis was fruitful, and it is not completely barren, Stevenson-Wydler and Bayh-Dole were not likely to generate an increase in technology transfer efforts. These laws, as written and implemented, did not give the labs any reason to adopt changes that would facilitate the technology transfer process. The

mission of the labs, their cultures, the institutional and individual incentives all worked against technology transfer. Until there was some change in these factors, significant transfer efforts were unlikely.

This chapter will examine both predictions. The first section will present two measures of technology transfer efforts. The results of one are equivocal and require a fairly extensive discussion. The other shows the expected result that the national labs did not focus on commercialization right after 1980. The next section will present two measures of technology transfer results. Though necessarily indirect, these measures show no changes at the time of Bayh-Dole and Stevenson-Wydler. Finally, the results of two other empirical studies will be discussed. These two studies compare the effectiveness of patent and licensing approaches to other transfer mechanisms, and confirm the conclusions about their limitations.

A. Technology Transfer Efforts: Patents

1. Patents as a Measure

The objective of Bayh-Dole was “to use the patent system to promote the utilization of inventions arising from federally supported research and development; ...”.¹⁷² Stevenson-Wydler was intended to “build links between the generators of knowledge (universities and Federal laboratories) and the users of knowledge (industry and state and local governments); ...”¹⁷³ Both laws, were

¹⁷² Bayh-Dole legal code: 94 STAT. 3019.

¹⁷³ Stevenson-Wydler legislative history, p.4893.

intended to draw public attention to opportunities for working with the labs, to exploit the technical resources therein. Conversely, both laws might be expected to have increased the attention paid to patenting by labs themselves.

This attention to patents might be expected to cause an increase in the number of patents produced by the national labs. Two of the four frameworks for measuring technology transfer discussed in chapter 6 lead to this expectation.¹⁷⁴ The two models that suggest that there would be an increase in patents as a direct result of the laws are the Political model and the Opportunity Cost model. The Political model suggests that the labs would recognize that their patrons, Congress, have focused on patents, and therefore would increase patenting to demonstrate attentiveness to Congressional goals. The Opportunity Cost model would suggest that the Patent offices or ORTAs within the labs would quickly seek to justify themselves within the organization by increasing their output of a measurable, desirable product--patents. These two models imply that patents would increase because the laws were passed.

On the other hand, the other two measurement models imply that patents would increase, only if the spirit of the laws was adopted. Only when the labs seriously increased technology transfer activity, would the number of patents increase. The Out the Door model would suggest that patents--seen as the end result of lab activity--would increase if technology transfer was adopted. And the Market model, too, would suggest that patents, conceived of as a

¹⁷⁴ Following Bozeman and Fellows. "Technology Transfer at the U.S. National Laboratories: Framework for Evaluation", (1988).

necessary intermediate step to development, would increase if technology transfer activity increased. My prediction is that patents should not be expected to increase, because the labs would not adopt technology transfer as a goal, because too many stronger factors conflicted with that new goal.

The centerpiece of this study is an analysis of patenting. It seeks to answer the question: Did Stevenson-Wydler and Bayh-Dole have any effect on patenting rates at the national laboratories. Specifically, I will look at the large Department of Energy laboratories in four states: Lawrence Livermore National Laboratory and Lawrence Berkeley Laboratory in California, Los Alamos and Sandia National Laboratories in New Mexico, Brookhaven National Laboratory in New York, and Argonne National Laboratory in Illinois. These choices reflect primarily the availability of R&D data specific to these labs, as well as a measurable history of patenting.

First, I examined the long term trend of patents at the Department of Energy to see if there is any evidence of a rise in patents corresponding to Stevenson-Wydler and Bayh-Dole. Next, since any rise, or fall, in patent levels may be caused by fluctuations in other factors, I examined the influence of both the economy at large and the funding levels at the labs. While the economy (measured by GNP) was found not to be statistically linked to lab patents, laboratory R&D was a strong predictor of patents. Once the proper lag time for the effects of R&D was determined, I was able to test whether the laws had any effect, independent of changing R&D levels. Surprisingly, the statistical test indicated a small rise in

patenting after Stevenson-Wydler and Bayh-Dole. This counterintuitive result is discussed at length, and other explanations for this rise are set forth.

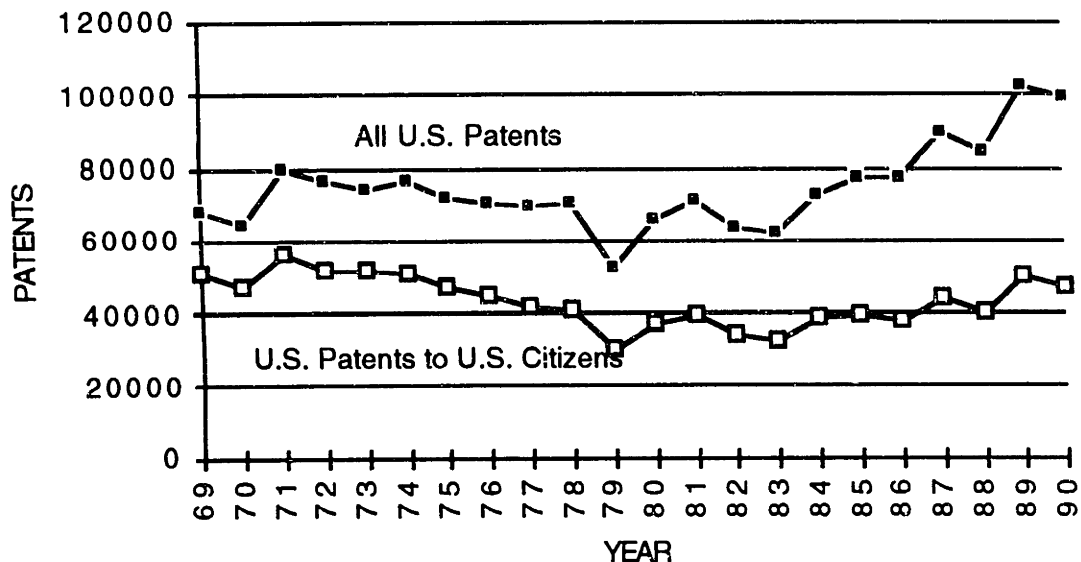
2. Patent Trends

The most general trends in patenting are shown in Figure 2. This graph shows numbers of patents granted from 1969 to 1990. At first glance the trend looks healthy, with a steady increase in total patents since 1979 (upper line). But, the growth throughout the 80's was mainly the result of an increasing number of awards to foreign inventors. The lower line in Figure 2 shows the number of patents awarded to domestic inventors. The trend of domestic patents shows a slight decline through the mid-Eighties with a recovery to prior levels after 1984.

The dip in 1979 in both the total patents and the domestic patents is a spurious result of problems within the Patent Office: it was due to the lack of budget for printing the approved patents.¹⁷⁵ This highlights one point that Griliches emphasizes: the production of patents reflects the number of applications and the resources within the Patent Office. The chief determinant of year-to-year variability of the number of patents is the number of patent examiners.

¹⁷⁵ Griliches, "Patents: Recent Trends and Puzzles", (1989) p. 293.

FIGURE 2
Patents Granted In the U.S. 1969-1990.



Source: United State Patent and Trademark Office,
CASSIS Database.

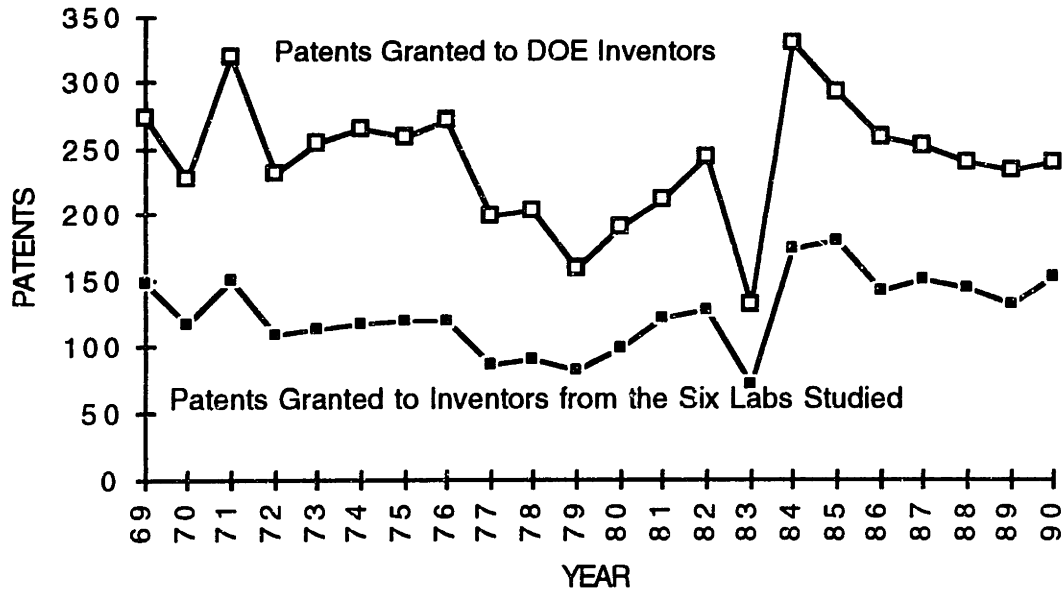
Moving from the national totals to the discussion of the patent changes within the federal labs, Figure 3 shows the numbers of patents assigned to inventors working for the Department of Energy. This category includes the large multifunction labs studied in depth, as well as the many smaller facilities.¹⁷⁶ The overall DOE trend is about level, with a dip in 1983 and recovery to a slightly higher level in 1984.¹⁷⁷ Also shown in Figure 3 is the aggregate level of patents for the six labs studied. Patents from these labs mirror the department-wide trends, only with less variability. The most

¹⁷⁶ Included in this graph are all DOE Labs, even those not covered in this analysis: such as Pacific Northwest, Oak Ridge, Savannah River, Solar Energy Research Institute, and others.

¹⁷⁷ The dip in 1983 is merely a statistical aberration, with no known explanation.

significant feature of the lower line is that the plateau after 1984 is higher than the general level before 1982.

