Chapter 8
Innovation Governance: From the "Endless Frontier" to the Triple Helix

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U.S. Government Role in Innovation

During World War II the U.S. Office of Scientific Research and Development (OSRD) spent significant sums at universities to support advanced weapons development, often on projects proposed by academics. Although this direct intervention authority was dismantled upon the close of hostilities, a revised format for government role in innovation was set in motion in response to the perception of an *innovation gap* that arose upon the Soviet Union's lofting of Sputnik in 1957. This shock was reinforced by Japan's postwar economic success in developing technological industries that threatened U.S. leadership in electronics by the 1970s. In succeeding decades, the governance of innovation emerged as a triple helix of university-industry interactions behind the facade of a "hands off" ideology derived from the *Endless Frontier* report, an iconic early postwar document that was widely read to legitimate only a limited government role focused on basic research, despite a series of support chapters delineating various practical research objectives, including housing, defense, and health.

The concept of *national innovation systems* was derived from the leading role of the Japanese governmental Ministry of Trade and Industry in selecting and directing limited resources to particular technical areas while closing down others and supporting innovation at the firm level (Freeman, 1987). In the United States, an alternative innovation model, often characterized by bottom-up and lateral initiatives, was developed under conditions in which government was typically constrained from playing an overt and direct role (Mazzucatto, 2013). Macro- and microeconomic policies have been balanced by mesolevel triple-helix initiatives in which government plays a significant cooperative role that is relatively hidden in U.S. circumstances where government is ideologically suspect and often operates

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sub rosa within a research rather than an innovation framework. Thus, innovation studies are much more highly developed in Europe, while indirect measures to induce innovation are a U.S. forte. Ironically, the pressure to downplay, even denigrate, government's role has the effect of encouraging U.S. intervention to the more risky, longer-term implications for disruptive innovation of basic research, while in Europe a general acceptance of government's role allows programs that intervene close to the market, thereby emphasizing incremental innovation.

By acting indirectly and involving universities in the formulating and execution of innovation policy, the United States arguably developed a more creative innovation model, exemplified by the rise of Route 128 and Silicon Valley. In the following, I discuss the changing role of government in innovation and the emergence of a *triple-helix* innovation system under laissezfaire conditions in the United States in comparison to statist regimes. I argue that university and government are indispensable elements in national innovation systems and demonstrate how and in which ways government is crucial to initiate and mediate systematic innovation and economy (Edquist, 2003).

Sources of the Assisted Linear Model

Despite barriers, a de facto innovation policy is created through pressures on government to act in crises. The World War II Office of Scientific Research and Development (OSRD), originated at the initiative of academic scientists, was active across the spectrum of research areas of potential military use. Under wartime conditions R&D, testing, manufacturing, and customer demand were integrated into a *seamless web*, ignoring traditional boundaries. Government negotiated R&D contracts with universities, accepting their argument that it *should* contribute to the infrastructural costs of the project. In the postwar period, practices of academic initiative and subsidization of the university were generalized into a metaphorical "contract" in which government assumed responsibility for support of science with public funds. The linear model of an automatic transmission belt from science to society was thus invented (Godin, 2006).

The role of government in innovation is, of course, longstanding; both to carry out traditional state functions, such as defense and enumeration of the population, as well as additional tasks, upon petition by the citizenry, such as agricultural and industrial advance and cure of diseases. Government has employed various means to achieve this objective: offering prizes for results, for example, for a method to calculate longitude to improve navigation of ships and reduce the risk of shipwreck in eighteenth-century Britain (Sobel, 1998); establishing laboratories to achieve specific objectives, such as improvement in weapons, sanitation, and farming practices in nineteenth-century United States (Rossiter, 1975); purchasing equipment such as the Hollerith card sorter to speed analysis of census data in the early twentieth century and transistors to reduce the size and weight of battlefield communications equipment during the early post-World War II period; and in the course of the second half of the twentieth century until the present, granting funds for research that government research officials and their peers in the scientific community expect will be of practical as well as theoretical import (Stokes, 1997).

Nevertheless, despite demonstrated success, such government actions have met with skepticism in a society characterized by a laissezfaire ideological orientation. Under such stringent sociopolitical conditions, strong justifications are required to carve out a role for government, typically by arguing that market forces are ill-suited to address an issue that is societally important. Emergencies such as those created by wartime also provide an impetus for conservatives who would usually oppose governmental action to strongly support and even take the lead in their initiation. Such was the case at the advent of the World War II, when academics who had been skeptical of government support of research during the Depression took the lead in creating government agencies to develop new science-based weaponry (Baxter, 1946).

The world view of many academic scientists was also transformed by their World War II research experience. For example, physicists who had put aside their basic research interests to work as engineers on weapons development projects soon found that they had ideas for basic research that they would pursue after the war. This rediscovery of the interconnection between the practical and theoretical, and the experience of working with virtually unlimited resources at their disposal, transformed academic scientists' antigovernment attitudes that had led them to refuse support in the depths of the 1930s Depression. Support was feared to bring control with it, but with the introduction of an organizational model that put scientists in charge of a significant portion of the decision-making process through peer review, such fears tended to dissipate and even morph into a converse euphoria, exemplified by the endless frontier metaphor.

