2 THE HISTORY OF PUBLIC/PRIVATE PARTNERSHIPS

The development of science, technology, and economic growth in the United States was greatly influenced by the scientific discoveries and university infrastructure within Europe during its colonial period. While it is difficult to pinpoint how or which specific elements of scientific and technical knowledge diffused across the Atlantic, certain milestone events can be dated and key individuals can be identified.

The background in this chapter, which draws on Unesco (1968) and National Science Board (2000), gives not only an appreciation for the role that science and technology resources have played in the development of the Nation, but also historical insights into the evolution of public/private partnerships in the United States.[1]

THE COLONIAL PERIOD

The first member of the Royal Society of London to immigrate to the Massachusetts Bay Colony was John Winthrop, Jr. in 1631, just a few years after the founding of the Colony. As a scientist, he is credited with establishing druggist shops and chemistry laboratories in the surrounding villages to meet the demand for medicine. According to Unesco (1968, p. 9), these ventures were "perhaps the first science based commercial enterprise of the New World."

Before the turn of the eighteenth century, colonists made noticeable advances toward what may be called a scientific society, organizing

[1] The original version of this chapter was set forth in Link (1999b), later expanded in Audretsch et al. (2002a), and then reproduced in book form as Feldman, Link, and Siegel (2002).

scientists who came from England and other European countries into communities that promoted scientific inquiry. In 1683, the Boston Philosophical Society was formed to advance knowledge in philosophy and natural history.

Benjamin Franklin formed the American Philosophical Society of Philadelphia in 1742 for the purpose of encouraging correspondence with colonists in all areas of science. This Society later merged with the Franklin-created American Society to promote what Franklin called "useful knowledge," and it still exists today. The combined society focused on making available advancements in agriculture and medicine to all individuals by sponsoring the first medical school in America (also supported by the Pennsylvania House of Representatives). Thus, Franklin's combined society was a hallmark of how public and private sector interests could work together for the common weal.

Influenced by the actions of Pennsylvania and later Massachusetts with regard to sponsorship of scientific institutions, the establishment of national universities for the promotion of science was first discussed at the Constitutional Convention in 1787. However, at that time, the founders of the Constitution believed educational and scientific activities should be independent of direct national governmental control. But, they felt that the national government should remain an influential force exerting its influence through indirect rather than direct means.

For example, Article I, Section 8, of the Constitution states:

> The Congress shall have the power ... To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries.

Soon thereafter, in 1790, Congress passed the first patent act.

Alexander Hamilton, in his role as Secretary of the Treasury, released on December 5, 1791 A Report on Manufacturers. Therein he advocated a direct role of the government in support of the Nation's manufacturing:

> The expediency of encouraging manufacturers in the United States, which was not long since deemed very questionable, appears at this time to be pretty generally admitted. The embarrassments, which have obstructed the progress of our external trade, have led to serious reflections on the necessity of enlarging the sphere of our domestic commerce; the restrictive regulations, which in

> foreign markets abridge the vent of the increasing surplus of our Agriculture produce, serve to beget an earnest desire, that a more extensive demand for that surplus may be created at home ...

Thomas Jefferson also championed a more direct role for the government in the area of science. While president, Jefferson sponsored the Lewis and Clark expedition in 1803 to advance the geographic knowledge of the Nation, thus making clear that "the promotion of the general welfare depended heavily upon advances in scientific knowledge" (Unesco 1968, p. 11). In fact, this action by Jefferson set several important precedents including the provision of federal funds to individuals for scientific endeavors.

Although the Constitution did not set forth mechanisms for establishing national academic institutions, based on the founders' belief that the government should have only an indirect influence on science and technical advancement, the need for a national institution related to science and technology was recognized soon after the Revolutionary War. For example, West Point was founded in 1802 as the first national institution of a scientific and technical nature, although Connecticut established the first State Academy of Arts and Sciences in 1799.

In the early 1800s, universities began to emphasize science and technical studies, and in 1824 Rensselaer Polytechnic Institute was founded in New York State to emphasize the application of science and technology.

The *American Journal of Science* was the first American scientific publication, followed in 1826 by the *American Mechanics Magazine*.

The social importance of the government having a direct role in the creation and application of technical knowledge was emphatically demonstrated in the 1820s and 1830s through its support of efforts to control the cholera epidemic of 1822. Also during that time period, federal initiatives were directed toward manufacturing and transportation. In fact, the Secretary of the Treasury—the Department of the Treasury being the most structured executive department at that time—directly funded the Franklin Institute in Philadelphia to investigate the causes of these problems. This action, driven by public concern as well as the need to develop new technical knowledge, was the first instance of the government sponsoring research in a private-sector organization.