FIGURE 3
Department Of Energy Patents
(By Grant Date, 1969-1990)



Source: United State Patent and Trademark Office,
CASSIS Database.

This superficial trendline analysis seems to support the claim that the Stevenson-Wydler and the Bayh-Dole Acts of 1980 led to an increase in patent rates in the national labs. If, hypothetically, one allows about a year for the legislative initiatives to provoke organizational changes, then the effects, if any, would show up in patents filed in 1981 or 1982. The average pendency period for national lab patents is two and a half years. Thus, the increase in patents granted that appears after 1984 seems to disconfirm the hypothesis that this legislation had little effect on patenting. Instead,

the graph seems to show a positive reaction in patenting. However, to confirm this finding, further analysis is needed.

3. Regression Analysis

The trendline alone is not enough to make the case for legislative impact. Other possible impacts must be accounted for. There was a recession during 1980 and 1981 followed by a number of years of a strengthening economy. Perhaps a rising economy leads to increased patenting. The early Eighties also were the height of the Reagan defense buildup, pumping billions into defense R & D. Perhaps the rise in patents in 1984 was simply the result of more money budgeted for the national labs. Both, or either, of these external factors may account for the trend in DOE patent rates. A regression analysis was performed to separate the possible effects of budget changes and economic activity, and to weigh each.

a. Lab Patents and GNP

First I set out to determine whether the economy has an influence on the rate of patents from the six labs. The yearly gross national product (GNP) was used to represent the effect of the economy. This figure was regressed on the patent counts in an attempt to determine the relationship between patent rates and the health of the economy. Current GNP, as well as GNP lagged up to four years was used.¹⁷⁸

Eventually, I concluded that there was no usable relationship between GNP and lab patents. For some labs, there was an extremely

¹⁷⁸ Other measures were tested, such as business capitalization rates, and the industrial production index of the Department of Commerce, but these differed little from the track of GNP, so only GNP results are shown.

strong link between funding levels and GNP¹⁷⁹, for others there was no connection. Figure 4 shows that for the overall lab pattern, the relationship was inverse. The coefficients for the current year, as well as the lagged effect of GNP from years past (up to four) are all negative. The statistical relationship (R^2) shown in Figure 4, is very low and strong enough to warrant consideration only in the case of the current year. (The regression model is Patents = Constant + GNP.)

FIGURE 4
Lab Patents as a Function of GNP

GNPLAG:	PATENTS = C +	GNP	R^2
Same Year	' ' = C +	-.06 (GNP)	0.255
GNP lagged 1 yr.	' ' = C +	-.05 (GNP)	0.170
GNP lagged 2 yr.	' ' = C +	-.12 (GNP)	0.100
GNP lagged 3 yr.	' ' = C +	-.02 (GNP)	0.040
GNP lagged 4 yr.	' ' = C +	-.05 (GNP)	0.020

Source: U.S. Patent Office; NSF: Science Indicators, 1990.

But an effect in the same year cannot be meaningful because there must be some time between inventive work and patent applications--which militates against same year effects. This consideration led me to conclude that patents at national labs are not related to GNP, so this variable was not included in subsequent regressions.

b. Relationship of R&D to Patents

I next focused on the relationship between patent rates and levels of R&D funding. Prima facie, this relationship makes sense: the

¹⁷⁹ Analysis not shown.

more money spent in a lab, the more output one will get. In this case, output is measured by patents. Since, more money buys more scientists, more technicians, more equipment, more money should lead to more patents. Furthermore, Griliches has shown this relationship holds strongly at the firm level.¹⁸⁰

I sought to determine the proper lag period to consider for this effect. The funding level at the year a patent is awarded is obviously not the proper choice, since patents are rarely awarded in the same year they are applied for, and virtually never in the year in which the work was performed.¹⁸¹ It takes about three years from the time the invention disclosure is turned over to the lab patent office for the patent to be granted. And, since projects may take a number of years to complete, the proper lag time between funding levels and patent grants is expected to be about four or five years. Figure 5 shows the relationship between patents and funding levels, when the funding levels are lagged for different numbers of years. It seems to indicate that the proper lag period between spending and patenting is 5 years. (The regression model is: Patents = Constant + lagged R&D level.)

¹⁸⁰ Griliches, "Patents: Recent Trends and Puzzles." (1989).

¹⁸¹ Vale Myles, patent attorney at Brookhaven, reported that the fastest turnaround from lab patent office to patent grant in his experience was 13 months. This did not include processing time within the lab patent office.

FIGURE 5
Lab Patents as a Function of Lagged R&D Spending

R&D LAG	PATENTS	=	C	+	coeff. (R&D)	R ²
SAME YEAR	PATENTS	=	10.9	+	.059 (R&D)	0.487
1 YEAR	"	=	9.6	+	.063 (R&D)	0.527
2 YEAR	"	=	8.2	+	.068 (R&D)	0.569
3 YEAR	"	=	6.7	+	.073 (R&D)	0.611
4 YEAR	"	=	6.1	+	.078 (R&D)	0.609
5 YEAR	"	=	4.8	+	.083 (R&D)	0.629
6 YEAR	"	=	3.8	+	.088 (R&D)	0.626
7 YEAR	"	=	3.3	+	.089 (R&D)	0.612
8 YEAR	"	=	2.7	+	.091 (R&D)	0.601

Source: U.S. Patent Office; NSF: Science Indicators, 1982, 1989.

The coefficient and the adjusted R² are greatest when the R&D spending is taken five years prior to the patent grant. The R² indicates a very strong relationship, as more than 62% of the variance is accounted for by funding levels from five years previous.

c. Rise in Patenting?

Having determined the proper lag period between R&D levels and patents, I examined the hypothesis that there was a rise in patent awarded after 1984, controlling for the effects of R & D spending. Since funding levels and patents are so closely linked, a large jump in funding could be the sole cause of the jump in patents after 1984. So a final regression that included funding levels, lagged properly, and a dummy variable, to catch the hypothesized change, was run.¹⁸² A dummy variable was tested for each year from 1979 to 1987 to check the robustness of the change in trend seen earlier

¹⁸² The dummy variable has the value zero for all years before, and one for all years after and including the test year.

for 1984. The size and strength of the coefficient of this variable captures the magnitude of the change in the trend which occurred each year.

Figure 6 shows the results of the regressions that included these dummy variables. Using a five year R&D lag, 1984 (highlighted) stood out clearly as the year with the highest coefficient and the highest R^2 . (The regression model is Patents = Constant + R&D level + Dummy variable.)

FIGURE 6
Test of Dummy Variables in a Regression
That Includes R&D Levels

Year of Rise	PATENTS =	C	+	coeff. (R&D)	+	Dummy coeff.	(R^2)	
None	' '	=	4.8	+	.081 (R&D)	+	n.a.	0.625
1979	' '	=	4.9	+	.082 (R&D)	+	0.3	0.621
1980	' '	=	4.7	+	.082 (R&D)	+	0.3	0.621
1981	' '	=	4.6	+	.081 (R&D)	+	0.5	0.621
1982	' '	=	4.7	+	.081 (R&D)	+	0.4	0.621
1983	' '	=	4.7	+	.081 (R&D)	+	0.2	0.621
1984	' '	=	4.4	+	.078 (R&D)	+	3.6	0.632
1985	' '	=	4.6	+	.080 (R&D)	+	2.1	0.624
1986	' '	=	4.7	+	.081 (R&D)	+	0.2	0.621
1987	' '	=	4.7	+	.081 (R&D)	+	0.3	0.621

Source: Patent Office: CASSIS Database; NSF: Federal Funds for R&D

The coefficient (3.6) of the dummy variable indicates that in 1984 and the years following, DOE inventors in each of the four states produced approximately three and a half more patents than expected for the given level of R&D funding. R&D lags of four, six, and seven years were tested with the same outcome: a coefficient of

about three and a half. It should be noted that while the effect is statistically significant, the actual increase in patenting is quite small. Three and a half patents per state represents only a 5% rise in CA and NM. In NY and IL the rise is about 15%.

Nevertheless, this result may be taken as a disconfirmation of my hypothesis.

4. Discussion of Patent Results

Rather than showing no effect as I have hypothesized, the results of my patent analysis indicate a small, but statistically significant increase in the patenting activity from four states containing six major DOE labs, beginning in 1984 and lasting through subsequent years. This effect has been separated from two possible sources of spurious correlation by controlling for R&D funding levels, and by checking for the effects of GNP.

This jump in patent rates could support the assertion that legislative changes in 1980 led to an increase in technology transfer activity which led to an immediate increase in patent activity at the labs. The reasoning leading to this conclusion would go thus: The Bayh-Dole Act of 1980, by drawing attention to the issue of national lab patents, may have encouraged patenting activity within the labs as it was implemented in 1981 and 1982. The Stevenson-Wydler Act of 1980 may also have had the effect of encouraging national labs to increase their patent activity. It created technology transfer offices and mandated technology transfer to be federal government policy. As technology transfer offices were set up, as the topic was given legislative attention, perhaps the labs were motivated to

respond--and patents would be one of the most concrete ways of responding. An increase in patenting activity in 1981, given a two and a half year pendency period, would have shown up in patents granted in calendar year 1984. The data do show a higher level in patents in 1984 and years following.

a. Why the Rise in Patents?

The question is then: is this what really happened? Statistical analysis can only tell so much. Nine patent attorneys who worked in the labs and at DOE headquarters and regional offices were contacted by phone and asked about the plausibility of this explanation for the rise in patents seen in 1984.¹⁸³ All said that they thought it was unlikely that the Stevenson-Wydler Act was the cause. Neither was Bayh-Dole remembered as significant for these large labs.

Two other explanations for the jump in patents in 1984 were favored: the effects of alternate energy projects from the late Seventies coming to maturity; and an increase in the number of patent attorneys in the labs and in regional DOE offices around 1981.¹⁸⁴ Both would have led to an increase in patents about this time.

As mentioned in Chapter 2, the labs have shifted their focus from time to time and one of the biggest shifts was toward developing alternate sources of energy during the Seventies. The amounts of money directed at alternate energy projects in the

¹⁸³ Nine attorneys were contacted, representing DOE headquarters in Washington, two regional DOE offices--Chicago and Albuquerque, and four labs--Argonne, Brookhaven, Lawrence Berkeley, and Sandia.