With the return of peace, universities and companies appeared to return to their previous boundaries, with an important difference: the heritage of their wartime experience of cooperation and collaboration. Prewar opposition to government funding at the universities was reversed as universities sought government funds to support research (Leslie, 1993). In addition to ad hoc appropriations for individual projects, a more systematic approach was sought. A rationale was needed to continue government funding of science after the war. Although a quid pro quo of public benefit was part of the "contract," few research results were actually translated into useful innovations, even given an extended timeframe. Two evaluation studies, carried out in the late 1960s, produced somewhat contradictory findings but the overall assessment was that a more structured approach would produce greater outcomes. This conclusion encouraged advocates of government playing an enhanced role in innovation (National Science Board, 1982). A series of initiatives were set in motion, balancing individual initiative in science and entrepreneurship with collective principles of regulation for public benefit, producing an immanent framework for innovation governance.

The Origins of the Endless Frontier

In 1944, Vannevar Bush, the head of the wartime Office for Scientific Research and Development (OSRD) had persuaded President Roosevelt to write a letter commissioning the report that was issued immediately after the war as *Science: The Endless Frontier*. However, he calibrated the report in accordance with his conservative view of government rather than his life experience as a scientific entrepreneur and reverse-linear theorist. The report contained an implicit concept of science as a self-regulating mechanism, operating according to a strict forward-linear progression: Put in the money at one end and the results will flow out at the other. World War II R&D successes such as radar, the proximity fuse, and the atom bomb encouraged the belief that similar results could be achieved in civilian areas of the economy and other countries picked up the model. On August 28, 1944, Vannevar Bush wrote a letter to the Secretaries of War and Navy and suggested that U.S. forces should gather any available "German technical information of an industrial nature" (Gimbel, 1990, p. 5). In autumn 1945 the so-called document program started. Its task was to photograph in 20,000 German industrial companies "secret patent applications, documents in original manuscript form, documents covering processes, formulas, and techniques not generally known in the United States" (p. 62).[1]

Practical results from basic research were the premise for the funding flow. Although the timeframe was generous, it was expected that scientific findings with practical applications would easily move to firms without an intermediary support structure (Mirskaya & Rabkin, 2004). This hands-off version of tight, "whatever-it-takes" wartime cooperation, while in accord with laissezfaire ideological predilections, was divorced from the realities of technology transfer practice. A reverse-linear model was also instituted: When a firm could not address a technical problem internally, it was encouraged to seek research externally, through acquisition of patent licenses from universities, purchase of startups, or collaboration with other firms, a strategy that has come to be called "open innovation" (Chesbrough, 2003). The resulting technologies would then be returned to the firm and taken to market. The former approach relies more on the university and the latter on the firm.

Nevertheless, despite the different emphases, both classic linear models relied on government to supply research funding. Business consortia, whether in the United States or Europe, often include university partners, with access to government funding that in Europe may more often be received directly through European Union (EU) Framework Programs. Government, however, has found it necessary to revise its role and play a more active part *downstream*, by crafting innovation policies and programs to insure that research results, however generated, are actually put into practice. However, there are massive differences between European countries not only in the coordination of the relations between government and

[1]According to Gimbel (1990) the Office of Technical Services had the task of distributing the some 500,000 documents (5 million pages) microfilmed in Germany about scientific scientific results, technologies, technical processes, and patents.

universities but also regarding the volume and scale of resource flow. Today about 85% of the aggregate budget of German universities are publicly provided subsidies from the state, whereas in the United Kingdom only 30% of the resources come from the state (OECD, 2014).

What is the optimum role of government in innovation? A Swedish university liaison director recently asked, "Why a triple helix; why not a 'double helix' of university–industry?" The answer is that it is only possible to develop university–industry relations up to a point, without considering the role of government. In the late 1970s, the U.S. Secretary of Health Education and Welfare rescinded the authority that had been developed by precedent in the National Institutes of Health to transfer intellectual property rights to universities on a case-by-case and university-by-university basis. Stable conditions for disposition of intellectual property arising from federally funded research were reestablished by law in 1980 and technology transfer assumed the format of a business-like activity between university and industry. Government's role in establishing a legitimate framework for technology transfer was the basis of this relationship (Berneman & Denis, 1998).

While the United States has established a series of programs and a regulatory environment to facilitate technology transfer in order to reap the benefits of munificent research funding that followed from World War II, the role of the state in innovation is also most clearly apparent in countries such as Mexico, where state-sponsored industry sector associations and university consultative councils coordinate these spheres. The Singapore government organized the transition to high-tech manufacturing and then to knowledge-based economic development. Other countries, such as Sweden, with a high rate of R&D spending and relatively low rates of economic return, have undertaken parallel steps, restructuring a series of basic research and technology programs into an innovation agency, VINNOVA.

Beyond the Endless Frontier

Despite numerous *eloges* for the linear model, especially in its forward format, a trend toward increasing reliance on science-based innovation can be identified in different countries. In Sweden, it is represented by a new research-funding sector focused on *strategic* science, in Singapore by the founding of a science-based institute sector, and in the United States by interagency research initiatives, such as those in nanotechnology, supported by the Department of Energy and the National Science Foundation. It is expected that many of the results of these initiatives will be introduced into the economy, not by firms tied to existing industries, but by new firms seeded by government funding as the basis of future industrial sectors.

The *innovation state* attempts to regenerate the sources of productivity, through such investments in science and technology, and by changing the rules of the game, through legal and administrative adjustments, to encourage the creation and growth of new firms. The state increasingly undertakes these tasks, not as a sole actor but through new forms of cooperative relations with industry and university. The innovation state is the successor to the capitalist, Keynesian, and welfare states, with their respective foci of assisting existing industry, promoting general economic advance, and securing the basic conditions of a good life for all the population.