In 1838, the federal government again took a lead in the sponsorship of a technological innovation that had public benefits. After Samuel Morse demonstrated the feasibility of the electric telegraph, Congress provided him with $30,000 to build an experimental line between Baltimore, Maryland, and Washington, DC. This venture was the first instance of governmental support to a private researcher.

In retrospect, one could make an argument that Jefferson's funding of Lewis and Clark was the first instance of public support for pure research, whereas Morse was funded to conduct applied research. Although not discussed herein, there are other historical examples of governmental support to individuals for research that had the potential to benefit society, such as the Longitude Act of 1714. The British Parliament offered a prize (equal to several million dollars in today's terms) for a practicable solution for sailing vessels to determine longitude (Sobel 1995).

Public/private research relationships continued to evolve in frequency and in scope. In 1829, James Smithson, gifted $500,000 to the United States to found an institution in Washington, DC for the purpose of "increasing and diffusing knowledge among men" (Unesco, p. 12). Using the Smithson gift as seed funding, Congress chartered the Smithsonian Institution in 1846, and Joseph Henry became its first Executive Officer. Henry, a renowned experimental physicist, continued the practice of a federal agency directly supporting research through grants to individual investigators to pursue fundamental research. Also, the Institution represented a base for external support of scientific and engineering research; during the 1850s, about 100 academic institutions were established with science and engineering emphases.

Thus, the pendulum had made one complete swing in the hundred or so years since the signing of the Constitution. In the early years, the government viewed itself as having no more than an indirect influence on the development of science and technology, but over time its role changed from indirect to direct. This change was justified in large part because advances in science and technology came to be viewed as critical in promoting the public interest. This changing pattern of advocacy during the colonial period is summarized in Table 2.1.

THE PERIOD OF NATIONAL SCIENCE AND TECHNOLOGY INFRASTRUCTURE

Scientists had long looked toward the European universities for training in the sciences, but in the early and mid-1800s an academic infrastructure was beginning to develop in the United States. Harvard University awarded its first bachelors of science degree in 1850.

The development of an academic science base and the birth of technology-based industries (e.g., the electrical industry) in the late 1850s established what would become the foundation for America's technological preeminence.

Table 2.1. Pendulum Swing of Government's Role during the Colonial Period

Direct Role for the Government	Indirect Role for the Government
	1787 Constitutional Convention: establishment of national university for promotion of science rejected in favor of an indirect influence
	1790 Based on Article I, Section 8 of the Constitution, Congress passed the Patent Act
1803 President Jefferson commissioned the Lewis and Clark expedition	
1822 National initiatives in response to medical emergencies	
1824 ff. States began to establish science and technology universities	
1838 Direct funding to Samuel Morse to build a telegraph line between Washington, DC and Baltimore, MD	

The Morrill Act of 1862 established the land grant college system thereby formally recognizing the importance of trained individuals in the agricultural sciences. The Act charged each state to establish at least one college in the agricultural and mechanical sciences. Each state was given 30,000 acres of federal land per each elected U.S. Senator and

Representative. An important outgrowth of this land grant system was a mechanism or infrastructure through which state and federal governments could financially support academic research interests.

In 1863, during the Civil War, Congress established the National Academy of Sciences. The federal government funded the Academy but not the members affiliated with it who had (Unesco 1968, p. 14):

> ... an obligation to investigate, examine, experiment, and report upon any subject of science or art in response to a request from any department of the Government.

Then, as today, the Academy was independent of governmental control.

Although the government was encouraging an infrastructure to support science and technical research, it did not have a so-called in-house staff of permanent professionals who were competent to identify either areas of national importance or areas of importance to specific agencies. In 1884, Congress established the Allison Commission to consider this specific issue. While many solutions were debated, including the establishment of a Department of Science—an idea that resurfaces every few decades—the Commission soon disbanded without making any recommendations much less reaching closure on the matter. One could conclude from the inaction of the Commission that it favored the decentralized administrative architecture that had evolved over time as opposed to a centralized one.

The changing pattern of advocacy during the period of infrastructural growth is summarized in Table 2.2.