¹⁸⁴ Analogously, Griliches notes that the strongest predictor of patent output at the national level is the number of patent examiners. (Griliches 1989,1990)

national labs was substantial. The DOE R&D budget increased 99%, in constant dollars, from 1974 to 1980.¹⁸⁵ These projects had a more pragmatic nature than military research or fundamental physics, and led naturally to patentable ideas. Given the time lag for R&D spending of about five years (determined above), projects from the late Seventies would have first started to come to fruition in the early Eighties, and patents would have followed two or three years later. These alternative energy projects are one explanation for the increase in patents identified above.

The second part of the explanation suggested by those I interviewed is linked to a general increase in patenting driven by an increase in the number of patent attorneys. James Denny, the Assistant General Counsel in the DOE Patent Office at this time, promoted a policy that led to the filling of a number of attorney positions, and he also advocated a more aggressive patent and licensing policy. Cognizant of the statutory language meant to encourage licensing of patents included in the 1974 Federal Non-Nuclear Act, as well as in Bayh-Dole, he took steps to emphasize this policy option. For licensing to occur, patents had to be filed in the first place. As the alternate energy projects proceeded, invention disclosures had piled up.¹⁸⁶ He noticed this and took action, adding staff and filling vacant patent attorney positions throughout the Department of Energy.¹⁸⁷

¹⁸⁵ National Science Foundation, Science and Engineering Indicators, 1989.

¹⁸⁶ Invention disclosures are the Departmental precursor to a patent filing.

¹⁸⁷ According to Paul Gottlieb, Brookhaven and Princeton Plasma Fusion Laboratory were actually investigated by a team from DoE to find out why no invention disclosures were forthcoming.

For example, in 1980, Brookhaven had no patent attorney, the position was vacant. One was hired in 1981, a second in 1984. At Argonne the story was the same--two attorneys were hired between 1980 and 1982, bringing the staff up to two. Also at the DOE regional office in New Mexico, staffing increased also during the early Eighties. Having only one attorney, a large backlog of invention disclosures had developed. Two additional attorneys were hired in 1981 and one more in 1984.¹⁸⁸

b. The Insignificance of Stevenson-Wydler

If an increase in patent attorneys is the explanation, then the question becomes: Did the passage of Stevenson-Wydler make the DOE see the importance of technology transfer and move toward creating more patents in order to respond? I asked the people I talked to this and they all said no. "Stevenson-Wydler had zero effect on patents."¹⁸⁹ "There was no direct connection of patents and Stevenson-Wydler, and no effect at all until 87 or 88."¹⁹⁰

The patent attorneys stressed that Stevenson-Wydler was not seen as significant by the labs. They pointed out that it gave no additional powers to the labs, nor gave them any incentive (or money) to assume these powers themselves. Without either, no change should be expected. When pressed, a couple of attorneys speculated that all the discussion of patents may have resulted in the increase of "borderline" invention disclosures being submitted to the

¹⁸⁸ Personal communication with James Denny, Paul Gottlieb, Judd Hightower, and Al Sopp.

¹⁸⁹ James Denny, personal communication, 9/9/93.

¹⁹⁰ Paul Martin, from the Lawrence Berkeley Patent Office.

lab patent offices. But even this effect was thought to be negligible.¹⁹¹

The only concrete result of Stevenson-Wydler, the creation of an Office of Research and Technology Application (ORTA) at each lab, was not likely to have had an effect as early as 1981 or 1982. Most ORTAs at the national labs were not created until the later 80's.¹⁹² Even at the Solar Energy Research Institute, where civilian uses of lab technology is clearly a relatively high priority, the ORTA was not created until 1983.¹⁹³ Furthermore, ORTAs were "not too substantive until they had something to sell" and some way to sell it.¹⁹⁴ That is, even if ORTA's had been created immediately, the effectiveness of ORTAs as a means of transmitting technology depended upon further institutional changes. The existence of ORTAs, by themselves, were unlikely to change the rates of patenting.

c.. Limits of Incremental Changes

The motives for James Denny's effort to emphasize patenting at the national labs makes an interesting point about organizational priorities within the labs. It also makes an interesting point about the possibilities for and the limits of procedural change. He could make small changes in staffing and small adjustments in attitude

¹⁹¹ This effect can be discounted as an explanation because the statistic used is patents granted, not invention disclosures. The patent office, it can be presumed, would not grant the borderline patent applications.

¹⁹² Systematic information about the date of origin for ORTAs is hard to come by. According to attorneys' recollections, ORTAs were created at Livermore and Sandia in 1987.

¹⁹³ Technology Transfer, 1987. Booklet published by Solar Energy Research Institute. Golden, CO. 1987.

¹⁹⁴ Paul Gottlieb, DOE patent attorney.

toward cooperative research, but he could not change the fundamental belief that the lab's mission is served by lab defined projects.

As mentioned, Denny used his administrative power to fill staff positions, and to emphasize patenting. Combined with the addition of patent staff at labs and regional offices, Denny also promoted opportunities for patent licensing and cooperative R&D at the National labs. He published an article in Research Management that was an effort to convince corporate R&D managers of the benefits of working with DOE labs.¹⁹⁵

His actions were not an anticipation of the winds of policy change. Instead, it was motivated by a desire to keep the labs intact, to keep the researchers busy. Acting from the DOE headquarters, Denny was trying to help the labs attract outside funding sources to offset the elimination of the alternate energy projects by the Reagan administration.

One obstacle that he faced was a perception on the part of industry that the DOE was difficult to work with, especially in regard to patent policy. To solve this problem, he had to change industry's perceptions of DOE. He also had to finish changing the Department's own attitudes. So the problem was really twofold, to convince industry of DOE new attitude, and to eliminate the prejudice against granting exclusive licenses that remained within the Department. To change this attitude within the organization, Denny had to hire

¹⁹⁵ James Denny, "Cooperative R&D: DOE's Patent Policy Need Not be a Barrier." Research Management, pp. 34-39, Sept-Oct. 1983.

lawyers oriented toward patent licensing, and outside the organization he had to sell these changes.

Denny had to convince potential industrial research partners of the ease of working with the labs. The Department had a terrible reputation on patent policy that kept qualified companies from becoming involved with the labs. Late in the Carter years, he reported, the DOE even had trouble getting companies to bid on development contracts.

The traditional patent policy of the labs, dating back to AEC days, was a strict title policy, with the government retaining control of patent rights, and all licenses were nonexclusive. The historical rationale for his policy was twofold. First, there was the heritage of secrecy associated with weapons work. Second, the experience of developing civilian nuclear power had been consciously guided by a non-exclusive licensing policy. This policy was intended to prevent the emergence of a monopoly or cartel that could control the relevant patents, thereby controlling this new technology.

The lingering perception that he faced was false, or at least changing, according to Denny. The legislation that allowed this change in DOE behavior was not Stevenson-Wydler or Bayh-Dole, but the Federal Non-Nuclear Energy Research and Development Act of 1974. To encourage contractors to get involved in these projects, language was included in this Act that allowed the labs to waive title to, or grant exclusive rights to government patents. Given the power to grant title or exclusive license by this law, the DOE had been

following a much more liberal patent policy with its contractors.¹⁹⁶

The need to get the word out on the labs' willingness to work with companies drove the changes that led to an increase in patent attorneys. Shrinking budgets put a strain on the labs, and attracting industrial research either collaborative projects, or "work for others"¹⁹⁷ was one way of keeping researchers busy. So, it was a very conservative impulse that motivated Denny: maintaining the organization.

Denny's objectives were relatively modest. He acted to preserve organizational integrity by helping increase the resources available. To accomplish this he had to work to change one organizational tradition. However this change was not overwhelmingly difficult, the tradition had outlived its origins and the legislative capacity for change was there--though not all realized it. Previous decisions had been made to grant title directly, but the word was not out. Denny also realized that aggressive patenting would help attract attention.

But this did not add up to a change in lab mission. Recalling the early 80's, Denny's own conclusion was that, "When money is plentiful, the labs are not interested in technology transfer. They haven't got time to interact with outsiders, because lab management

¹⁹⁶ According to Denny, in the very large projects such as coal gasification and coal liquefaction, patent title rights were granted in the contract, in exchange for a promise of open licensing. Exclusive patent licenses were also granted by DOE on a case by case basis in other projects. Personal communication.

¹⁹⁷ This is the DOE category for projects that do not come out of the department's budget.

and DOE management want to have people working on their projects. But, when money gets tight, then the labs get interested in cooperative development projects and work-for-others." This indicates that interacting with other organizations remained a second rank priority. While Denny could try to change outside impressions, and make small administrative changes, and counter anachronistic prejudices that conflicted with actual department policy, he could not, nor did he seek to, make cooperative research or technology transfer take first priority.

B. Technology Transfer Efforts: R&D 100 Awards

The results of the patent analysis are equivocal. The statistics indicate that Stevenson-Wydler and Bayh-Dole might have had some effect on the labs, expressed through a rise in patenting. But, participants in the process indicated otherwise, and suggested two other explanations to account for the statistics. To clarify this issue, I will present another indicator of the labs commercialization efforts.

Research and Development magazine, for the last 31 years, has given awards to the 100 best technological innovations available for sale or license in the prior year.¹⁹⁸ The innovations are judged on "importance, uniqueness, and usefulness from a technical standpoint." Inventions are submitted by the inventor or the

¹⁹⁸ Research and Development magazine has undergone several name changes during this time: At first Industrial Research, then Industrial Research and Development, now Research and Development. The award has always been the "R&D 100". Scherer has used this award to test whether the average cost per invention has been rising over time. (The data indicate that the cost has not been rising.) "Discussion of Griliches", Brookings Papers: Microeconomics 1989, pp. 320-323.