The innovation state builds upon these various bases, incorporating elements of each of these models into a broader framework to support their realization under changed conditions of global competition. Neither socialism nor capitalism as an isolated national model is feasible but it is difficult to give up policies to realize these goals. In the laissez faire model of separate institutional spheres, moving beyond Keynesian macroeconomic policies arising from the 1930s depression, such as central bank adjustments of interest rates or money supply, was also a difficult transition. Similarly, in statist societies, the relaxation of the total state, based upon central planning, to a more modest role of incentivizing innovation, without going all the way to inaction, was also a difficult transition (e.g., Meusburger & Jöns, 2001).

Thus, one path to the innovation state is from a top-down model of bureaucratic control, with the state devolving its authority to various degrees. The other is from a standpoint of modest participation by central government in which case the pathway is to increased activity. The two different starting points intersect at some midpoint, where government, industry, and university assume relatively equal status as interdependent institutional spheres. It is especially at the intersection of the spheres that enhancements of innovation systems may be constructed that ultimately strengthen the sources of product innovation.

The Triple Helix

In industrial society the university was a support structure supplying trained people and knowledge; in a knowledge-based society the university moves from a secondary status to become an equal player with government and industry as the source of growth poles for economic development based on new knowledge that it generates or existing knowledge whose transfer it facilitates (Miao, Benneworth, & Phelps, 2015). Also, in these triple helixes one often sees each of the institutional spheres "taking the role of the other": Universities participate in forming firms, playing a classic industrial role; government acts as a venture capitalist, providing the funds for these entrepreneurial ventures; industry raises the levels of its training and research activities in university-like units.

The factor that differentiates different forms of the triple helix is the relative presence or absence of civil society. The ability to freely associate, brainstorm new approaches to innovation and form new organizations to realize them is the basis of a vibrant triple helix. Rather than a fourth helix, civil society is a platform on which enhanced triple-helix innovation regimes may be built. The optimal triple-helix model (Figure 8.1) may be viewed as a classic Venn diagram, with intersection of three interrelated and overlapping spheres, each taking the role of the other and working closely together, with free association in civil society encouraging lateral

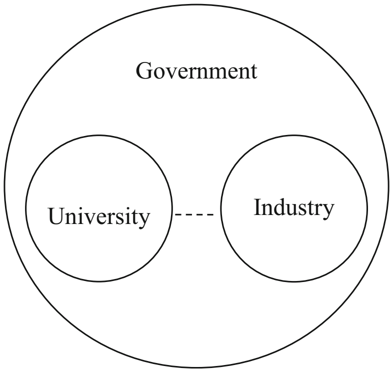

Fig. 8.1 The optimal triple-helix model.
Source: Design by author.

and bottom-up interactions. Under these conditions civic entrepreneurship flourishes along with business entrepreneurship, with each enhancing the other.

The *second academic revolution* is the translation of research into use, the development of an entrepreneurial format in which it becomes an explicit mission of the university to create new firms and networks with industrial and government stakeholders. This process is nonlinear and progressive, with the first revolution, the inclusion of research as an academic mission usually preceding the second one. Nevertheless, both revolutions sometimes happen simultaneously. Indeed, the second revolution can even precede the first when a teaching university engages in entrepreneurship utilizing existing knowledge. From an entrepreneurial base such a university may raise its level of resources and undertake research. I think it is possible to also see a bi-evolution of university missions from a traditional focus on individuals, in seminar rooms, classrooms, and lecture halls. However, university is not only training individuals, it is also training organizations in its incubation facilities and experiential education programs.

We may thus experience an expansion of the physical university rather than its contraction even as lecture courses are delivered electronically. Instead of students using the classroom for 90 minutes three times a week, they need availability of tools, materials, and locale on a 24/7 basis for collaborative project work. Some of these needs can be addressed outside the university. For example, Radicand is a Stanford spinoff, a consortium of mechanical engineering and design PhDs who have rented space in a former industrial building for their consulting organization. One of their objectives is to provide space for larger student projects from the university that cannot be handled in the normal space available to the Mechanical Engineering 310, the university’s graduate interdisciplinary design and prototyping course.

A bi-evolution of the university is taking place in the entrepreneurial university’s tripartite missions of education, research, and economic and social development: This is seen in research, the movement from the traditional dyadic relationship of professor and students in humanities to the research group. The organization of professors, postdoctoral students, and technicians in teams with lateral relationships and bottom-up initiatives, as well as in the traditional hierarchical relationship, has become commonplace. In the new economic development mission of the university, moving from an initial focus on capturing value from individual pieces of intellectual property through technology transfer, the university has come to play a broader role in innovation by becoming involved in efforts together with other stakeholders to enhance the future development of the region.

A key feature of a triple helix, building upon the work of classic sociologist Georg Simmel on the formal properties of different numbers in social interaction, is that triadic interactions allow for mediation and nurturance of novelty (Wolff, 1950). A two-sided relationship is subject to the inherent love/hate properties of a dyad. On the one hand, agreement to a proposal made by a prestigious person or organization may be made without full consideration. On the other, there is a tendency to fall into conflict over goals and objectives. A three-sided relationship moderates these tendencies by introducing possibilities for mediation, coalition building, and indirect bonding. A triple helix raises Simmel's analysis of the potential of the triad from the individual level of personal and familial relationships to the institutional and organizational levels of university–industry–government interaction. A triple helix provides a format for innovation in a knowledge-based society that takes shape in different formats.

