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| The Economics of Science, Technology, and Government Intervention |
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**Introduction**

Studying economics enables us to learn more about the way the world works. One of the most fun parts of economic analysis is being able to look at the world in a different way, to see through common fallacies or old myths. In *Economics in One Lesson*, Henry Hazlitt (1946) explains that economics allows us to analyze both the seen and the unseen effects of policy. In the introduction, he explains, “The art of economics consists in looking not merely at the immediate but at the longer effects of any act or policy; it consists in tracing the consequences of that policy not merely for one group but for all groups” (p. 5). One myth which economic analysis enables us to debunk is the idea that government must be involved in scientific research and technological development.

A discussion of the seen and the unseen also brings up the important distinction between normative and positive or descriptive economics. Positive economic analysis simply tells what is happening in the economy, or what will happen if a certain policy or action is taken. Normative economics, on the other hand, asks what *should* be done. Many of the arguments for government intervention in science and technology simply stem from the fact that the government is already involved. Advocates ask, who will step up if the government is not involved? The strength of economic analysis is that it allows us to criticize the status quo, and offer a possible alternative that may be superior to the current arrangement.

In this paper, the role of government in science and technology will be critiqued. However, science and technology must first be examined on their own, and how they fit into economic analysis. The paper is structured as follows. Sections one and two will define and differentiate between science and technology as concepts within an economic framework, and discuss the intricate interaction between them. Section three will examine the relationship between science, technology, and economic growth. Section four will outline the history and current climate of government intervention in the realms of science and technology. Section five will critique arguments for government intervention in science and technology, and discuss the effects of government intervention. Section six will conclude.

**1. Science and Knowledge**

Science can be viewed in many different ways. In this section, we will categorize science in three different ways: (1) science as a particular kind of knowledge, (2) science as research to gain access to this knowledge, and (3) science as a community of researchers.

According to the Merriam-Webster dictionary, scientific knowledge is defined as “knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method”. Usually when people use the word “science,” they are referring to the physical sciences of physics, chemistry, or biology. For our purposes here, “scientific knowledge” will be restricted to knowledge that is obtained and tested using the scientific method. The scientific method involves developing a hypothesis and testing it through scientific experimentation. This experimentation must be observable, testable, repeatable, and falsifiable[[1]](#footnote-1) in order to be considered truly scientific. Scientific knowledge is obtained when a researcher successfully and repeatedly tests his hypothesis. This knowledge must be published in some way in order to contribute to the community of science, as discussed below in more detail.

Since scientific knowledge must be published, it is public in nature. Knowledge that is not made available to others is not considered scientific in the same sense. Many economists[[2]](#footnote-2) have deemed the production of scientific knowledge as a public good since public knowledge is both non-rivalrous and non-excludable. Thus, private firms will not produce science research, or at least not the socially desirable amount. Many arguments that the government should be involved in science stem from this claim, which will be critiqued in several ways below.

Scientific knowledge is gathered and collected in a process called research. For analytical purposes, research is often split into three different categories.[[3]](#footnote-3) The first kind of research is called basic research.[[4]](#footnote-4) This is what most people think of when they think about scientific research. At this level of scientific investigation, scientists ask questions without any specific goal in mind, other than the advancement of our knowledge of the discipline. For example, a chemist doing basic research may want to find out how many atoms are in a particular chemical, not because there is some immediate application of this knowledge, but merely to increase our knowledge about the physical world.

This kind of research can be difficult to commercialize for two reasons. First, the benefits of basic research are often not reaped until the distant future, causing this kind of research to be risky for private firms. Second, given the public nature of science, the benefits of basic scientific research are diffused across firms, not given solely to the firm conducting the research. Despite these facts, however, firms can still benefit from doing their own research. There is a tacit component to scientific knowledge; simply reading the published research of other researchers is often not enough. In addition, first-mover advantages emerge as firms benefit from discovering something first. Second-mover advantages emerge in addition as firms generate commercial applications of already existing basic research (Butos and McQuade 2006, p. 187).