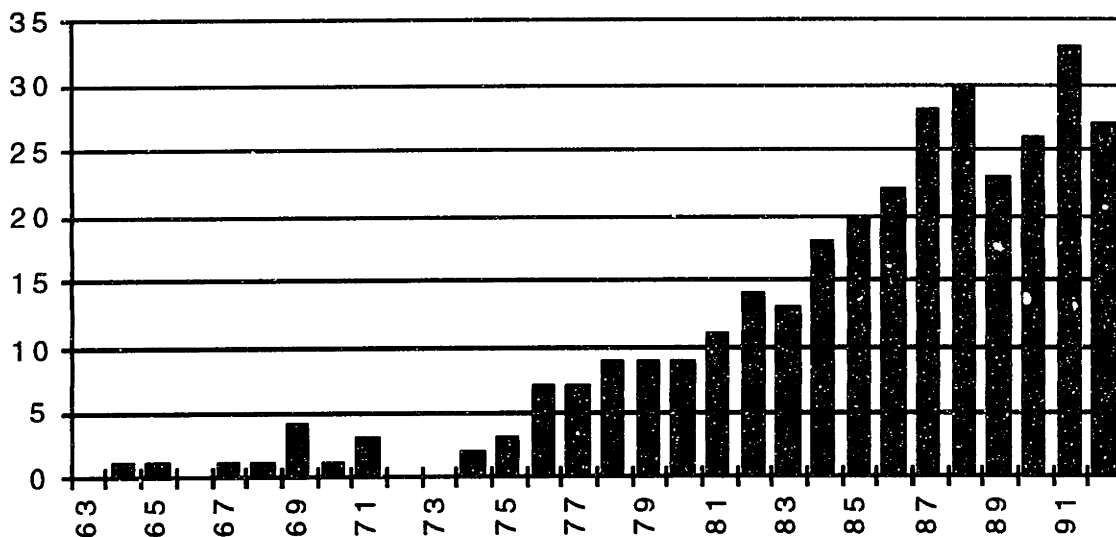
inventor's organization to the magazine. And, there is a fee, \$125 in 1993. The magazine then forwards the submissions to a panel of experts in the relevant fields and they are judged and ranked. The award has a "twofold purpose: 1) To recognize innovators and organizations for outstanding practical technical developments. 2) To identify significant technological advances."¹⁹⁹ By requiring submission for the invention to be considered, the award reflects two things: the submitting organizations' desire for publicity and recognition; and the quality of the technical product. In the case of the national labs, I would argue, the award indicates the lab management's' desire to publicize its technology, and their recognition of the importance of commercialization efforts.

In 1964, the second year of its existence, one award was won by a national lab (Argonne). The national labs were occasional winners throughout the 60's and 70's, but recently, they have come to be the top performing organizations. Since 1986, the DOE labs, as a group, have been bringing down 25 to 30 awards a year.

Figure 7 is a graph of the number of R&D 100 awards won by lab inventors over the years. It shows a continuous increase in lab award winners from the mid-seventies on. The increase after 1980 seems to indicate that awareness of commercialization burgeoned at this time. This might indicate that the labs interest in technology transfer increased immediately following Stevenson-Wydler and Bayh-Dole.

¹⁹⁹ From the 1993 R&D 100 application form.

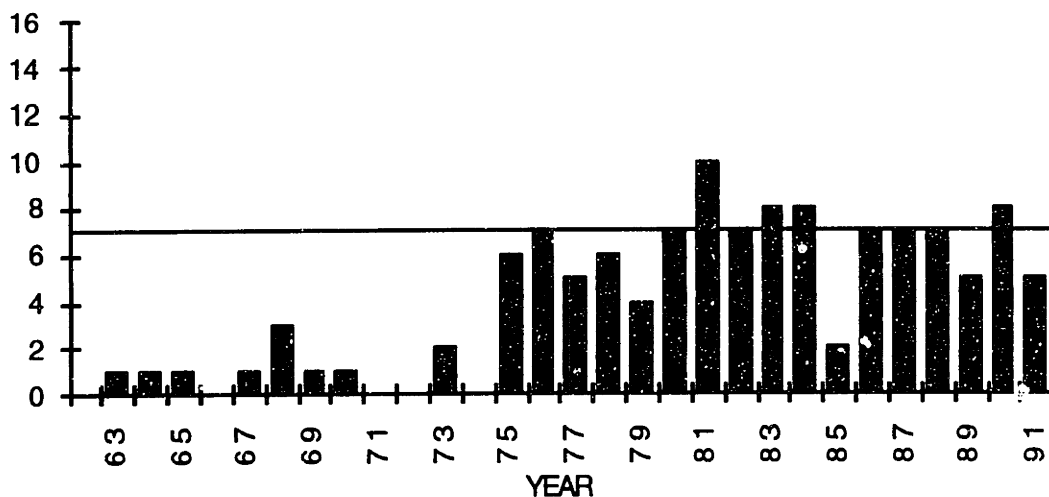
FIGURE 7
R&D 100 Awards to DOE Inventors



Source: Research and Development, 1963-1992.

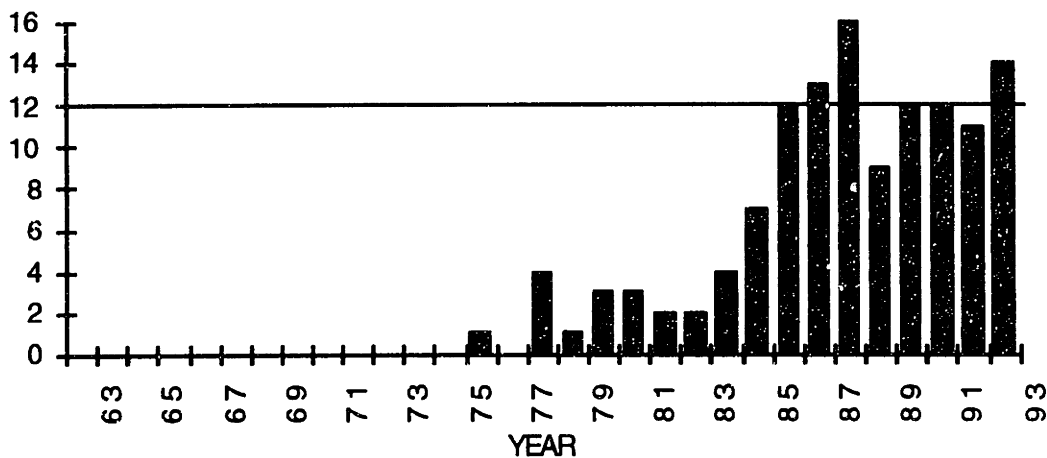
However, there are really two trends hidden in this data. One reflects the attention paid to this award since 1976 by two national laboratories: Oak Ridge and Argonne. This effort has accounted for about seven awards a year since then. Imposed on this is a significant effort by the other labs, especially Lawrence Livermore, Lawrence Berkeley, Sandia and Los Alamos that started in 1986. These labs have tallied about 12 a year in recent years. Figures 8 and 9 show the two breakdowns.

FIGURE 8
R&D 100 Awards to Inventors at Oak Ridge and
Argonne National Laboratories



Source: Research and Development, 1963-92.

FIGURE 9
R&D 100 Awards to Inventors at Sandia,
Los Alamos, Lawrence Livermore and Lawrence Berkeley



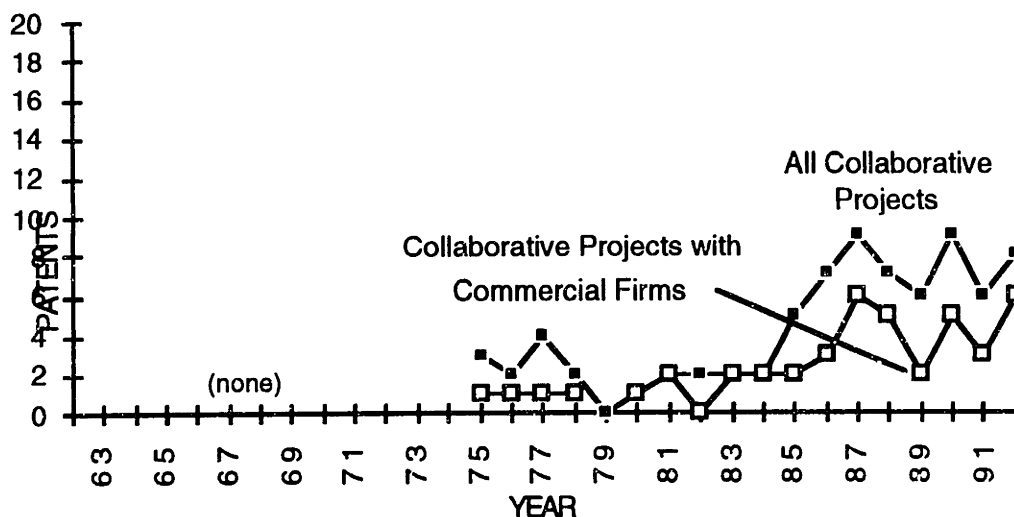
Source: Research and Development, 1963-93.

Separating these two trends shows that, for whatever reasons, a couple of labs started to seek these awards around 1976, and most started to seek them only around 1986. Either way, neither burst of attention is centered around 1980, the year of Stevenson-Wydler and Bayh-Dole.

This data is an indication that the labs now consider the public awareness of commercialization opportunities important. But the data is also a strong indication that these Stevenson-Wydler and Bayh-Dole had little effect on the national labs when they were passed. Only later in the 80's, with substantive changes in the labs motivations and authority, did most labs start to face the market.

One of the more interesting subdivisions of this data, which also reflects changes since 1986 is shown in Figure 10. Here, I have graphed the awards won by collaborations between DOE lab researchers and researchers from other organizations. The top line represents all collaborations, including with universities or other government agencies. (Collaboration among DOE national laboratories is not counted.) The second line represents only collaborations between a national lab and a commercial enterprises. As discussed in chapter 3, it is this kind of cooperative research that is most likely to be effectively commercialized. The graph shows a strong growth in lab-firm cooperative projects that won R&D 100 Awards in the late 80's.

FIGURE 10
R&D 100 Awards to DOE Collaborative Projects



Source: Research and Development, 1963-93.