THE PERIOD OF INDUSTRIAL SCIENCE AND TECHNOLOGY INFRASTRUCTURE

Most scientists in the United States in the 1870s and 1880s had been trained in Europe, Germany in particular. What they experienced firsthand were the strong ties between European industries and graduate institutions of learning. Companies invested in professors and in their graduate students by providing them with funding and access to expensive materials and instruments, and in return the companies gained lead-time toward new discoveries as well as early access to the brightest graduate students as soon as they completed their studies. This form of symbiotic arrangement became the norm for the European-trained scientists who were working in U.S. industries and U.S. universities toward the end of the century.

By the turn of the century, it was widely accepted among industrial leaders that scientific knowledge was the basis for engineering development and it was the key to remaining competitive. Accordingly, industrial research laboratories soon began to blossom as companies realized their need to foster scientific knowledge outside of the university setting. There are a number of examples of this strategy.[2]

Table 2.2. Pendulum Swing of Government's Role during the Infrastructural Growth Period

Direct Role for the Government	Indirect Role for the Government
1862 Morrill Act—established the land grant college system	
1863 National Academy of Sciences established	
	1884 Allison Commission did not recommend the establishment of a federal Department of Science

General Electric (GE) established the General Electric Research Laboratory in 1900 in response to competitive fears that improved gas lighting would adversely affect the electric light business, and that other electric companies would threaten GE's market share as soon as the Edison patents expired.

Similarly, AT&T was at the same time facing increasing competition from radio technology. In response, AT&T established Bell Laboratories to research new technology in the event that wire communications were ever challenged.

And as a final example, Kodak realized at the turn of the century that it must diversify from synthetic dyes. For a number of years Kodak relied on German chemical technology, but when that technology began to spill

[2] Hounshell (1996) provides an excellent history of the growth of U.S. industrial research organizations.

over into other areas, such as photographic chemicals and film, Kodak realized that their competitive long-term health rested on their staying ahead of their rivals. Kodak, too, formed an in-house research laboratory.

Many smaller firms also realized the competitive threats that they could potentially face as a result of technological competition, but because of their size they could not afford an in-house facility. So as a market response, contract research laboratories began to form. Arthur D. Little was one such contract research laboratory that specialized in the area of chemicals.

Just as industrial laboratories were growing and being perceived by those in both the public and private sectors as vitally important to the economic health of the Nation, private foundations also began to grow and to support university researchers. For example, the Carnegie Institution of Washington was established in 1902, the Russell Sage Foundation in 1907, and the Rockefeller Foundation in 1913.

In the early-1900s science and technology began to be embraced—both in concept and in practice—by the private sector as the foundation for long-term competitive survival and general economic growth.

THE PERIOD OF THE WORLD WARS AND AFTERWARDS

Increased pressure on the pace of scientific and technical advancements came at the beginning of World War I. The United States had been cut off from its European research base. Congress, in response, established the Council of National Defense in 1916 to identify domestic pockets of scientific and technical excellence.

The National Academy of Sciences recommended to President Woodrow Wilson the formation of the National Research Council to coordinate cooperation between the government, industry, and the academic communities toward common national goals. The Allison Commission had failed in 1884 to formulate an infrastructure to undertake this task.

The prosperity of the post-World War I decade also created an atmosphere supportive of the continued support of science and technology. In 1920, there were about 300 industrial research laboratories, and by 1930 there were more than 1,600. Of the estimated 46,000 practicing scientists in 1930, about half were at universities and over a third were in industry. Herbert Hoover was Secretary of Commerce at this time. He adopted the philosophy that (Unesco 1968, p. 18):

> ... pure and applied scientific research constitute a foundation and instrument for the creation of growth and efficiency of the economy.

Two important events occurred in 1933 in response to the Great Depression and the subsequent national economic crisis. One event was the appointment of a Science Advisory Board, and the other event was the establishment of a National Planning Board. Whereas the National Research Council had been organized around *fields of science* to address governmental needs, the Science Advisory Board was multi-field and organized around *impending national problems*. The National Planning Board was formed on the presumption that there were areas of economic concern that required a national perspective rather than a field-of-science perspective.

In 1934, the National Resources Committee replaced the National Planning Board, and the Committee then subsumed the Science Advisory Board. The bottom line, after all of the organizational issues were settled, was that the federal government recognized through the formation of these committees and boards that it had and would continue to have an important coordinating role to play in science and technology planning toward a national goal of economic well being. Hence, the pendulum began to swing again, this time away from government having a hands-on role toward it having an indirect influence on planning the environment for science and technology.