A triple-helix statist model (Figure 8.2), where government encompasses industry and academia, with direction top-down can accomplish great projects. However, the downside is that a triple helix coordinated entirely by the state may neglect potential contributions from other spheres. Under these circumstances, government may take initiatives without consulting others; it is not the most productive form of triple-helix relationship since ideas are coming only from one source, the central government. Conversely, if the state is absent from the innovation picture, then coordination, regulation, and funding necessary to encourage improvements may be insufficient. There is no single answer to finding an appropriate balance between intervention and nonintervention. However, the previous history of the role of the state in society will set some bounds and also determine whether it is most useful for the state to intervene directly or indirectly, acting through other institutional spheres.

In statist societies direct intervention is expected while, under laissezfaire conditions, only indirect approaches may be possible. The laissezfaire triple helix with institutional spheres far apart, interacting across strong borders, which is said to be the way that the United States operates, is largely an ideological model. I always say to Europeans, especially those looking to the States for an innovation model, who are told by their American colleagues that government should desist from taking a role in university-industry interactions: "Don't look at what your U.S. colleagues say. Look at what the U.S. does and you will find a very strong role for government in innovation." However, the relationship is likely to be indirect and thus obscured, such as with the Bayh-Dole Act of 1980, incentivizing universities to move closer to industry without actually providing direct support for doing so. But the universities can charge administrative expense for technology transfer and patenting to the overhead rate that they receive for research grants. Without direct appropriations, the relationship is supported indirectly. It is hidden and indirect in agencies, such as

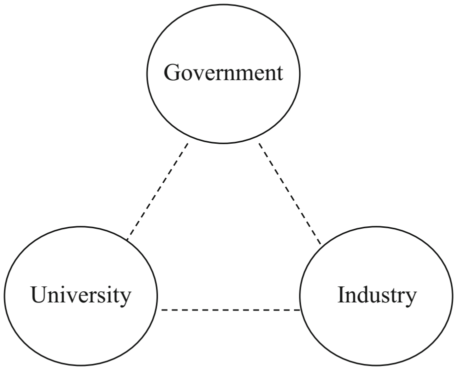

Fig. 8.2 The statist triple-helix model.
Source: Design by author.

the Defense Advanced Research Projects Agency (DARPA), which has academics seconded for short periods of time as program officers. They bring in new ideas, such as the Internet, and then move back to academia and a new set of people come in to take a temporary role in government.

What are the implications of triple helix for policy and practice? The triple helix is an analytical and normative concept derived from the changing role of government and university in relation to industry in different societies. Interaction among university–industry–government, as relatively independent, yet interdependent, institutional spheres is the key to improving the conditions for innovation in a knowledge-based society (Etzkowitz, 2003). This approach was derived from a response of the political infrastructure of New England after recruiting the academic and industrial leadership of the region to formulate and implement a response to the region's loss of industry in the early twentieth century. Triple-helix interactions have since been identified or put into practice in a variety of settings in industrialized and industrializing countries and regions as an entrepreneurial strategy to fill gaps in clusters or even create them ab initio. From Amsterdam to Niteroi, Brazil; Linkoping, Sweden, to Linyi, China, a variety of efforts, involving the three classic actors and substitutes, as necessary, have been identified (Etzkowitz & Zhou, 2017).

Crossnational comparisons are instructive to explain why the same organizational mechanism can produce different outcomes in different contexts. For example, a Mexican researcher at a conference asked: "Why has the incubator been successful in Brazil but not in Mexico?" One explanation is that an incubator movement arose in Brazil, with industry associations and local and national government supporting university initiatives, rather than being an isolated top-down initiative. The Mexican government has a program to provide funds to universities to start incubators. However, it is a relatively limited project with a very narrow base of support, rather than a movement that has spread throughout the entire society. In Brazil, the incubator initiative was part of the revival of civil society in the postmilitary era, with various institutional spheres involved, and national government, only one among several sources of support.

The existence of an organization infrastructure to receive a new element also explains why transfer may *take place* or be rejected. An initial attempt to introduce

CONNECT, a local level networking format from San Diego to Sweden, made by members of the local biotechnology association in Skane region did not succeed, lacking sufficient support from the region and the university. A later effort undertaken by the prestigious Academy of Engineering in Stockholm attracted support from regional officials and universities across Sweden and several CONNECT networks, linking entrepreneurs, business advice providers, patent lawyers, accountants, and "angels," were successfully established (Walshok, 1995). The cultural carryover of a top-down tradition of initiative was decisive.

Different state capacities affect both the trajectory and visibility of a triple helix, whether it is organized openly and transparently or is routed through hidden channels. In *high-state* societies, where triple-helix relationships have traditionally been directed top-down, bottom-up initiatives appear in conjunction with the emergence of regions and the growth of civil society. In *low-state* societies with a laissezfaire tradition, the emergence of the triple helix is associated with a strengthening of the role of the state, acting together with university and industry. Activating regional levels of government to become innovation actors, and creating such levels when they are lacking, becomes a key issue in creating such a system.