An indication that DOE headquarters was aware of these awards, by 1990, was the testimony at a Congressional hearing of Secretary of Energy, Admiral James Watkins, who spoke proudly of the DOE performance in winning these awards.²⁰⁰ He stressed the number of total awards that the labs had garnered: 275 by 1989. He mentioned that 29 companies had been formed to commercialize these award winning technologies. And he declared that 45% of the DOE award winners since 1963 had been commercialized. While 45% is much greater than the 3% rate of use often cited for utilization of government patents as a whole, for award winning products supposedly for sale or license, 45% seems very low. This seems to indicate that the DOE labs still have a way to go toward integrating even their best work into the market.

²⁰⁰ "Department of Energy's National Laboratories", Hearing before the subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources, United States Senate, July 25, 1990.

Like all measures, R&D 100 Awards are an imperfect metric of the labs' reaction to Stevenson-Wydler and Bayh-Dole. Since this award is not the only way of turning attention to technology transfer, it can only show so much. Nevertheless, it is clear that the labs have decided the award is worth winning.

It is also clear that this decision was not prompted by Bayh-Dole or Stevenson-Wydler. For Argonne and Oak Ridge their discovery of the Award occurred around 1976, and did not increase about 1980. And the rest of the labs seem to have applied themselves in this direction only in the late 80's. This supports the assertion that more effective legislation came later in the 80's. The R&D 100 awards, while not perfect, do seem to show that Stevenson-Wydler and Bayh-Dole had little effect on the labs' efforts at commercialization.

C. Measures Of Technology Transfer Results

My working hypothesis has been twofold, that Stevenson-Wydler and Bayh-Dole were not likely to provoke changes in the national labs efforts at technology transfer, and even if they did, that any increased efforts would have little effect. The first point is that the incentive and reward structure of the labs, and the organizational goals and culture were not oriented toward patenting and licensing or any form of technology transfer, and the laws were too weak to change any of that. The first two measure presented above were intended to address that question.

The second point is that even if transfer efforts were increased, results were not likely to be great. The approach to technology transfer stressed by the laws, once Stevenson-Wydler had been gutted, was patenting and licensing of preexisting technology from within the labs. This approach, for the reasons explored in Chapter 3, is not likely to generate much new technological development. On the other hand, the passage of these laws, and the publicity surrounding them, may have enhanced the existing potential for spinoff through other means, such as personnel transfers or new startup companies. Therefore, it may be worthwhile to try to measure the results of technology transfer following Stevenson-Wydler and Bayh-Dole.

As I have mentioned before, effective measures are difficult to develop and the best candidates have not been collected. These might be: sales of products embodying national lab developed technology; sales, profits, or net value of spinoff companies; employees or salaries of employees of startups or divisions relying on lab technology. Even patent licenses or patent license revenues are not available on a lab by lab basis, nor at all before 1980. The data that is available shows that little licensing activity was taking place in the early Eighties, though it has increased substantially in the Nineties.²⁰¹

²⁰¹ GAO reports Technology Transfer: Federal Agencies' Patent Licensing Activities. RCED-91-80, (1991); Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness. RCED-93-6, (1993). Also, for analytical purposes, it is unclear which of the many laws, executive orders, or rule changes might be responsible for the recent increases in revenue generated through license agreements.

I will present in this section two measures of the results of technology transfer: changes in type of employment, and changes in the rate of new business creation. Analysis of these measures supports the claim that the labs did not respond to Stevenson-Wydler and Bayh-Dole. Of course, since these metrics show no effect, they can be attacked as just bad measures. I will discuss each of the measures to try to rebut that argument.

1. High Tech Employment Sectors

Spinoffs from the national laboratories are likely to be clustered in certain employment sectors. Electronic machinery or scientific measuring devices are more likely to be the product of spinoff or technology transfer than, say, forestry or trucking. Data is available that breaks down the levels of employment by types of industry, for every state and every county.²⁰² This data will be used here to compare the changing levels of “high tech” employment in three states: New Mexico, Arizona, and Montana.

State level comparisons are used and New Mexico is taken as the best case scenario for the possible spillovers of national lab presence on a state economy. If any state will show the effects of national laboratories on its employment patterns, it will be New Mexico. Los Alamos and Sandia are the largest employers in the state. Thus, if the effects of the lab spinoffs are localized around the labs--there is conflicting opinions on this question--then it will show up in the state data. And, if it shows up in the state data, New

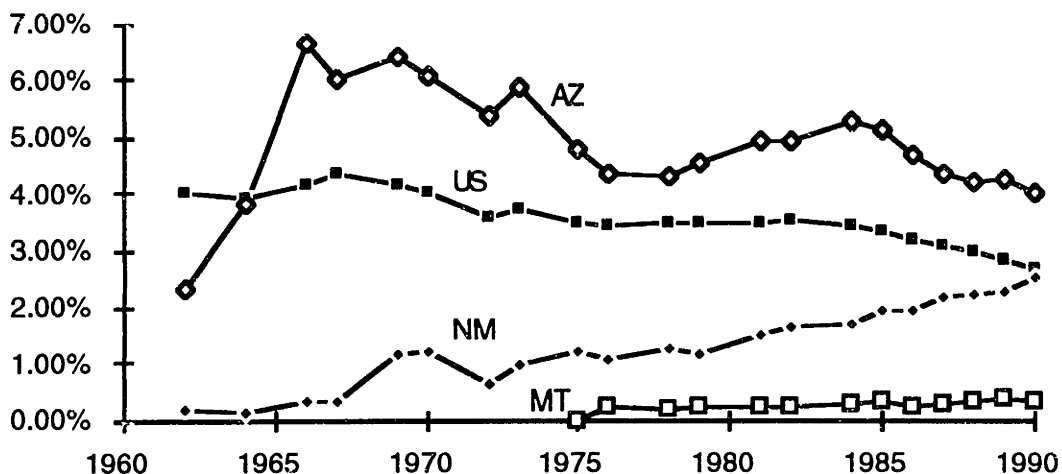
²⁰² County Business Patterns, U.S. Census Bureau. U.S. Department of Commerce. 1962-1990.

Mexico will be the place to look. Arizona and Montana are used as comparisons because of their geographic and natural resource similarity, and because they lack any laboratory presence.

Using the Standard Industrial Classification (SIC) codes of the Department of Commerce and census data, I have compared the changes in the percent of the labor force employed in SIC classes 36 and 38. SIC class 36 is 'electric and other electronic devices' and SIC class 38 is 'instruments and related products'. They are used here as indicators of high tech employment. By comparing the different proportions of this kind of employment over time, some conclusions about the changing composition of work is indicated. And by checking for changes after 1980, the results of Stevenson-Wydler and Bayh-Dole may be discovered.

Figure 11 shows the levels of employment in these categories in New Mexico compared to Arizona, Montana, and the US national average. The trend clearly shows employment in these two categories increasing in New Mexico. New Mexico is becoming more "high tech." The graph also shows that the trend in New Mexico is running counter to all three comparisons. The proportion of employment in these classes is declining in Arizona and in the US, and not rising in Montana. This data shows impressive relative performance of New Mexico by this measure. The data does not show, however, a change in trend occurring after 1980. The trend is a steady increase since 1972.

FIGURE 11
Percent of Total Employment in SIC Classes 36 and 38



Source: U.S. Census Bureau, County Business Patterns.

Of course, eyeballing a line graph is not always reliable. A regression was run to determine whether this line is as linear as it looks. Taking the New Mexico data starting from 1972 (in earlier years class 38 was not available) and regressing this on a linear variable resulted in an equation with R^2 of .972. This means that, indeed, the trend is almost perfectly linear. Double checking this by including a dummy variable for 1981 and later, resulted in no improvement to the first regression. (The R^2 was .971 and the coefficient of the dummy was not statistically significant.) In other words, the trend is as linear as it appears, and no change occurred after 1981.

If there had been a noticeable change after 1980, then one could argue that it reflects an increase in technology transfer efforts at the two labs in New Mexico. But, this data does not support this

argument. The steady trend shows no evidence of an effect of Stevenson-Wydler and Bayh-Dole.

The relevance of this data, could be argued against three ways. First it could be argued that the spinoffs from the labs did not take place within these two SIC categories. Second, it could be argued that this measure is too far removed from the technology transfer efforts of the labs to be a good measure. The third criticism is that employment spillovers will not be localized by state.

The first argument requires the proposal of more likely categories than SIC 36 and 38. None seem to me to be, *prima facie*, more likely indicators of technology transfer related employment.

The second argument is that the measure is too far removed from technology transfer efforts to indicate anything. This criticism could mean that the effects have not been seen yet, but will be eventually; or that the effects will not be measured as percent of employment. Admittedly, the measure used is indirect, and employment gains will require time, but the steady increase of the trend line before and after 1980 indicates no delayed effect to legislation passed in 1980. To the second part of this criticism, if employment is not a good measure of technology transfer effects, then what is? If the response is that technology transfer efforts have no effect on employment, then this is just an argument that transfer efforts may have increased, but they are ineffectual. To this, no counter can be presented.

The third criticism is that the employment effects will not be localized. Much of the work in regional economics and regional development suggests that the economic spillovers from universities

will be concentrated locally. However, the opposite point has also been argued.²⁰³ I do not wish to replay this argument here. Though much of the rhetoric surrounding the benefits of the labs stresses the local development benefits.

2. New Business Creations

Another measure of technology transfer results is new business creations. If technology transfer efforts are having any effect, new company start ups should be expected to be among them. Data is available by state that shows number of new businesses formed. This can be taken as a direct measure of entrepreneurial activity, or as an indirect measure of entrepreneurial climate. If the opportunities for new business creation are increased through technology transfer efforts, then more new businesses will be created (all things being equal, which they rarely are).