In 1938, the Science Committee of the National Resources Committee issued a multi-volume report entitled, *Research—A National Resource*. Some important first principles were articulated in that report. Since then, these principles have formed a basis for economists and policy makers to rationalize and justify, again, a direct role of government in science and technology. The report is explicit that:

- There are certain fields of science and technology which the government has a Constitutional responsibility to support. These fields include defense, determination of standards, and certain regulatory functions.
- The government is better equipped to perform research in certain fields of science than the private sector. These are areas where "research is unusually costly in proportion to its monetary return but is of high practical or social value" (p. 25). Examples cited in the report include aeronautical and geological research.

- Research by the government "serves to stimulate and to catalyze scientific activity by nongovernmental agencies. In many fields, new lines of research are expensive and returns may be small or long delayed. Industry cannot afford to enter such fields unless there is reasonable prospect of definite financial gain within a predictable future, and it is under such circumstances that the Government may lead the way." (p. 26). One example cited was the Navy Department's influence on the development of the steel industry.

The involvement of the United States in World War II had a dramatic impact on the scope and direction of government's support of science and technology. Prior to the war, there were about 92,000 scientists, with about 20 percent in government and the remaining 80 percent being almost equally divided between universities and the more than 2,200 industrial laboratories. Clearly, the United States had a significant scientific resource base to draw upon for its war efforts.

In 1940, President Franklin D. Roosevelt established the National Defense Research Committee, and he asked Vannevar Bush, President of Carnegie Institution of Washington, to be its chairman. The purpose of this committee was to organize scientific and technological resources toward enhancing national defense. It soon became apparent that this task required an alternative administrative structure.

In 1941, Roosevelt issued an Executive Order establishing the Office of Scientific Research and Development (OSRD) with Bush as Director. The OSRD did not conduct research, rather it realized that there were pockets of scientific and technological excellence throughout the country, and through contractual relationships with universities and industry and government agencies, it could harness national strengths with a focus on ending the war. One hallmark event from the efforts of the OSRD was the establishment of the Los Alamos Laboratory in New Mexico under the management of the University of California. What came about from the collective efforts of the resources acquired by the Office were not only atomic weapons but also radar.

It was clear by 1944 that World War II was almost over. President Roosevelt then asked Bush to develop recommendations as to how scientific advancements could contribute in the larger sense to the advancement of national welfare. In his November 17, 1944 letter to Bush, President Roosevelt stated:

> The Office of Scientific Research and Development, of which you are the Director, represents a unique

> experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war. ... There is ... no reason why the lessons to be found in this experiment cannot be profitably employed in times of peace. This information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living. ... New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life.

Shortly before asking Bush to prepare this report, Senator Harley M. Kilgore from West Virginia had introduced a bill to create a National Science Foundation. The Kilgore bill recommended giving authority to federal laboratories to allocate public moneys in support of science to other government agencies and to universities. Clearly, this recommendation gave a direct role to government in shaping the technological course of the country not only in terms of scientific direction but also in terms of what groups would conduct the underlying research. The bill was postponed until after the war.

Bush submitted his report, *Science—the Endless Frontier*, to President Roosevelt on July 25, 1945. In Bush's transmittal letter to the president he stated:

> The pioneer spirit is still vigorous within this Nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The reward of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress.

The foundations set forth in *Science—the Endless Frontier* are:

- "Progress ... depends upon a flow of new scientific knowledge" (p. 5).
- "Basic research leads to new knowledge.[3] It provides scientific capital. ... New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science" (p. 11).
- "The responsibility for the creation of new scientific knowledge ... rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research" (p. 7).
- "A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill" (p. 15).
- "The Government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth" (p. 7).
- "If the colleges, universities, and research institutes are to meet the rapidly increasing demands of industry and Government for new scientific knowledge, their basic research should be strengthened by use of public funds" (p. 16).
- "Therefore I recommend that a new agency for these purposes be established" (p. 8).

Bush recommended in his report the creation of a National Research Foundation. Its proposed purposes were to:

> ... develop and promote a national policy for scientific research and scientific education, ... support basic research in nonprofit organizations, ... develop scientific talent in American youth by means of scholarships and fellowships, and ... contract and otherwise support long-range research on military matters.

Bush envisioned a National Research Foundation that would provide funds to institutions outside government for the conduct of research. Thus, this organization differed from Kilgore's proposed National Science

[3] The term "basic research" is credited to Vannevar Bush. He proffered the definition: "Basic research is performed without thought of practical ends."