Devolution of Responsibility for Innovation

There has been a significant devolution of powers in recent years in countries, such as Great Britain, France, and Sweden, lacking a strong regional level of governance (Greyson, 2002). Formerly central government operated through regional levels that mandated common policies. Increasingly, it is seen that it is necessary to have policies specific to the competencies and capacities of different areas. Given the lack of an activist regional tradition, an initial step from the center may be to incentivize regional actors to come together and develop new initiatives. Sweden's Innovation Agency, VINNOVA, has taken this approach in a funding competition based on triple-helix actors developing joint proposals for science-based innovation.

On the other hand, there is a need to knit together different local initiatives that might otherwise be at odds with each other in the complex of innovation initiatives that have been established by Swedish government agencies and foundations. Government has provided the universities with *holding companies* to transfer technology and help start new firms, but it is only a modestly funded initiative. Technology Bridge foundations were established in several regions with a significantly higher level of funding, for much the same purpose. The triple-helix model provides a rationale to cooperate and aggregate resources to a common end and reduce friction among what otherwise might be a set of small competitive projects. VINNOVA's Vinnvext program incentivized regional innovation actors to come together in triple-helix coalitions and create joint initiatives as a condition of further funding (Etzkowitz & Klofsten, 2005).

The Changing Role of Government

Top-down models have been highly successful in organizing large military and space projects in both socialist and capitalist regimes. In countries with a planning system, government kept the entire innovation process under its control. Thus, in the former Soviet Union and Eastern Europe, a system of research institutes focused on industry problems. However, the results could only be implemented if they were centrally approved, although there were always informal exceptions to the rule. Nevertheless, bureaucratic controls were an impediment to the introduction of inventions. Although research and production were formally linked by intermediary organizations, industry’s focus was on quantity production, not qualitative innovation and local technology transfer.

Transition from Statism to Laissez Faire

In the postsocialist era, top-down coordination was removed and each element in the former system was left to fend for itself, with sharply reduced funds from the state. The abrupt reconfiguration from a statist to laissezfaire regime left a question mark where the state had formerly played a leading role (Figure 8.3). Science and technology policy had formerly been the centerpiece of regimes legitimated by a thesis of a *scientific-technological revolution*. Given the discrediting of government it was difficult to justify more than a minimalist state, confined to basic security and welfare activities. Science and technology policy was barely a legitimate activity, no longer a priority in postsocialist countries. Nevertheless, after more than a decade of hands off, it is said that “government officials have come to their senses and realize that Government should stimulate . . . reforms” in Russian science and the academic community (Mirskaya & Rabkin, 2004, p. 13).

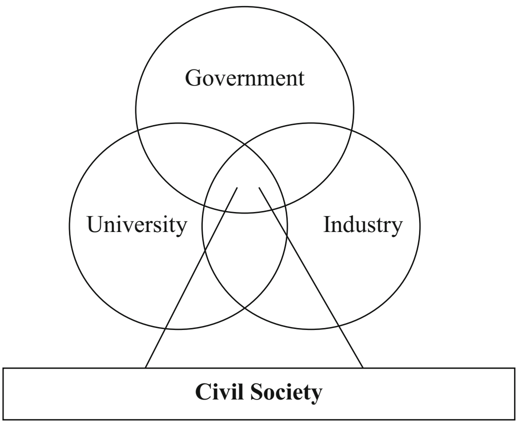

Fig. 8.3 The laissezfaire triple-helix model. Source: Design by author.

Transition from Statism to Civil Society

The possibility of individuals and groups to freely organize, debate, and take initiatives, is the basis for a triple helix including bottom-up as well as top-down initiatives. This can be seen most clearly in countries that are just emerging from military dictatorships. Bottom-up initiatives became possible in Brazil with the recreation of civil society that took place when the military gave up control in the early 1980s. University science and technology researchers introduced the concept of the incubator from the United States. In succeeding years, various levels of government as well as industry and civil associations took up the incubator concept and spread it throughout Brazilian society, applying it to a variety of problems from raising the level of low tech industry to creating jobs for the poor (Etzkowitz, Mello, & Almeida, 2005).

Transition to an Innovation State

The Finnish case is a focused version of the linear model of R&D pump priming, with funding opportunities focused on a relatively few areas of IT and biotechnology identified as having future economic potential. Much less research intensive in the early 1990s than Sweden, Finland has moved ahead by using monies from privatization of public enterprises to sharply raise the level of R&D spending (Benner, 2003). In relatively few years, the Helsinki region has come close to Stockholm in its concentration of biomedical research. The city of Tampere by the early 2000s was home to 3,000 information technology researchers in contrast to few dozen in the early 1990s. Nokia rose and fell but the skilled people left behind then became the initiators of new firms. To insure that the Nokia success was not an isolated instance, Finland made innovation a direct responsibility of the prime minister's office.

Transition to an Interventionist State

The United States is often misperceived as a laissezfaire society where innovation is left up to industry. Thus, there is reluctance to recognize that a plethora of specific policies and programs accumulated over the past half century constitutes a U.S. innovation policy. Government is playing a greater role in promoting innovation, often utilizing the university to reach its objectives. Given the resistance to government action at the federal level, when intervention is decided upon, it is typically occurs indirectly, utilizing universities as an interface between government and industry. In response to ideological constraints, the trajectory of immanent industrial policy formation creates networks and initiatives that cut across the institutional spheres.