Once again, New Mexico is compared to its neighbor Arizona, and to Montana. Neither have labs, and both are Western, mountain states. Also included is a figure for the mountain state region--of which New Mexico is not a member in this data.²⁰⁴ The graph in Figure 11 shows the rates of new business formation, with the amounts standardized at the level seen in 1981. The number of new business incorporations in 1981 is 1, and all other years are a percentage of this level. Presented this way, the performance of the states since 1981 is emphasized. If New Mexico fails to outperform

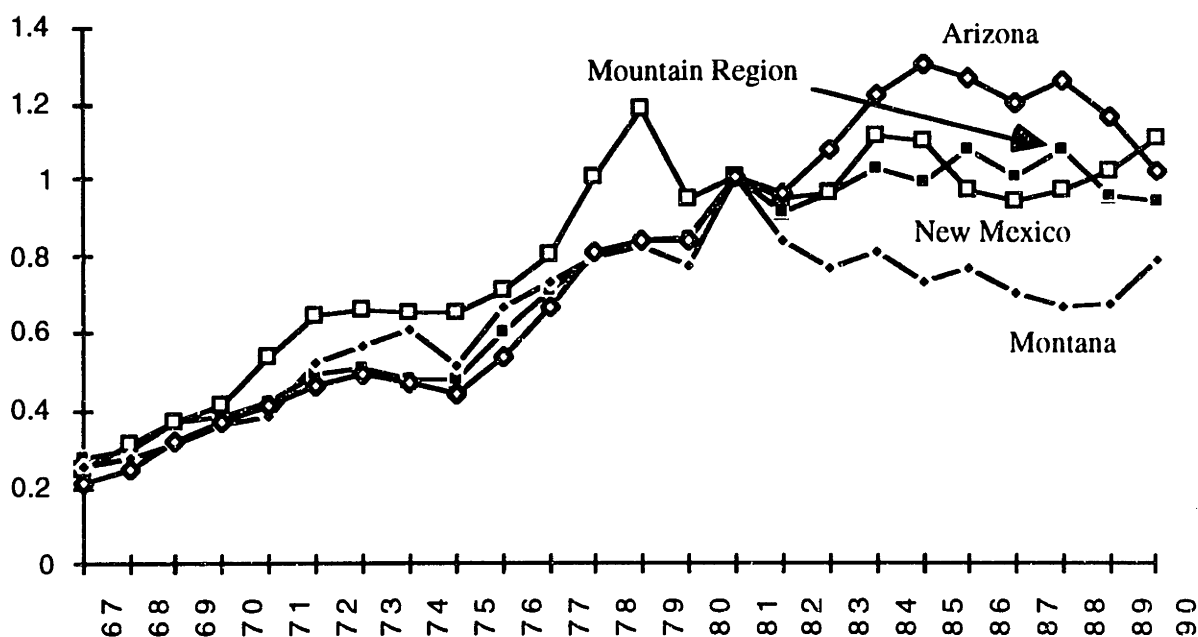
²⁰³ Paul Krugman, in Regional Economics (1991) describes this debate.

²⁰⁴ The States in the Mountain region are Arizona, Colorado, Utah, Wyoming, Montana, and Nevada. New Mexico is grouped with Oklahoma, Texas, Louisiana in a different region.

the others, this would support the hypothesis that Stevenson-Wydler and Bayh-Dole had little effect. 1981 is used arbitrarily, any reference year would show the same relative performance.

The data in Figure 12 show that the rates of new business incorporations since 1981 for New Mexico to be in the middle of the pack. They were greater than Montana, but roughly equal to the mountain region, and lower than Arizona. This data gives indirect support for the hypothesis that Stevenson-Wydler and Bayh-Dole had little effect. It also shows that the rate of new business formation was greater in 1979, before Stevenson-Wydler, that it was in any year after.

FIGURE 12
Rate of New Business Incorporation



Source: Report on Small Business, SBA, 1991.

Like the first measure, the rate of new business formation at the state level is indirect and subject to attack. Three criticisms can be anticipated. New business creation is not the only means of technology transfer, nor even the means emphasized by Bayh-Dole and Stevenson-Wydler as implemented, so there may be much technology transfer activity that this measure would not capture. The high level of aggregation of the data may wash out the effects of technology transfer efforts. And, the state level is inappropriate for capturing technology transfer effects.

These criticisms have some merit. New business creation was not emphasized by Stevenson-Wydler and Bayh-Dole. This is why patents were the primary focus of this study. Still, start-ups are one of the means of technology transfer used in practice.

It is true that even in the case of a large response to Stevenson-Wydler and Bayh-Dole, the state level data includes many more start ups not resulting from tt. For this reason this measure is only likely to catch a strong reaction to tt. No change was detected.

Finally, as above, there is no response to a criticism that denies that technology transfer efforts would be felt primarily locally, and thus measurable in the case of New Mexico. In any case, I do grant that this is a very gross measure, as state level data for new business incorporations contains the effects of many other factors, such as differences in regulations, tax structures, availability of capital, and many other potentially relevant forces.

These two measures, while not entirely satisfying, reinforce the hypothesis of the paper: Stevenson-Wydler and Bayh-Dole had little or no effect. Specifically measured here are technology transfer results. The two measures, state level analyses of employment composition and the number of startups, indicate that the economy of New Mexico (as the best case scenario) experienced no major shifts after 1980 that could have been attributable to the effects of Stevenson-Wydler or Bayh-Dole.

D. Other Studies

So far, I have presented two measures of changes in technology transfer efforts at the national labs, and two measures of the results of technology transfer from the labs. These generally support the hypothesis that Stevenson-Wydler and Bayh-Dole were not likely to have caused many changes in the labs. Much of the weight for this hypothesis was derived from theoretical perspectives on technology transfer and on the technical development process. From this body of work, I concluded that patent licensing is not likely to be a fruitful type of technology transfer. In the upcoming section, I describe two studies, done by others, that gives direct empirical support for this conclusion.

James Winebrake reports the results of a analysis of technology transfer case studies done in 1989. He broke technical development into stages, and asked what means of transfer correlated with success for technology in each stage of development. J. David Roessner industry people with experience working with the federal labs. He asked them which forms of technology transfer have been

most useful and which do they foresee as being most successful in the future. Both studies' conclusions were similar, patent licensing is not linked to successful technology transfer episodes, and patent licensing is not seen as a promising avenue for technology transfer.

1. Effectiveness of Patent Licensing in Technology Transfer

Winebrake's study was based on evaluations of 116 technology transfer case studies, representing both successful and unsuccessful transfers.²⁰⁵ The subjects of the transfers ranged from product technology to process technology from simple information transfer to standards and practices. Many different mechanisms of transfer were present, and these were broken down into seven types. The stage of the technology at the time of transfer was determined, and the success of the transfer experience was graded for each case.

It is a simple analytical step from dividing the development process into steps, to asking which type of transfer is most effective for projects in different stages of development. Winebrake's study is focused directly on this question. He differentiates the stages of development into 1) Basic and exploratory. 2) Applied and information based R&D. 3) Technology development. 4) Market penetration.

And he identifies seven types of transfer mechanisms: 1) advisory groups, 2) collaboration with cost sharing, 3) collaboration without cost sharing, 4) personnel exchanges, 5) licensing/spinoffs, 6)

²⁰⁵ Winebrake, "A Study of Technology Transfer Mechanisms for Federally Funded R&D." Technology Transfer, 1992.

active dissemination of information, 7) passive dissemination of information.

His study did find that different transfer mechanisms worked better for ideas at different stages of development. And, the results confirm the theory-based expectations. The mechanisms that were correlated with success were the use of advisory groups, collaboration with cost sharing, and active dissemination of information. Transfers using licensing/spinoff as a technology transfer mechanism were less successful than those not using it, when the technology was in the basic/experimental stage and in the market penetration stage. (In the intermediate two stages the results were neutral.)

The other three mechanisms, collaboration without cost sharing, personnel exchange, and passive dissemination of information, were associated neither with success nor failure.

His two strongest results centered on collaboration with cost sharing and the use of advisory groups. Collaboration with cost sharing was linked to success for the transfer in general, and particularly for technology in the market penetration stage. Winebrake suggests a number of reasons for this. The requirement to spend money may make the industry partner choose the project more carefully. Only participants who have already developed expertise may be willing to spend their money on a collaborative project. It may be that cost-sharing instills a greater commitment to project success. Or it may be that the ancillary arrangements that usually accompany cost shared agreements, such as exclusive

licensing, allow the company to extract profit from the experience.²⁰⁶ These explanations seem to resonate with the observations that the national labs need to work through cooperative projects, and be able to contact the 'right' industry partners. The point is clear, too, that mere collaboration is not good enough, committed industry partners are essential.

The second strong finding is that the advisory group mechanism helps transfer succeed when the technology is in the development stage. "It is in this stage that specific questions arise that need to be addressed by a diverse and often market-oriented group of experts."²⁰⁷ This result supports the assertion, made in chapter 3, that technical projects need to have, or have available, an understanding of user needs and attention to marketing and publicity, as well as scientific and technical expertise.

Winebrakes results confirm that patent licensing was not likely to generate extensive results in the wake of Bayh-Dole and Stevenson-Wydler. Instead, more powerful mechanisms that involve collaboration, active interaction, and market awareness need to be developed.

2. Preferred Transfer Mechanisms

Pursuing a similar path to Winebrake, Roessner also examined the different forms of technology transfer interactions. His approach was to ask the industry users of the labs which types they

²⁰⁶ Winebrake "A Study of Technology Transfer", (1992) p.59.

²⁰⁷ Winebrake "A Study of Technology Transfer", (1992) p.58.

preferred.²⁰⁸ Here, too, the starting point is a list of types of technology transfer. The official DOE list of technology transfer types has grown to ten.²⁰⁹ Roesnner's list is also ten, listed on Figure 12.

Roessner surveyed 62 division directors of large, research intensive companies that had had at least 'moderate' levels of interaction with a national laboratory. They were asked to rank the ten ways of interacting in terms of 'overall value' to the division or lab. 'Overall value' was supposed to subjectively include more than just immediate bottom line concerns. Indeed, when asked what form the benefits of interaction took, 'access to expertise' ranked highest, with 'profit potential' about equal to 'leveraging or supporting ongoing R&D'.

