Swimming Against the Current: The Rise of a Hidden Developmental State in the United States*

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Despite the dominant role of market fundamentalist ideas in U.S. politics over the last thirty years, the Federal government has dramatically expanded its capacity to finance and support efforts of the private sector to commercialize new technologies. But the partisan logic of U.S. politics has worked to make these efforts invisible to mainstream public debate. The consequence is that while this "hidden developmental state" has had a major impact on the structure of the U.S. national innovation system, its ability to be effective in the future is very much in doubt. The article ends by arguing that the importance of these development initiatives to the U.S. economy could present a significant opening for new progressive initiatives.

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On a number of key dimensions, the trajectory of the United States has diverged sharply from that of Western Europe over the past thirty years.[1] The divergence is most marked in social policy and the philosophy of governance, where the choices made by the United States have been influenced by market fundamentalism—a vastly exaggerated belief in the capacity of market self-regulation to solve economic and social problems. To be sure, many Europeans have also been taken with the idea of Afree markets since the fall of the Berlin Wall, but their actual policies have been far more restrained in cutting back government regulation of business, leaving the poor and sickly on their own, and directly challenging the institutionalized role of organized labor at the workplace and in the political arena. As a consequence, most Western European societies have not experienced the dramatic increases in economic inequality and heightened economic insecurity that have occurred in the United States.[2]

But in one important and often overlooked respect, European and U.S. policies have converged. On both sides of the Atlantic, governments have played an increasingly important role in underwriting and encouraging the advance of new technologies in the business economy.[3] Consistent with ideas of the "knowledge economy" or postindustrial society that stress the economy's immediate dependence on scientific and technological advance, governments have embraced developmental policies that support cutting edge research *and* work to assure that innovations are transformed into commercial products by companies.[4] Governments do this because they recognize that in a competitive world economy, failing to create new high value added economic activities in the home economy will ultimately threaten their citizen's standard of living.

But the way in which governments pursue these policies differs dramatically between Europe and the United States. In Europe, both national governments and the European Community are open and explicit about their developmental agendas, and political parties occasionally compete over which will be more effective in pursuing such initiatives.[5] In the United States, in contrast, the developmental state is hidden; its existence is not recognized in political debate or in the media. Congress, under the rubric of "competitiveness policy," periodically passes legislation that bolsters and expands the developmental capacities of the U.S. state, but this happens with little public debate or discussion.[6]

The hidden quality of the U.S. developmental state is largely a result of the dominance of market fundamentalist ideas over the last thirty years. Developmental policies have lived in the shadows because acknowledging the state's central role in promoting technological change is inconsistent with the market fundamentalist claim that private sector firms should simply be left alone to respond autonomously and spontaneously to the signals of the marketplace.

For example, in their highly influential book, *Free to Choose,* Milton and Rose Friedman see no economic justification for the government funding scientific research through the National Science Foundation.[7] If funding scientific research is not a proper governmental role, then certainly there is no justification for public agencies getting involved in the commercialization of new technologies.

In this sense, it is remarkable that the United States has any kind of developmental policies outside of the defense and national security sectors. That they exist at all is testimony to the powerful dynamism of an emerging knowledge economy that has been able to swim upstream against the current of a hostile political philosophy. But the inevitable result is that U.S. developmental practices have been significantly distorted by the constraints within which they have emerged. It is here where the divergence between the United States and Europe again becomes apparent. In Europe, developmental state policies often work in synergy with the legacy of social democratic and Christian democratic policies that emphasize social inclusion, partnership between business and labor, and a commitment to the sharing of rewards.[8] In the United States, in contrast, the "winner takes all" model with its attendant increases in inequality tends to work at cross purposes with developmental state policies.