The second kind of research is called applied research.[[5]](#footnote-5) In contrast to basic research, scientists doing applied research ask questions with a specific application in mind. For example, the chemist from above is doing applied research when he wants to know the chemical composition of a particular substance in order to know how the material will act under stress or under heat so that it can be used in an current or future product. This kind of research is more easily commercialized, as firms take the knowledge gained from research and then apply it to the products they produce. This knowledge is also much more specific to the firm, and even if publicized, does not necessarily directly benefit other firms or parties.

The third kind of research is called development.[[6]](#footnote-6) At this level, the goal of the researchers is no longer to learn more about the physical world in the abstract. Development converts our scientific knowledge into technology. This stage of research can no longer be considered science per se because it is not generating scientific knowledge proper. Technological innovation and its distinction from science will be discussed in section two below.

Rosenberg (1990) rejects the sharp distinction between these categories of research. The distinction is usually made based upon the motives of those doing the research, “but that is often not a very useful, or illuminating, distinction” (p. 169). There are many historical examples of scientists whose research motivations were primarily applied in nature, but actually made scientific breakthroughs that would usually be contributed to basic research. Back in the 1870s when Louis Pasteur was doing research to learn more about fermentation and putrefaction as it applied to the French wine industry, his motivations were directed toward application of the knowledge. But his research also laid the groundwork for the modern science of bacteriology, enabling us to learn a lot more about the natural world. Likewise, when Sadi Carnot was trying to improve the efficiency of steam engines, he invented the modern science of thermodynamics as a byproduct of his research (p. 169).

In addition to knowledge and research, science may also be viewed as a community. The research to gain scientific knowledge obviously does not occur on its own; scientists must conduct it. Polanyi (1962) explained that the scientific community was a kind of Hayekian social order that emerged without centralized coordination. In the words of Ferguson (1767), an emergent social order such as the market appears as “the result of human action, but not the execution of any human design” (p. 205). The community of scientists is similar to the market in that “scientists, freely making their own choice of problems and pursuing them in the light of their own personal judgement, are in fact cooperating as members of a closely knit organization” (Polanyi, p. 54).

Within this social order, professional standards have emerged, without top-down mandates from a centralized body. The scientific merit of an individual contribution primarily depends upon three different criteria. First, the scientific pursuit must fulfill “a sufficient degree of *plausibility*” (p. 57). The contribution must be scientifically sound in order to be taken seriously. This criterion is enforced by publications who reject papers which appear to be scientifically unsound. Second, the scientific contribution is assessed by its *scientific value*. The value of a contribution has three different components: (1) its accuracy, (2) its systematic importance, and (3) the intrinsic interest of its subject-matter. Each of these components varies in weight for each field of scientific inquiry. Similar to economic value, scientific value is determined solely by the subjective valuations of other scientists within the community. The third criterion, that the contribution must be *original*, pushes back against the first two criteria. A scientific pursuit must bring something new to the table to have merit, given that it is also plausible and has scientific value. Conformity is enforced by the criteria of plausibility and scientific value, while dissent is encouraged by the necessity of originality. According to Polanyi (1962), “This internal tension is essential in guiding and motivating scientific work” (p. 58).

Butos and McQuade (2012) call the mechanism by which scientific knowledge is generated within the scientific community the “Publication-Citation-Reputation” process. The process begins when scientists publish speculations and observations about scientific phenomena. Once published, other scientists, who find them useful (or in some cases incorrect), cite these findings. These citations affect the reputation of the publishing scientist, which in turn “not only affects the notice given to his future publications and citations but also his ability to attract funding or to advance in academic position” (p. 2). The integrity of scientific research as a legitimate way to discover scientific knowledge, according to Butos and McQuade, is dependent upon this process.

Reputation also acts as an incentive for scientists to produce scientific knowledge. Reputation, more of a sociological factor than an economic one, is the most powerful incentive for scientists, and is generated through the PCR process outline above. Stephan (1996) highlights the importance of priority for scientists. The first person to communicate an advance in knowledge receives the recognition. “There are no awards for being second or third” (p. 1202). Recognition awarded priority gives scientists access to better academic or industry positions as well as access to larger and better grants. To some extent, scientists may also gain utility from the recognition itself, without secondary awards (p. 1203).