Behind the laissezfaire presumption of the linear model that academic research results would seamlessly pass to industry through graduated students taking employment and industrial researchers following the journal literature, a more focused organizational approach to technology transfer, utilizing the patent system, had grown from its origins at the Massachusetts Institute of Technology in the early twentieth century. According to a George Washington University technology transfer official, “the national innovation strategy is to put federally-funded R&D on a conveyer belt that gets the R&D commercialized either by tech transfer to established companies or by wrapping the R&D into a university start-up” (Stanco, 2004). Previous governmental foci included regulation of exchange in the market to maintain competition, manipulation of macroeconomic aggregates through monetary policies, and redistribution of the results of productivity to redress inequalities (Hirst, 1994).

Innovative Governance

The basic precepts of *innovation governance* are set forth in a series of propositions about the transformation of traditional state functions to promote innovation:

1. Establishment of legitimate control of violence within a territory, promoting stability and reducing uncertainty as the basis for public authority, is extended from the public to the private sphere.
2. Corollary: Government guarantees are given to private capital so that, with this insurance, it may take greater risks in investing in new ventures.
3. Levying of taxes to support the protection of the nation and promotion of the general welfare is extended by using the tax system in a targeted fashion to provide special incentives and benefits.
4. Corollary: R&D tax credits and reduced capital gains taxes are made available to promote innovation.
5. Establishment of rules to structure economic life including procedures to charter firms and foundations, regulate the conduct of markets and currency systems.
6. Corollary: New agencies are established to promote innovation, including hybrid public/private entities.
7. Use of legal system to establish special rights such as patents as temporary monopolies to promote innovation.
8. Corollary: Universities are granted control of intellectual property rights from government-funded research, incentivizing them to become involved in technology transfer and innovation (United States, 1980; Denmark, 2000; Germany, 2002). Universities in Sweden are subsidized through the holding company initiative to encourage them to implement the *third mission*.
9. Provision of basic research funding to establish a linear model of innovation.
10. Corollary: Provision of public venture capital to create an assisted linear model of innovation.

U.S. Innovation Policy

Despite ideological structures against industrial policy and disbelief in the efficacy of attempting to "pick winners," the United States has arguably the world's strongest innovation policy, comprising bottom-up pressures from aspiring research universities, less research-intensive states, federal agencies under pressure to show practical results from research funding, and increasing international competition. No single impetus is decisive; rather it is the interaction of the various forces and initiatives that has generated an active innovation model wherein, if one level is forced to be inactive, say the federal government in supporting stem cell research, the state level picks up the slack, as in California's proposal to support research on this topic with a 3 billion dollar bond issue.

During the postwar period in the United States, high overhead payments became a method of funding the major research universities directly from the federal government, without explicitly acknowledging an elitist federal higher education policy. These universities thus supported were clustered in relatively few parts of the country, on the east and west coasts, with a few in the Midwest. This disparity was not a major issue as long as academic institutions were primarily seen in their traditional role as educational and research institutions. As a few universities with concentrations of research became foci of economic development, other less research-intensive regions wished to emulate their success.

Pressure has increased on the federal government to increase research spending and to distribute it more broadly, eschewing peer-review mechanisms instituted in the early postwar period to focus federally funded research on a relatively small group of schools. Nevertheless, regions with low levels of federal R&D spending are unwilling to depend upon modest set-asides, instituted to reduce pressures for equalization, or slowly building up their capabilities with local funds. Modest set-asides in the National Science Foundation (NSF) budget targeted at less research-intensive states in the Established Program to Stimulate Competitive Research (EPSCOR) program were insufficient to slake the thirst for R&D funds.

A de facto innovation program was instituted that works the same way as appropriations for roads or bridges or any local improvement that a Senator or Congressperson wants to obtain for their district. A legislator attaches a provision for a research center for a local university to a funding bill for another purpose, the so-called "earmark." When earmarks were eventually discouraged at the federal level, the states took up some of the slack. New York's Governor Cuomo recently announced that a 50 million dollar state program to encourage spinoffs from universities around the state would be doubled to 100 million. When one state takes the lead in a field where others feel they have strength, there is pressure to match the leader. Thus, when California developed a 4 billion dollar stem cell initiative in 2004, New Jersey and Massachusetts developed their versions in the hundreds of millions.

Competitive pressures drive the innovation system. Universities that have been outside of the federal research funding arena but want to increase their research strength have become active in seeking targeted federal and state funds. Typically as this emerging group of research universities enhances their capabilities, through such targeted measures, they then begin to compete successfully for peer-reviewed funds through the normal research funding channels. It is this increase in competition from universities across the country that has given the older research universities the feeling, indeed it is a reality, that competition for research funds has increased even as federal research budgets have risen significantly, especially in health and security.

Bottom-up Activates Top-Down

As new industrial areas arose from an academic research base in molecular biology and computer science in a few locations, other parts of the country became aware of the significance of universities as engines of economic development and wished to follow this model: first in North Carolina in the 1950s. By the end of the 1980s, virtually every state had some kind of science and technology agency focused on creating economic growth from research, typically by expanding research at local universities. In addition to state governments funding, research focused on economic development rose to a total of 3 billion by the turn of the new century, although it has since declined somewhat due to budgetary pressures (Berglund & Coburn, 1995).[2]

Strategies typically follow from the industrial and scientific condition of the state. Less research-intensive states attempt to build up the research capabilities of local universities in fields related to local resources. A longer-term goal is to create new firms from this research. Oklahoma and Georgia offer research funds to professors who have developed successful research groups to entice them to relocate, thereby improving the competitive chances of the state's universities in the federal research funding system. On the other hand, research-intensive industrial states, such as Michigan and New York, fund their universities to develop research capacities related to existing industries.