The argument is developed in five main sections. The first section introduces the concept of a Developmental Network State and tells the story of how this institutional structure emerged in the United States beginning in the 1980's. The second explains how partisan politics and ideology worked to keep this U.S. developmental system hidden. The third provides an overview of how the Developmental Network State functions currently in the United States. The fourth section explains how its peculiar development, and particularly its covert character, undermines the sustainability of U.S. developmental efforts. The conclusion argues that the pressing need to reform the Developmental Network State provides significant political opportunities for progressives in the United States.

UNDERSTANDING THE DEVELOPMENTAL NETWORK STATE

The types of developmental policies being pursued in both Europe and the United States are quite distinct from the more familiar form of developmentalism that was deployed in East Asia in the decades after World War II.[9] That approach, exemplified by Japan's Ministry of Industry and Trade (MITI), was a centralized form of state policy that has been usefully called a Developmental Bureaucratic State (DBS).[10] The DBS was designed to help domestic firms catch up and challenge foreign competitors in particular product markets. As practiced in Japan and South Korea, it worked by government planners providing a series of economic incentives and subsidies to established firms to compete in markets that they would otherwise have considered too risky to enter. When this type of developmental state was identified by journalists and academics, it was easily grasped as the coordinated activity of a unified group of government officials who often worked under the same roof.

What Europe and the United States have created is something very different called a Developmental Network State (DNS).[11] The main focus of the DNS is to help firms develop product and process innovations that do not yet exist, such as new software applications, new biotech medications, or new medical instruments.[12] For this, the older Japanese model is basically irrelevant because there is no international leader that firms can imitate. Moreover, firms already have strong incentives to innovate, so the addition of government subsidies or incentives is unlikely to have any additional impact. Instead of the DBS reliance on providing firms with incentives, the DNS is much more "hands on"; it involves public sector officials working closely with firms to identify and support the most promising avenues for innovation.

A precondition for a Developmental Network State is a community of people with high levels of technological expertise. It requires substantial previous investments in higher education and in the production of scientific and engineering knowledge. Once the mechanisms for producing expertise and new knowledge are already in place, the DNS attempts to make this technological community more effective in translating research into actual products. The DNS can be thought of as a set of government actions that are designed to improve the productivity of a nation's scientists and engineers.[13]

The work of the DNS can be divided into four distinct but overlapping tasks—targeted resourcing, opening windows, brokering, and facilitation. Targeted resourcing involves government officials identifying—often after considerable consultation—important technological challenges, the solution of which would open up important economic possibilities. Officials then provide funding and other resources to groups that have promising ideas for achieving breakthroughs. Targets can include both fundamental problems, such as figuring out how to splice DNA to create new organisms as well as much more focused problems, such as developing improved imaging technologies for better cancer screening.

This kind of targeted resourcing requires that funders exert considerable discipline over the technologists. They have to set benchmarks and withdraw funding from those groups who fail to show adequate progress in meeting goals. This makes it very different from standard practices in military contracting where procurement officials often keep the money flowing despite slow progress in meeting goals.

Targeted resourcing is intended to focus the energies of scientists and engineers on a particular set of tasks and create synergies by getting groups of highly skilled people working together. It follows the basic model of the Manhattan Project demonstration that technological progress can be accelerated by concentrating resources.

Opening windows rests on the contrasting logic that many good ideas for innovation will bubble up from below and might not fit with the targeted priorities being pursued by particular agencies. The goal is to create multiple windows to which scientists and engineers, working in university, government laboratories, or business settings, can bring ideas for innovations and receive funding and other types of support. This is the "let a thousand flowers bloom" dimension of technology policy where government agencies provide fertilizer to help new ideas grow.[14] Money is not the only fertilizer; sometimes in-kind assistance, such as use of specialized equipment in government laboratories, is critical.