These sociological factors are not sufficient for the production of scientific knowledge, however. Since some people have a comparative advantage in doing scientific research, they should specialize in it. But these scientists must be paid, since their monetary opportunity cost of doing research is equal to their next best career alternative. Studying the chemistry of bread is not necessarily enough to put it on the table. In addition, some fields of research (such as chemistry or particle physics) have large capital and materials expenditures that must be funded.

There are three main sources by which research is funded. The most common and well-funded individual source is government. In 2013, the federal government spent over $121 billion on research and development (NSF 2015). While the government has a lot of money to give away, there are some major downsides. Government funding requires coercive and inefficient taxation, and government agencies cannot do economic calculation to determine if their investment was cost-effective.

Another common funding source is private firms. Historically, firms like Bell Labs and IBM have conducted a lot of basic and applied research with their own money. As a whole, private firms spent over $67 billion on basic and applied research in 2013 (NSF 2015). However, individually, firms are an inferior funding source to government in the sense that they are limited in how much they may spend on scientific research. But viewed a different way, this downside is actually an advantage. Private firms must do economic calculation in order to determine whether or not the research they are conducting is economically valuable, making private firms more efficient.

A third source of research funding is non-profit organizations. The most well-known non-profit research organizations are those that fund research to fight cancer or other deadly diseases, such as the American Cancer Society. In 2013, non-profits as a whole spent over $17 billion on research and development (NSF 2015). Non-profits are, in some ways, inferior to both government and private firms, since they generally have less available funds and they cannot do economic calculation. An advantage of non-profits, however, is that their research endeavors are restricted, not by the political climate (for government) or by economic profitability (for private firms), but by the preferences of the donors. This means non-profits may be able to pursue some important kinds of research that the government or private firms will not.

**2. Technology and Innovation**

For economic purposes, technology is the improvement of production or productive processes. Technology can take one of two different forms. Some technology must be physically embedded in capital or consumer goods. For producers, technology takes the form of more efficient and productive capital goods, such as car-building robots or faster microchips. For consumers, technology takes the form of consumer goods that also make them more productive or increase their standards of living, such as iPhones or more efficient motor vehicles. Since scientific knowledge is vital for the development of physical technology, it seems as though more advanced technology requires access to more advanced scientific knowledge. But this is not always the case. In some cases, “the science that was essential to some technological breakthrough was simply ‘old’ science” (Rosenberg 1994, p. 142).

The other form of technology is more knowledge-based than physical. Technical knowledge about how to produce products is different from the capital goods required to produce them. Much of this kind of knowledge is tacit in nature, and must be gained through experience, not simply by producing a good. Rosenberg (1982) explained the importance of learning by doing and learning by using. Both of these kinds of knowledge are gained by “direct involvement in the production process” (p. 121). Learning by doing is achieved through practice and minor innovations within productivity itself. Learning by using is similar, except it involves the end user, often after production but prior to final release of a product. Sometimes knowledge about a product is gained when it is used that could not be discovered prior. For example, computer software is often developed and refined by utilizing the “learning by using” method. It is often impossible for developers to discover every problem with the software prior to its release, so they will allow the users to provide feedback in order to improve the software. Here, the technology is improved by gaining knowledge about the product by using it, knowledge that could not have been gained by simply studying computer science.

Technological innovations are specific applications of knowledge, and thus particular standards develop around them. These standards are often first-to-market technologies that become entrenched in the market. A well-known example of path-dependency is the QWERTY keyboard. The QWERTY keyboard layout was designed in the late 1860s along with the invention of the typewriter. The layout was known to be inefficient from the start, and at the time, this was an advantage since early typewriters would jam if one typed too quickly. The standard of the QWERTY layout quickly became “the universal” layout. Even as typewriters improved, the layout remained because human capital was already invested in the QWERTY layout and typists were largely unwilling to change (David 1985).