The Emergence of a "Bottom-Up Planning System"

Although states can be explicit, the federal government can only set very general outlines in civilian innovation policy for fear that it will be accused of attempting to pick winners. Government is ideologically perceived as naturally and inevitably incompetent, despite manifest success in military, health, and agricultural

[2]Direct state investment in science and technology policy remains a relatively small sum in comparison to other sources of R&D spending. Nevertheless, it made a significant, if modest contribution to the increase in academic R&D from $7 billion in 1980 to $17 billion in 1993 (in 1987 dollars). During the same period industry funding of academic R&D expanded by 265% from $334 million in 1980 to $1.2 billion in 1993 (Berglund & Coburn, 1995).

innovation. Nevertheless, it is advisable to watch what the United States does rather than what it says with respect to government's role in innovation. Even the most conservative politicians are activists when it comes to creating new knowledge-based industry in their locality.

Since the federal government is precluded from playing a direct role in civilian technological innovation, it often seeds other institutions with ideas and develops them collaboratively. For example, ATP program officers regularly made visits to companies and held national and regional conferences to encourage firms to work together with universities and government labs. Brainstorming sessions at these meetings typically included representatives of large and small companies, academics, and government technology experts. The objective of the discussion is to reduce the general category of a critical technology to a particular point, at which the people who are closest to the technology agree that a blockage exists. White papers were encouraged around these strategic points and the funding competition is thus made much more specific.

The result was a bottom-up planning process, an immanent triple helix arising across strong boundaries, with both top-down and bottom-up features. Nevertheless, the official mandate given by the first Bush administration was for a government–industry model in response to the European Union's emerging Framework programs. Although universities participated and even played a covert leadership role in an underground fashion, the overt prominence of government made the program vulnerable to attack, including charges of "corporate welfare" and eventually resulted in its defunding (Etzkowitz, 2003). Other initiatives, such as the Industry/University Cooperative Research Centers and Small Business Innovation Research (SBIR) programs, with universities in a prominent role and industry and government relatively subordinate had a better survival rate and SBIR has even received increasing resources.

There are positive implications of innovation policy makers having to deal with ideological resistance to government interventions. Since it is only considered to be legitimate for government to intervene in the event of clear *market failure*, such as when it is needed to support basic research, policy measures are forced upstream toward the research frontier. This tends to lead to a focus on startups and in creating new industries rather than providing input into existing industries. Policy measures are typically instituted as an extension of basic research funding programs that take the form of grants rather than loans. Thus, a higher degree of business risk can be taken. Again this is conducive to supporting the early stages of bringing advanced technology to the market. On the other hand, it is more difficult for the federal government to take steps to support later stages of firm growth and development, with the important exception of military and security related technologies.

Indirect Industrial Policy

Increased international competition has called attention to the role of government in innovation. During the economic downturn of the 1970s there were proposals for government to become directly involved in aiding existing industries and building up new ones, but these were quickly defeated. Instead, government went through the universities to reach industry. The patent system was reorganized to give intellectual property rights from federally funded research to the universities, with the condition that they had to take steps to put them to use. After 1980, technology transfer mechanisms, which had only been utilized by a relatively few universities, were diffused throughout the research university system.

Since the late 1970s the federal government has played an indirect role in encouraging academic-industry cooperation by changing the legal framework for federally funded research at universities. Laws such as the 1980 Bayh-Dole Act were passed to tie government-supported basic research at universities more closely to industry by creating a series of incentives and requirements to encourage universities to transfer technology deriving from federally funded research on campus. The new framework requires and offers incentives to encourage academic institutions to commercialize their research.

This policy has led to the emergence of a technology transfer profession, primarily based at universities. Their task is to negotiate agreements to move research across boundaries from one sector to the other. The university licenses intellectual property to a company, sometimes with little continuing of academic involvement apart from consultation. Increasingly, a more intensive effort takes place locally through the founding of a firm, with continuing academic participation in research and product development, at least in the early stages of firm growth. The 1980 Stevenson-Wydler Act extended the effort to transfer technology from research organizations to industry by mandating technology transfer efforts by the laboratories and research agencies of the federal government. The objective was to take intellectual property or capacities that exist within government laboratories and infuse them into companies as a part of a strategy to improve their international commercial competitiveness.

Government→Industry Initiatives

In addition to regulatory changes, basic research funding models were adapted to close the gap between research and innovation, the so-called “valley of death.” To solve this problem, programs have been created that provide support for the early stages of firm formation. This *public venture capital* does not take minority ownership but fulfills the seed capital function in all but name (Etzkowitz, Gulbrandsen, & Levitt, 2000). For example, the NSF program officers who founded the SBIR program created a neutral language for direct government intervention in the economy. They delineated a three-phase model of the entrepreneurship process, with a transition from public to private funding in the third phase.

The strong focus on scientific and technical criteria provided a resemblance to (previously justified) basic research. Finally, *small business* can be viewed as a strong ideology by itself that very few people oppose. An advocate of SBIR and similar initiatives said:

> We definitely see the programs as a de facto industrial policy, but we cannot use that term, so we usually call it R&D policy and things like that instead; but it [SBIR] is a federal program that has created a whole lot of new industrial activity.