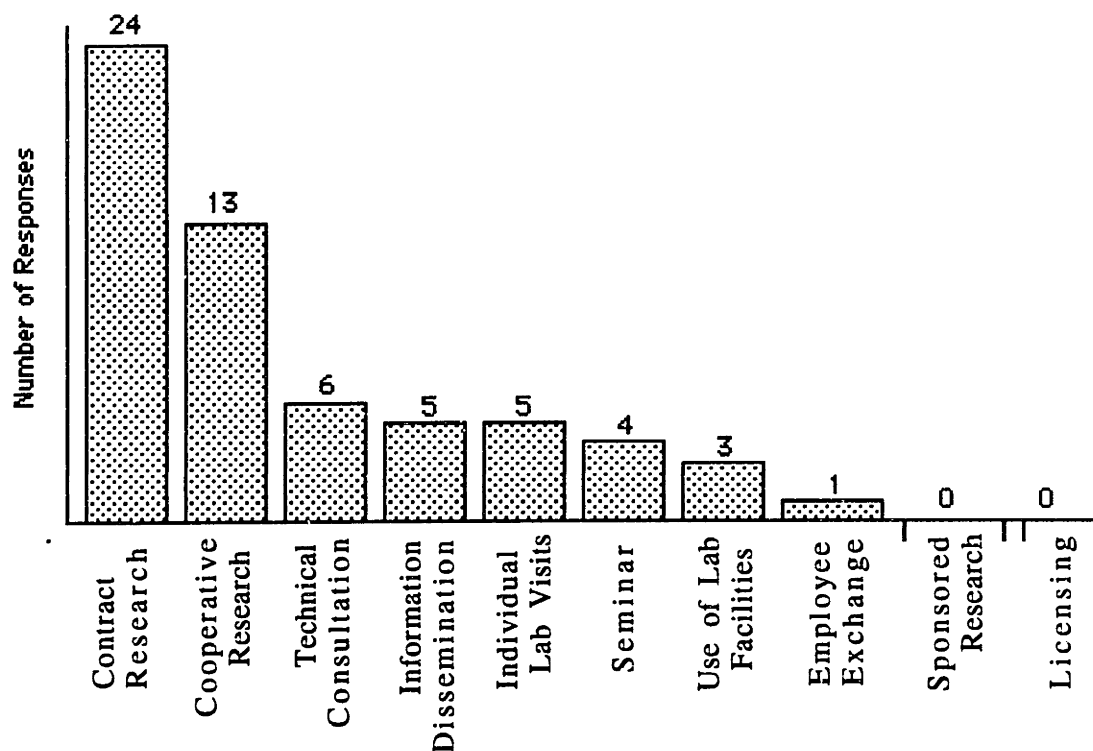
Figure 13 shows the respondents 'first choice' of interaction. The leading choices were contract research²¹⁰ and cooperative research. Contract research was overwhelmingly favored by firms from the defense and space sectors.

²⁰⁸ J. David Roessner, talk at AAAS meeting, Feb, 13, 1993. Published as J. David Roessner and Anne Wise, "Pattern of Industry Interaction with Federal Laboratories", Atlanta: School of Public Policy, Georgia Institute of Technology, May 1993.

²⁰⁹ Industrial interaction, technical personnel exchanges, technical documents and software, contracting arrangements, consulting arrangements, technology and software licensing, interactions with academic institutions, scientific user facilities, collaborative projects with industry, and reimbursable work for others. From DOE publication, Technology Transfer 92/93 (1993), p.4.

²¹⁰ Contract research refers to research projects in which the federal laboratory contracts with industry for the performance.

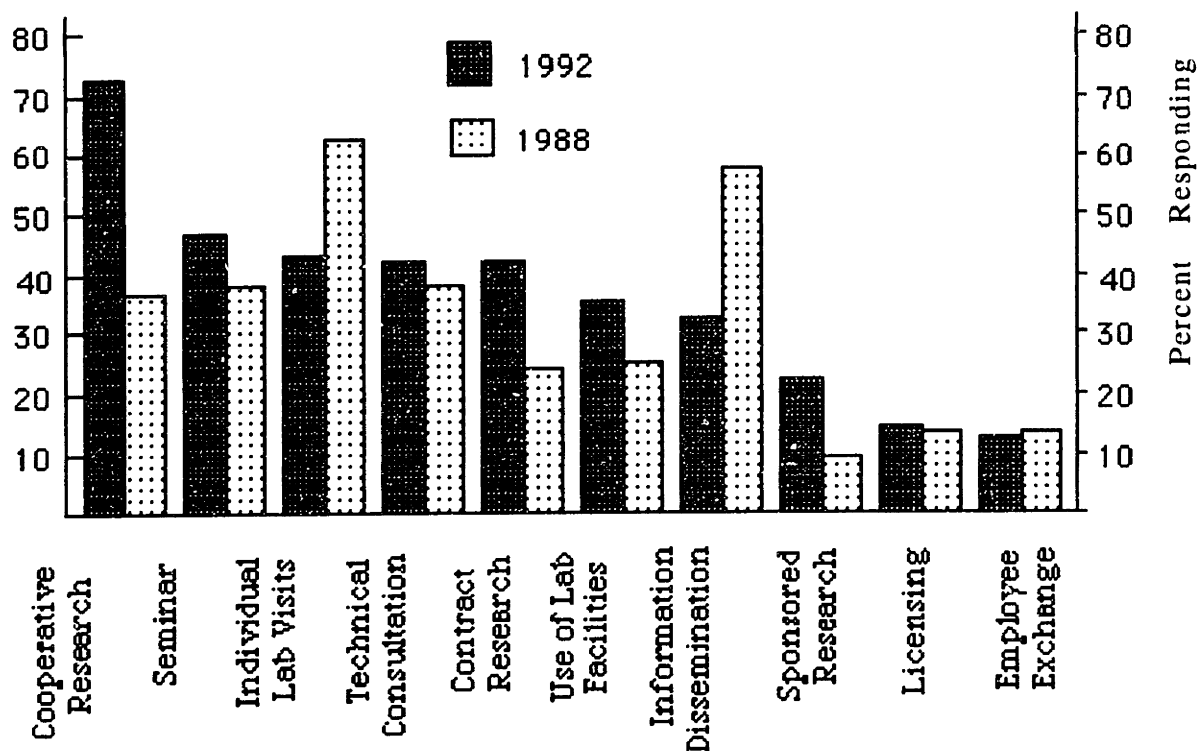
FIGURE 13
First Choice of Interaction by Industrial
Laboratory Director, 1992



Source: Roessner (1993)

The research directors were also asked about which forms of interaction they foresaw as having the greatest future promise for them. In Figure 14, cooperative research stands out with more than 70% of the directors stating that it had the greatest promise. Following, with more than 40% each, were workshops/seminars, individual lab visits, technical consultation, and contract research. Licensing held little appeal, with only 14% indicating that they felt it had significant future promise.

FIGURE 14
Types of Interactions with Federal Laboratories Judged to have
Significant Future Promise, 1988 and 1992.



Source: Roessner, (1993).

Notable also is that “information dissemination” was ranked as a promising means of transfer by 56% in a similar survey in 1988, but by only 32% in the 1993 survey. I would suggest that this reflects a learning experience about the helpfulness (not very) of this kind of technology transfer. In the same years, “cooperative research” jumped from being seen as promising by 36% to 72% of the R&D directors. This represents the emergence of cooperative research as an option, following 1986 and 1989 legislation. It also probably reflects some of the current hype surrounding CRADAs.

The studies of Winebrake and Roessner detail the utility of different types of technology transfer mechanisms in practice. Roessner found that licensing is held in little regard by those who have had experience interacting with the national laboratories, but that cooperative research is seen as very promising. Winebrake, likewise found that a licensing approach is not linked to technology transfer success, on the contrary, it is associated with less successful transfer cases. Approaches that utilize cost-shared collaboration, and advisory boards were more likely to succeed.

Their findings empirically corroborate the hypothesis that patent licensing is something of a blind alley. Unfortunately, the licensing approach is the one emphasized by Bayh-Dole, and Stevenson-Wydler, as implemented, had nothing else to offer either.

F. Conclusion.

This section presented measures of technology transfer efforts in the wake of Stevenson-Wydler and Bayh-Dole. Patents showed a rise that seemed to disconfirm my hypothesis. But alternate explanations were put forward. Indeed, the patent story, in many ways confirmed my view that Stevenson-Wydler and Bayh-Dole were too weak to spur institutional change. No one involved with patents at the time recalled them as significant, and one of the actions that explains the rise in patents--the addition of patent attorneys to attract industry attention--was motivated by a very conservative desire to preserve the institutional status quo. The other measure of efforts to make lab technology commercially relevant, the R&D 100 Awards, clearly showed that the labs have

become conscious of commercialization. But equally clear was that this turn was not linked with Stevenson-Wydler and Bayh-Dole.

Though I have argued that the goal of technology transfer did not receive a warm welcome from the labs--for many reasons, I still tried to measure any technology transfer effects. Though good measures are hard to find, two were examined. New business creations and the changing characterization of employment both gave no indication of technology transfer results attributable to Stevenson-Wydler or Bayh-Dole.

Finally, two other studies that directly evaluated different types of technology transfer measures were reviewed. Both strongly confirmed the conclusion drawn from Chapter 3 that patent licensing is a relatively weak mechanism for moving technology out of the national labs. Nor is it seen as promising by those who have had experience with the federal labs. Insofar as Bayh-Dole (and Stevenson-Wydler by default) relied on this approach they were not likely to succeed.

CHAPTER NINE: CONCLUSION

A. Summary

This paper has been an exploration of the effects of Stevenson-Wydler and Bayh-Dole. Passed in 1980, these two laws represent a Congressional effort to improve the rate of innovation within the American economy. Specifically, they seek to encourage and facilitate the utilization of government R&D conducted within the federal laboratory system.

These laboratories, whose funding was about \$25 billion in 1993, are a large part of the U. S. science and technology system. They consume about a third of the federal budget for R&D. There is a widespread feeling, right or wrong, that the technical capability of the labs could be applied more effectively toward the development of novel commercial technology.²¹¹

Two laws were passed in 1980 intended to utilize the resources of the labs more fully. The Bayh-Dole Act set out to improve the utilization of federally funded technology by changing federal patenting law. It allowed for small businesses, universities, and non-profit organizations to take direct title to inventions done under contract to the federal government. It also emphasized that large business contractors could gain exclusive licenses to federal patents and set forth a procedure to expedite this. The Stevenson-Wydler Technology Innovation Act set out to increase the productivity of the economy at large by increasing the interactions of researchers from the federal laboratories, universities and private industry. However,

²¹¹ This sentiment is expressed in the legislative history of Stevenson-Wydler.

its multi-faceted approach suffered upon the change in administration in 1981, and most of its programs were never funded. Thus, it was effectively reduced to a declaration that technology transfer should be a function of all government agencies, and a requirement for the creation of an Office of Research and Technology Application at all federal labs.