As this example shows, sometimes technological standards are inferior to potential alternatives. Some economists use this fact to argue for government-mandated standards, with the hope that technology could be made more efficient and productive. However, this argument falls prey to the nirvana fallacy, since the government does not have the information to know what the efficient arrangement of technology should be. Rather, a more subtle lesson can be learned from the path-dependency of technology. There is not “one way” to solve economic problems. Most of the time, technological innovations are creative solutions to provide for human wants and needs. Entrepreneurs and innovators are able to use their tacit and local knowledge to solve problems in accordance to consumers’ preferences.

There are two models for how technological innovation comes about. The first and simpler model is called the linear model (see figure 1 in Appendix). In the linear model, innovation begins with scientific research, which is then developed into usable technology. This technology is then produced by the firm, marketed to the public, and sold as a product. This model, however, grossly simplifies and even distorts the actual process. The true path of innovation is much more complicated and nuanced.

The second and more accurate model of innovation is called the chain-linked model (see figure 2 in Appendix). In this model, innovation does not begin with blind basic research. According to Kline and Rosenberg (1986), “the initiating step in most innovations is not research, but rather a design” (p. 302). Innovation begins by finding potential demand in the market, and then inventing or producing an analytic design to meet this demand. At this point, the research and development team will look to existing scientific knowledge to determine the technical feasibility of the design. If the knowledge exists, the developers will go to the next step. If the knowledge is lacking, researchers may conduct further research to answer the important questions. As innovation continues down the path towards production and distribution, developers continually look to science to test the feasibility of and improve upon the technological innovation. In the chain-linked model, scientific research is more of a consultant for technology than a father, as presented in the linear model.

As discussed, a common view of the interaction between science and technology is that science begets technology. That is, scientific research informs what technology can be produced and technology-producing firms develop technology according to what scientific knowledge is being generated. In this view, scientific knowledge is a necessary requisite for technological innovation. This view is supported by the linear model of technological innovation.

Another view of the interaction between science and technology makes the opposite claim: that technology begets science. Historically, technological knowledge existed long before scientific knowledge, as defined above. Cavemen knew how to build fires long before scientists discovered the laws of thermodynamics. In many cases, innovations are developed before scientists know why the technology even works. In fact, some technological innovations ask questions that scientists must answer. For example, the invention of the steam engine prompted scientists to learn more about thermodynamics. In many ways, this is more accurate than the linear model, but is still a little too non-nuanced.

Most of the time, the true interaction between science and technology is more complementary than a one-way causal relationship. The chain-linked model of technology shows that technology informs science and science informs technology. Given this fact, it cannot be said that scientific advance leads directly to technological improvement, or that innovation leads directly to the pursuit of particular scientific truths. The tacit or localized nature of both scientific and technical knowledge further blurs their relationship.

**3. Science, Technology, and Economic Growth**

Science and technology are widely accepted by economists as vital factors for economic growth. The modern view of the importance of technology for economic growth largely began with Robert Solow’s article “A Contribution to the Theory of Economic Growth.” Solow (1956) argued that while capital and labor were essential to economic growth, advances in technology were essential for explaining increases in productivity over time. Technology has two effects on economic growth. First, it directly effects growth “by increasing the amount of output that can be produced with fixed quantities of capital and labor.” Second, technological change affects growth indirectly by raising the returns on investments in capital, which encourages capital accumulation (Nelson and Romer 1996, p. 13).

Since they are vital to economic growth, the government has a vested interest in supporting science and technology. A benevolent view of government sees that the government desires economic growth because wants its citizens to have higher standards of living. A more pessimistic view sees that the government desires growth to increase the tax base and spend more money on themselves. Either way, the government wants to encourage economic growth by supporting science and technology.[[7]](#footnote-7)

Regarding the interaction between technology and economic growth, an important point must be made. The economic impact of a technological innovation is based in the subjective value of the technology, not in any objective standard. The technology must be able to meet human needs and wants (directly or indirectly) in a more efficient or productive way than already existing technology. Economically successful technology cannot be simply an interesting solution to an economic need; it must be valued by its consumers. The ultimate impact of technology is not improved performance but identifying human needs in ways that have not yet been articulated. This requires imagination, not merely expertise (Rosenberg 1994, p. 5).