Foundation in that Bush advocated an indirect role for government. There was agreement throughout government that an institutional framework for science was needed, but the nature and emphases of that framework would be debated for yet another five years.

Science—the Endless Frontier affected the scientific and technological enterprise of this Nation in at least two ways. It laid the basis for what was to become the National Science Foundation in 1950. Also, it set forth a paradigm that would over time influence the way that policy makers and academic researchers thought about the process of creating new technology. The so-called linear model set forth by Bush is often represented by:

Basic Research → Applied Research → Development → Enhanced Production → Economic Growth

Complementing *Science—the Endless Frontier* was a second, and often overlooked, report prepared in 1947 by John Steelman, then Chairman of the President's Scientific Research Board. As directed by an Executive Order from President Harry Truman, Steelman, in *Science and Public Policy*, made recommendations on what the federal government could do to meet the challenge of science and assure the maximum benefits to the Nation. Steelman recommended that national R&D expenditures should increase as rapidly as possible, citing (p. 13):

1. Need for Basic Research.
   Much of the world is in chaos. We can no longer rely as we once did upon the basic discoveries of Europe. At the same time, our stockpile of unexploited fundamental knowledge is virtually exhausted in crucial areas.
2. Prosperity.
   This Nation is committed to a policy of maintaining full employment and full production. Most of our frontiers have disappeared and our economy can expand only with more intensive development of our present resources. Such expansion is unattainable without a stimulated and growing research and development program.
3. International Progress.
   The economic health of the world—and the political health of the world—are both intimately associated

with our own economic health. By strengthening our economy through research and development we increase the chances for international economic well-being.

4. Increasing Cost of Discovery.
The frontiers of scientific knowledge have been swept so far back that the mere continuation of pre-war growth, even in stable dollars, could not possibly permit adequate exploration. This requires more time, more men, more equipment than ever before in industry.
5. National Security.
The unsettled international situation requires that our military research and development expenditures be maintained at a high level for the immediate future. Such expenditures may be expected to decrease in time, but they will have to remain large for several years, at least.

An important element of the Steelman report was the recommended creation of a National Science Foundation, similar in focus to the National Research Foundation outlined by Bush. And, Congress passed the National Science Foundation Act in 1950.

Renewed post-war attention toward science and technology came with the success of the Soviet Union's space program and the orbit of its Sputnik I in October 1957. In response, President Dwight D. Eisenhower championed a number of committees and agencies to ensure that the United States could soon be at the forefront of this new frontier. Noteworthy was the National Defense Education Act of 1958, which authorized $1 billion in federal moneys for support of science, mathematics, and technology graduate education. This proposal is precisely the type of support that Bush recommended in his report.

As the post-World War II period came to close, there was a well-established national and industrial infrastructure to support the advancement of science and technology. But, more important than the infrastructure, there was an imbedded belief that scientific and technological advancements are fundamental for economic growth, and that the government has an important supporting role—both direct and indirect—to ensure such growth.

The changing pattern of advocacy during the period of the World Wars, and afterwards, is summarized in Table 2.3.

Table 2.3. Pendulum Swing of Government's Role during the World Wars Period and Afterwards

Direct Role for the Government	Indirect Role for the Government
1938 National Resources Committee report, *Research—A National Resource*	
	1945 Vannevar Bush's report, *Science—the Endless Frontier*
	1950 National Science Foundation established

Every president since President Eisenhower has initiated at least one major science and technology policy initiative. Representative initiatives are:

- President John F. Kennedy set the goal of sending a man to the moon by the end of the 1960s and funded the needed programs to make this a reality.
- President Lyndon B. Johnson emphasized the use of scientific knowledge to solve social problems through, for example, his War on Poverty.
- President Richard M. Nixon dramatically increased federal funding for biomedical research as part of his War on Cancer.
- President Gerald R. Ford created the Office of Science and Technology Policy (OSTP) within the Executive Branch.
- President James E. Carter initiated research programs for renewable energy sources such as solar energy and fission.
- During President Ronald W. Reagan's administration, expenditures on defense R&D increased dramatically as part of his Star Wars system.
- President George H. W. Bush (not related to Vannevar Bush) set forth this Nation's first technology policy and increased the scope of the National Institute of Standards and Technology (NIST).
- President William J. Clinton established important links between science and technology policy, championing programs to transfer publicly-funded technology to the private sector.

- President George W. Bush advocated making the R&E tax credit permanent.