The effort to transfer technology from the federal laboratories to commercial use has received much attention since 1980. But the results have been disappointing. Reports and hearings still appear on the subject of removing barriers to technology transfer. Neither the efforts to increase technology transfer nor the results of the efforts were very significant at first. Additional legislation has been passed to address the perceived deficiencies of the first laws. (Listed in the appendix, following.) But no attempt has been made to measure the effects of these first two laws.

There are two reasons to expect that Stevenson-Wydler and Bayh-Dole would have little effect. First, the approach to technology transfer that was emphasized by these laws, patent licensing, is probably not the most effective way of promoting commercialization. A number of perspectives on technology transfer, explored in chapter three, all suggest that forms of industry laboratorycollaborative research are much more likely to lead to commercial results.

Second, the labs, as organizations were not receptive to the addition of technology transfer as a goal, and the laws as written and implemented did little to overcome this. The existing organizational

mission and goals, organizational culture, and practical incentives were indifferent or even hostile to technology transfer.

The measurement of the effects of technology transfer is difficult, and most measures are indirect or imperfect. Furthermore many promising would-be measures have not been collected. Patents are one means of revealing changes in technology transfer efforts, though they are limited as indicators of results. Bayh-Dole reflected a shift in traditional thinking on the proper disposition of government patents. The change that resulted was intended to facilitate the utilization of federal owned patents.

The analysis of patent rates in chapter six reveals a small but statistically significant rise in patenting from the DOE labs. The rise started with patents granted in 1984 and was independent of any concurrent changes in GNP or in R&D funding for these labs. The rise coincided with the passage of Stevenson-Wydler and Bayh-Dole and could have been caused by them. What would be implied if this were true is that these laws created a change in incentives, a change in organizational structures, even a change in organizational culture, that was strong enough to lead to increased patent activity.

A fundamental change would be required since in 1980, the labs were not oriented toward patenting. The goal of work at the national labs was not patenting, but basic science and project oriented research; and the reward system did not, by and large, take patents into account. Filing for patents based on research was a somewhat time consuming byproduct of the main line of professional activity. At some of the labs there was a small monetary reward for

patenting--while at others there was no institutional reward at all.²¹² Before 1980, patents were not part of the reward and incentive system motivating scientists at the national labs.

For these reasons, I believe it is unlikely that the jump in patents detected here was a result of this legislation. More probable are two other causes: the delayed effects of the Carter era push to develop commercializable alternate energy technologies; and an increase in staff in the patent offices at DOE and at the labs. This increase of staff originated from the Washington headquarters of DOE, and was an effort by a few people to maintain the structural integrity of the labs.

The proper conclusion is that these laws were not enough to spark an increase in patents. The true significance then, of Stevenson-Wydler and Bayh-Dole is historical: they mark the legislative origin of the technology transfer mission assigned to the national laboratories. More powerful legislation came later, and so have some real changes.²¹³

B. Discussion

The Stevenson-Wydler and Bayh-Dole Acts were intended to address the problem of national productivity and competitiveness. As discussed in Chapter One, this is a new role for the US

²¹² The rewards were small: Brookhaven \$275, Los Alamos \$250, which would not have compensated the researcher for the time involved. There was no reward at Sandia, as patenting was not seen as significantly above and beyond what the researcher was getting paid for. Source: several patent attorney phone interviews.

²¹³ The Federal Technology Transfer Act of 1986 mandated rewards for inventors involved in technology transfer, and this law and the national competitiveness and Technology Transfer Act of 1989 created CRADAs. For a full list of subsequent legislation, see Appendix 2.

government. To achieve this goal requires either creating new organizations or adapting existing ones to new tasks. The national laboratories were the focus of Stevenson-Wydler and Bayh-Dole because they were perceived to contain underutilized resources that could be applied to this new task. However, the national laboratories already had missions and cultures and procedures, and were given little incentive to change. The limited effect of the first laws reflects the difficulty of changing institutions that are not interested in changing. {external changes required to change labs mission or culture}

Since 1980, the labs have had to respond to changes in their external environment. The federal budget deficit is putting pressure on all agencies to both trim their programs and to justify their existence. The repeated legislative attention focused on the labs has, itself, changed the atmosphere they operate in. And the end of the Cold War has had a deep impact, fiscal and psychological, on the weapons labs. Combined with the development of more effective transfer instruments, such as CRADA's, these external forces are leading, slowly, to real improvements in the effectiveness of technology transfer programs.

Of course, the development of any new government program is never easy. A clear analogy can be drawn between the effort to craft an effective technology transfer program within the national labs and the evolution of the US agricultural research and extension system.²¹⁴ This system is often praised as an effective public R&D

²¹⁴ This analogy is developed in Feller, "Recent Theoretical and Organizational Approaches to U.S. Technology Policy", (1992), p.127.

program that links public research to user needs and market demands. But three relevant points need to be made. First, it took a while: 52 years passed between the first legislation and the last. Second, each of the subsequent laws was intended to address limitations of prior legislation in achieving the linkage of research and technology transfer sought by users and researchers. Third, at no time has the linkage of these different groups occurred without stress. The lesson here is that an integrated research and technology system takes time to craft, needs some experimentation, and requires organizational change.

While technology policy is still contentious politically, there appears to have developed a consensus that whatever resources the federal labs have to offer should be utilized more fully. Developing effective procedures has involved a process of trial and error. Indeed, the process is ongoing. But, beyond the need for the 'right' transfer procedures, success depends on receptive organizations. Only when the federal labs actively adopt technology transfer as a mission are real results possible.

APPENDIX ONE: DOE NATIONAL LABORATORIES

Multiprogram Laboratories

Location

Argonne National Laboratory	Argonne, IL
Brookhaven National Laboratory	Upton, NY
Idaho National Engineering Laboratory	Idaho Falls, ID
Lawrence Berkeley Laboratory	Berkeley, CA
Lawrence Livermore National Laboratory	Livermore, CA
Los Alamos National Laboratory	Los Alamos, NM
Oak Ridge National Laboratory	Oak Ridge, TN
Pacific Northwest Laboratory	Richland, WA
Sandia National Laboratory	Albuquerque, NM

Major Single-Program Laboratories

Ames Laboratory	Ames, IA
Continuous Electron Beam Accelerator Facility	Newport News, VA
Fermi National Accelerator Laboratory	Batavia, IL
Morgantown Energy Technology Center	Morgantown, WV
National Renewable Energy Laboratory	Golden, CO
Oak Ridge Institute for Science and Education	Oak Ridge, TN
Pittsburgh Energy Technology Center	Pittsburgh, PA
Princeton Plasma Physics Laboratory	Princeton, NJ
Savannah River Technology Center	Aiken, SC
Stanford Linear Accelerator Center	Stanford, CA
Westinghouse Hanford Company	Hanford, WA

APPENDIX TWO: TECHNOLOGY TRANSFER LEGISLATION SINCE 1980.

Stevenson-Wydler Technology Innovation Act of 1980 [PL 96-480].

- Established Offices of Research and Technology Application at major federal laboratories.
- Established the Center for the Utilization of Federal Technology within the National Technical Information Service.
- Declared it federal government policy to support technical cooperation and utilization.

Bayh-Dole Act of 1980 [PL 96-517].

- Made uniform the federal patent policy across agencies.
- Permitted universities, not-for-profit corporations, and small businesses to obtain title to inventions developed with government support. (Not including contractors of the national laboratories.)
- Created a procedure to grant exclusive licenses of patents to large businesses.

Small Business Innovation Development Act of 1982 [PL 97-219].

- Required agencies to provide special funds for small business R&D connected to the agencies missions.

Trademark Clarification Act of 1984 [98-620].

- Permitted labs run by universities and non-profit institutions, such as Brookhaven and Argonne, to retain title to inventions, with Department level approval. (This did not include the weapons labs.)
- Removed the restriction on large companies receiving exclusive licenses.
- Moved the awarding of patent licenses to the laboratory level.

Cooperative Research Act of 1984 [PL 98-462].

- Permits the formation of research consortia, for non-profit ventures registered with the Department of Commerce. Removes the treble damages aspect of anti-trust laws for these ventures. This results the formation of SEMATECH and MCC, among others.

Federal Technology Transfer Act of 1986 [PL 99-502]

- Creates Cooperative Research and Development Agreements, (CRADAs) and grants lab directors authority to assign title and licensing agreements resulting from them to large or small companies. (This applies only to government-owned government operated labs. Excluding all major DOE labs.)
- Made technology transfer a responsibility of all federal laboratory scientists and engineers.
- Mandated that technology transfer be considered in employee performance evaluations. Established the principle of royalty sharing for federal inventors.
- Gave a federal charter to the Federal Laboratory Consortium for Technology Transfer.
- Allowed current and former federal employees to participate in commercial development, to the extent there is no conflict of interest.

Executive Order 12591 of April 1987.

- Mandated that technology transfer be part of the purpose of all executive departments and agencies.

National Defense Authorization Act of 1987.

- Encouraged the Secretary of Defense to transfer DoD developed technology to the extent that it is consistent with national security objectives.

Omnibus Trade and Competitiveness Act of 1988 [PL100-418].

- Changed the National Bureau of Standards to the National Institute of Science and Technology, and broadened its role to include promoting commercialization and transfer of federally developed technology.
- Established regional centers for transferring manufacturing technology, made provisions to assist state technology extension programs, and authorized technology transfer training centers to be administered by the Department of Education.

National Competitiveness Technology Transfer Act of 1989 [PL 101-189].

- Extended CRADA authority to all government-owned, contractor-operated labs, (most DOE labs).
- Provided a technology transfer mission for the weapons labs.
- Protected proprietary information resulting from CRADAs from public disclosure.

National Defense Energy Technology Transfer Act of 1989.

- Made explicit the technology transfer role of weapons labs.

Defense Authorization Act FY 1991 [PL 101-510].

- Established model technology transfer programs at DoD labs.
- Provided for development and implementation of National Defense Manufacturing Technology Plan.

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