Landau (1998) emphasizes the importance of the commercialization of science and technology for wealth creation. Institutions play an important role for successful commercialization. Like most industries, financial markets and institutions are vital for investment in science and technology. Additionally, legal and intellectual property regimes can make or break the economic success of technology innovation. Competition is essential in all industries, but especially in high-tech industries. Lastly, Landau highlights the importance of education in the creation and maintenance of industries dependent upon science and technology. The government’s historical role in science technology will be explored in the next section.

**4. History of Government Intervention in Science and Technology**

As discussed in section three, the government has a vested interest in promoting scientific advancement and technological innovation. The modern role of the government in science and technology emerged largely after World War II. The federal government wanted to take a larger role, especially to compete with the Soviet Union and promote American economic dominance. Both national defense and economic development was now used as justification for government involvement.

In 1945, Vannear Bush, the director of the Office of Scientific Research and Development (OSRD) under the Roosevelt administration, drafted a report entitled “Science: The Endless Frontier.” This document outlined three ways in which science is important, and why the government must be involved. First, scientific progress is essential “for the war against disease.” Basic research is vital for fighting against diseases, which falls primarily upon medical schools and universities. Private funding for this research was diminishing at the time, so Bush argued that “the Government should extend financial support to basic medical research in the medical schools and in universities.” Second, scientific progress is essential “for our national security.” Even though the nation is in peacetime, Bush argued that military research must be up to date in order to hold off the enemy.

Third, scientific progress is essential “for the public welfare.” Bush believed that basic scientific research was required for innovation and economic growth. He explained, “New products and processes are not born full-grown. They are founded on new principles and new conceptions which in turn result from basic scientific research.” His goal was full employment, and believed that government-sponsored scientific research could help lead to this. He recognized that applied research was important “science to serve as a powerful factor in our national welfare.” In addition, Bush highlighted the importance of the training of scientists. In order to have a competitive labor force for science and technology, scientific education needed to begin as early as possible. For public schools, this meant ramping up education in the sciences as early as elementary school. Bush encouraged Congress to fund both undergraduate scholarships and graduate fellowships to those in science and technology related fields.

There was an important difference between the pattern envisioned by Bush and his committee and the actual postwar organization of science. Bush wanted a single research and development agency called the National Research Foundation to be responsible for all scientific research sponsored by the government. Instead, a plurality of agencies were created, which collectively served the same function as the NRF (Brooks 1986). These agencies included the National Institutes for Public Health (NIH) “for the war against disease”; the Office of Naval Research and those for the Army and the Air Force, and the Advanced Research Projects Agency (which became the Defense Advanced Research Projects Agency) “for our national defense”; and the National Science Foundation (NSF) responsible for basic research and science education “for our public welfare.”

Brooks (1986) divides science policy in the years after World War II into several different periods, each defined by its goals. The Cold War period lasted from 1945 to 1965. Science policy during this time was organized to compete with the Soviet Union. The competition was primarily two-fold, with a military component and a space component. The military race was stimulated by the ever present threat of the Soviet Union as a powerful military force. The space race was initiated by the space achievements of the Soviets, especially after the launch of the *Sputnik* in 1957. Within the next year, Congress and President Eisenhower passed the National Defense Education Act, which authorized over $1 billion in federal expenditures to be invested in promoting science and technology through education (Dow 1991).

The next period is defined by its focus on social problems. People asked, “If we could organize science and technology to put men on the moon, why could we not organize them to solve problems on earth?” (Brooks, p. 130). In 1962, President Kennedy even suggested that with science and technology, we could solve all social problems. He said that “most of the problems, or at least many of them, that we now face are technical problems, are administrative problems.” Interestingly, as this attitude began to be manifested in actual policies, there began to be backlash against science, or at least the government’s involvement in it. Some of this backlash stemmed from the unpopularity of the Vietnam War, other backlash came from the environmental movement (p. 131), while even more backlash came from the religious right (Dow 1991).