Nevertheless, SBIR offically operates as a grant-based federal R&D procurement program for small business. The growth of partnerships between large and small firms, between large firms and startup firms and between university and government laboratories, is also encouraged. The Advanced Technology Program (ATP) was founded in the late 1980s, partly in response to concerns that the EU Framework programs would encourage large U.S. corporations to move significant portions of their research to Europe to take advantage of subsidies. Although, ATP consortia programs were expected to provide a counter attractant, the focus on large corporations was strongly attached as corporate welfare, from both sides of the political spectrum. Nevertheless, many of these projects were actually initiated by startups or universities who found firms to apply on their behalf. After deep cuts in funding, the ATP shifted its strategy to partnerships of universities and startups, conforming to the politically acceptable U.S. model of focusing on small firms and university-industry interactions.

Several other federal programs, such as the Manufacturing Extension Centers of the National Institute of Standards and Technology (NIST), provide support that has allowed state-initiated programs to expand their efforts. The focus of these new collaborative arrangements is on translating research capacities into economic development. Building upon the 1980 Bayh-Dole Act's incentivizing universities to transfer technology concomitant with their receipt of federal research funds; the 1984 Stevenson-Wydler Act mandated government agencies with R&D capabilities to follow suit. The Department of Agriculture had long been involved in technology transfer in its field and NASA, seeking to increase support for spaceflight by demonstrating uses for its technological capabilities closer to home, eagerly took up the task.

A cooperative R&D agreement mechanism (CRADA) has been created to encourage and subsidize collaborative technology development projects between federal laboratories and industry. Consortia of companies, large and small, and universities are being supported to develop new technologies in response to international competition. These or similar formats have been utilized in a variety of general purpose innovation programs, such as the U.S. NSF Engineering Research Centers, NSF Industry-University Research Centers Program, NIST Advanced Technology Program, and Defense Advanced Research Project Agency (DARPA), at varying levels of funding, as well as in special purpose projects, such as the SEMATECH rescue effort mounted to save the U.S. semiconductor industry from Japanese competition in the 1980s.

Industry→ Government Initiatives

Government-industry R&D cooperation is emerging as an overlay upon a hidden industrial policy of encouraging academic-industry ties. Incentivized by relaxation of antitrust laws U.S. industry initiatives are largely confined to joint projects among firms. However, in certain circumstances, where the challenge is great and industry feels it cannot succeed by itself, and the danger of loss is too great, industry calls upon government assistance. Two instances exemplify industry's relation to government: The formation of SEMATECH and Joint Venture Silicon Valley, at the national and regional levels. During the early 1990s decline of Silicon Valley, an industry-initiated consortia invited participation of local governments and universities in what was initially a series of brainstorming meetings to generate ideas for renewal of the region. A venture-capital approach of selecting a few ideas for further development was followed and an organization was formed to support the initiatives, led by a local politician.

When the semiconductor industry was at risk due to intense Japanese competition from the 1970s, industry leaders developed a strategy to jointly develop a new generation of production technology and sought significant government support from the Department of Defense. The Reagan administration overcame its ideological objections and approved the project. Thus, an industry-initiated university-industry government collaboration was created at the national level. University research centers, such as the Center for Integrated Systems at Stanford, brought together academic and industrial researchers who moved the larger project forward. SEMATECH contributed to the revival of the U.S. industry and later dropped government funding to admit foreign firms and reorganize as an international consortium for precompetitive research to support the industry as a whole.

These instances exemplify an evolving knowledge and innovation infrastructure that is increasingly constructed from elements of the triple helix. University research centers explicitly adopt industrial models of research management to provide a support framework for academic research groups, balancing these coordination and control elements with research autonomy, including the right of graduate students to have a considerable say in the formulation of research projects through negotiation with their mentor. Similarly, startup firms are a hybrid creature, embodying academic, industrial, and government elements rather than a pure business model, even though they are legally constituted as firms.

Conclusion: Endless Frontier and Triple Helix

The intersection of dual linearities induces nonlinearity and interactive innovation through networked rather than isolated entities. When the forward-linear model of university research groups and its support structure of technology-transfer offices and incubator facilities meets the reverse-linear model with its clusters of learning firms, each infuses the other. It is increasingly recognized that government plays an important, if sometimes hidden, role in innovation in market economies and that government programs have an important role to play, not only from the national level—top-down—but also from the local level—bottom-up, in a movement from a hands-off linear to an assisted linear model of innovation.

Beyond the development of new products, innovation is the creation of new configurations among the institutional spheres. University-industry-government interactions are increasingly the basis of economic and social development strategy in both advanced industrial and developing societies. Heretofore, innovation was expected to largely take place within industry with other institutional spheres playing only a limiting contributing role, government, for example, acting only when clear market failures could be identified. Innovation is being transformed from a relatively simple set of linear and reverse linear processes within industry, extending from research to the market and vice versa, to a nonlinear process in the transition to a knowledge-based society

The insertion of Bacon's (1620/2011) practical vision of a series of institutional mechanisms realizing the promise of science was the way forward. An assisted linear model, consisting of a series of organizational mechanisms, such as technology-transfer offices and programs to explore the practical implications of research, inserted between the producers and users of research emerged through a series of government initiatives at the national and regional levels. By combining top-down and bottom-up approaches, arising from opposite starting points in laissezfaire and statist societies, the promise of the endless frontier is realized.

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