In the late 1970s, the federal government began to move its focus away from social issues and towards international industrial competitiveness. The government increased federal investments in industrial R&D in an attempt to stimulate economic growth. Politically, some of this push stemmed from the oil crisis of the 1970s, whose solution took the form of the expansion of the Department of Energy. In the mid-1980s, there was a major shift to an emphasis on longer-term projects (Brooks, p.133).

Today, the government is still very much involved in science and technology. In many ways, the ideals laid out by Bush 70 years ago continue to be the main influence on our contemporary science policy. In 2014, the federal government spent about half of its $60 billion nondefense research and development budget “for the war against disease” primarily in the form of grants from National Institute of Health. The government also spent over $70 billion in research and development “for our national defense.” The remaining $30 billion was spent on projects in general science, energy, and transportation “for the public welfare.”

Despite the intentions of the advocates of government-funded science and technology, a lot of money has gone toward politically expedient ends. For example, in the aftermath of the 9/11 terrorist attacks, there was an increase in antiterrorist research and development spending. Additionally, the government has invested billions of dollars into climate science in the last few decades as a result of political pressure to combat climate change (Butos and McQuade 2015).

These funds come in various forms. Much of the funding for basic research goes to universities and colleges, while funding for applied research technological development goes to firms and federal research facilities (NSF 2015). Many of these firms and universities are dependent upon the government for these funds, because they have developed a labor and capital structure with the assumption these funds will continue. The consequences of this dependence will be explored in section five.

Now that we have seen a historical overview of the government’s intervention within science and technology, we can examine the different ways in which the government becomes involved. One way is the direct funding of scientific research. This kind of intervention is usually manifested in the form of grants from agencies such as the National Science Foundation to researchers at universities or private firms. The goal of direct funding is to promote both basic research and the application scientific knowledge.

A second way the government encourages science and technology is by subsidizing technological innovation. This may be done several different ways. One way is by simply giving subsidies or tax breaks to technology producing firms. Another way the federal government subsidizes innovation is by allowing private firms such as Space-X to use federally funded facilities for research.

A third, more indirect, way the government promotes science and technology is through intellectual property protection. This usually takes the form of patent protection. Patents encourage technological innovation by guaranteeing innovators that they will be able to profit from their inventions. However, patents may also have the effect of preventing diffusion of technology throughout the market. Strengthening patents may lead to firms increasing prices of technology, discouraging diffusion (David 1986). In the most extreme cases, firms will hold onto patents with the purpose of preventing other firms from developing certain ideas into usable technology.

**5. Arguments For Government Intervention and Its Consequences**

The arguments for the continuation of government intervention within science and technology are numerous. Brooks (1986) argues that there is consensus on federal involvement in several areas pertaining to science and technology. First, the government has a role to play when it is acting as the costumer (p. 147). This primarily includes research and development in areas involving public goods, such as national defense. While there is debate over whether or not the government should be involved the production of any public goods, it is difficult to argue that the government ought to play no role whatsoever when it is already involved.

Second, Brooks (1986) argues that the government as a role in funding, but not necessarily performing, fundamental or basic research (p. 148). The argument, examined briefly in section one, is that the benefits of scientific knowledge are so “widely diffused among end users, so that no one user has a sufficient stake in those benefits to sponsor the necessary research.” This argument falls short, however, theoretically and, to a lesser extent, empirically. Private firms can and do profitably conduct basic research (with their own money) because of first-mover advantages. Rosenberg (1990) says, “All that is necessary is that market forces allow the firm to capture enough of these benefits to yield a high rate of return on its own investment in basic research” (p. 167). Firms do fund about 25 percent of all basic research, totaling over $21 billion in 2013 (NSF 2015).

Third, Brooks (1986) argues that the government should intervene when externalities are involved (p. 148). When the government is regulating externalities that have a major research component, such as environmental protection (Environmental Protection Agency) and health and safety (Food and Drug Administration), it makes sense that the government should be involved in the research itself. However, the fact is that both of these agencies rely heavily upon research conducted within the regulated industry itself. With a sufficient tort law system in place, there is no reason to suggest that firms, especially those within potentially hazardous industries, would not make an effort to sufficiently fund research related to their externalities.[[8]](#footnote-8)

Brooks (1986) also outlines various areas in which the role of the federal government is fairly controversial. First, some argue that the government must be involved in research and development involving high-risk areas (p. 152). Following the arguments of Arrow (1962), some research requires such a high magnitude of investment accompanied by a high risk of failure that no profit-seeking firm would undertake the investment. Examples of high-risk research include space technology and early nuclear power. This argument falls flat, however, when a cost-benefit analysis is considered. Although the government is hypothetically able to invest in high-risk research, the benefit of doing so is unlikely to outweigh the high costs, especially if private firms refuse to take up the investment. This kind of research is more like the government gambling with our tax dollars than it is a serious investment.

Second, others argue that the government must intervene in science and technology when the research would result in exceptionally high social returns compared to the private returns (Brooks p. 153). An example of this policy in action was the creation and expansion of the Department of Energy after the 1973 oil crisis. This argument, and its weaknesses, are similar to the high-risk argument above. While there may be insufficient private interest in this kind of research, it is likely because the costs truly outweigh the benefits. If the investment is truly beneficial, first-mover advantages enable firms to internalize the social benefits of such research.

Third, the government is seen by some as a vital component of research in fragmented industries, especially those involving merit goods (p. 154). Merit goods are “private goods to which everybody in society has in some sense has an entitlement” such as medicine and agriculture. The argument is that it is too easy for consumers to “free ride” on the benefits of research in these areas, since the benefits are conferred to everyone whether or not they contributed to the research, so government must be involved. The argument falls apart, however, in two big ways. First, similar two preceding argument, if the research is economically beneficial, firms will likely find ways to internalize these benefits, likely through first-mover advantages. Second, the importance of medicine and agriculture mean that these are areas where we *do not* want the government to be involved. It seems more dangerous to surrender such important industries to the political process, which is inherently less, not more, efficient or effective than the market.

A final area where government may be involved is in narrow markets, where there are very few end users. For example, for diseases that only affect a very small number of people, it is not likely that investment in pharmaceuticals to cure these diseases would be profitable for private firms. This is the probably most difficult argument for government intervention in science to reject, both analytically and emotionally. Without government, it appears that those afflicted have no hope. However, such a dichotomy neglects the third, and often forgotten, source of research: non-profit organizations. While they do not have nearly as large of a budget as the government, as the economy grows and we get richer, their viability as legitimate sources of research increases. The generosity of billions like Mark Zuckerberg[[9]](#footnote-9) improve the prospects of this becoming a reality.

Some of the arguments discussed above, however, fail to account for the distinction between descriptive and normative economics, as outlined in the introduction. Evidence that the government has or has not been involved in the funding or conducting of research and development in the past is not an argument that they should continue to be involved. Likewise, evidence that firms are able to conduct research on their own is not, by itself, an argument that the government should have no role.

Instead, we must look at some of the consequences of government intervention within science and technology. Butos and McQuade (2015) discuss the concept of the government as a “Big Player” regarding the funding of scientific research. This means that, as the largest individual funder of research, the government can influence both the direction and the distribution of science. Destabilization effects may occur as scientific assets are allocated “toward the attempted prediction of the activities of the Big Player” (p. 168).

This becomes a problem if the government changes the direction or distribution of funding with little notice. The scientific process itself may become disrupted, as “certain aspects of the funding process may promote a knowledge-generating and certification process not consistent with [the PCR processes] that confer scientific legitimacy” (Butos and McQuade 2012, p. 6). As explored briefly in section four, politics often gets in the way of legitimate scientific research. Political pressures, whether from within the government or from the electorate, may influence the kinds of research that is funded by the government. This political pressure can undermine the PCR process, and in part, illegitimatize the scientific research process.

Kealey (1996) demonstrates that the Big Player effects are compounded since the government often crowds out private funding of research and development. If the government is going to fund research and publically release the results, private agencies have little incentive to conduct their own research. This reality, then, is analogous to the “public good” problem outlined in section one, but in reverse. Privately-funded research is conducted at a suboptimal level, not because they cannot conduct research, but because they do not need to. Kealey also explains that the political process is no better at picking winners and losers in scientific funding than it is in the market. Waste often occurs as federal funding goes towards projects that are more politically expedient than economically desirable.

**6. Conclusion**

Science and technology are distinct concepts and must be analyzed as such. But they also have a close and intricate relationship, which means that policies that affect one also affect the other. Together, they affect economic growth by improving capital and labor, which gives the government a vested interest in supporting them. For many years, the government has funded research and innovation in an attempt to ensure scientific and technological progress. After examining and analyzing the history, the theory, and examples behind government intervention in science and technology, it is not clear that the government must be involved in science and technology at all. In fact, the costs of intervention may be greater than the benefits that would be lost if the government stepped away altogether.

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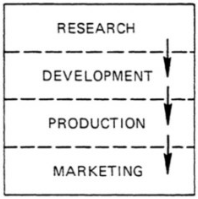
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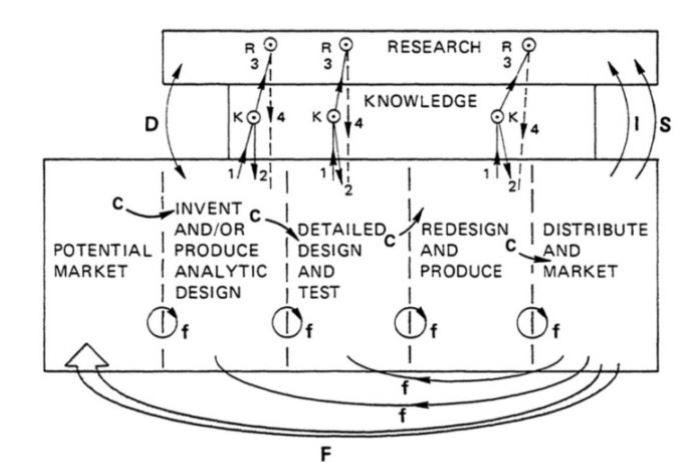
**Appendix**

**Figure 1: Linear model of innovation**



Source: Kline and Rosenberg (1986)

**Figure 2: Chain-linked model of innovation**



Source: Kline and Rosenberg (1986)

1. See the work of Karl Popper, esp. *The Logic of Scientific Discovery* (New York: Routledge, 2002 [1959]). [↑](#footnote-ref-1)
2. Kenneth Arrow, Harry Johnson, and Richard Nelson have commented on the public nature of knowledge. [↑](#footnote-ref-2)
3. These three categories are defined by the National Science Foundation (2015). [↑](#footnote-ref-3)
4. In 2013, a total of $80 billion was spent on basic research (NSF 2015). [↑](#footnote-ref-4)
5. Comparable to basic research, a total of $90 billion was spent on applied research in 2013 (NSF 2015). [↑](#footnote-ref-5)
6. By far the most common research. A total of $285 billion was spent on development in 2013 (NSF 2015). [↑](#footnote-ref-6)
7. Hypothetically, the government also wants to support science for its own sake. However, the history as explored in section four suggests that the government has been fairly pragmatic in its pursuit of science. [↑](#footnote-ref-7)
8. Rothbard (1997) outlines a similar argument regarding air pollution, given sufficient property rights. [↑](#footnote-ref-8)
9. http://www.forbes.com/sites/kerryadolan/2015/12/01/mark-zuckerberg-announces-birth-of-baby-girl-plan-to-donate-99-of-his-facebook-stock. [↑](#footnote-ref-9)