Brokering encompasses two overlapping dimensions—technological brokering and business brokering. Technological brokering is a central part of the innovation process, since it often involves putting together already existing technologies in new ways or one laboratory combining a new technique from another laboratory with its own incremental change to make something new and different.[15] Brokering is the activity of connecting these different groups together so they can take advantage of each other's knowledge. Officials engaged in targeted resourcing are sometimes able to play this role effectively because they have developed a broad overview of the research activities going on within a particular technological subfield. But those at open windows can sometimes also play this role by making connections that would not otherwise occur.

Business brokering is more obvious. It involves helping a group of technologists who are trying to commercialize a new product to make the business connections that they need to create an effective organization, get the required funding, and find potential customers for the product. Again, public sector technology officials, who have built up networks both within the government and with private firms, including venture capitalists, are sometimes able to play this role effectively.

Finally, facilitation encompasses a range of activities. Often, the more radical the technological innovation, the more obstacles have to be cleared away to create viable markets for the new technology. With the railroad and the automobile, for example, expensive infrastructure had to be put in place before the new technology could mature.

At the less radical end of facilitation, standards are often an issue, since purchasers need to know that a new product actually does what is promised and will work effectively in combination with existing infrastructure. Some technologies also require creating new regulatory frameworks that makes it safe for firms to invest and overcome consumer concerns. Sometimes considerable coordination is required because a new technology depends on multiple firms making investments in the same time frame. In the case of the Internet, facilitation involved an extended period in which the state effectively manages the technological infrastructure before privatizing it.

This brief catalog helps to understand why the DNS is necessarily a highly decentralized structure. Most of these activities require a very high level of specific expertise within the relevant government agencies. To be effective, these officials require "embedded autonomy"; they have to be deeply rooted in the particular technological community that they are funding.[16] For example, an official at the National

Cancer Institute within NIH might be very effective at providing resources and brokering for scientists working on ways to cut off the blood supply to tumors, but he or she might be completely ineffective if shifted over to work on genetic markers for breast cancer. Facilitation is somewhat different; the more ambitious version cannot be done by one or two people working in a single office; it usually requires networks of collaboration within the government, since different types of expertise need to be brought to bear. But in this case as well, *some* of those involved must have a deep understanding of the particulars of the technology.

Moreover, for opening windows and brokerage to be most effective, it is desirable to have some redundancy built into this structure. Without that redundancy, a single small office might be able to completely shut down a promising line of investigation by denying funding. With multiple windows and multiple potential brokers, an idea might be able to survive and ultimately flourish despite initial negative responses. Since centralization tends to eliminate duplication of functions, this is yet another reason that a DNS is highly decentralized.

This decentralization makes any DNS far less visible to journalists, scholars, and the public than a DBS. A DNS is not housed in a single place; rather its activities might be carried out in literally hundreds of different offices located in different government agencies or facilities. It also doesn't have a unified budget; spending is disbursed across a wide range of different agencies. Even its impact tends to be decentralized as hundreds or thousands of distinct groups of technologists are supported in their work across a wide range of different economic sectors.

In both Europe and the United States, constructing the DNS required significant policy innovations and the creation of new institutions and funding streams. The difference is that most European nations had stronger twentieth century traditions of active state engagement in the management of the civilian economy than the Unites States. Both at the national and the European Community level, officials could draw on strong traditions of state leadership to justify these new policies. In the United States, in contrast, the transition to a DNS was necessarily more convoluted.

THE EMERGENCE OF THE DNS IN THE UNITED STATES: ARPA

The United States has a long history of state developmental efforts that go back to Alexander Hamilton and the beginning of the Republic.[17] But this tradition has co-existed uneasily with the counter tradition of laissez-faire and reliance on the market.[18] In the twentieth century, the tension was resolved by carrying out developmental policies within the framework of national defense. In the years after World War II, the Pentagon worked in close cooperation with other national security agencies such as the Atomic Energy Commission and the National Aeronautics and Space Agency (NASA) and as a consequence, government funding and infrastructure played a key role in such technologies as computers, jet planes, civilian nuclear energy, lasers, and ultimately, biotechnology.[19]

Not surprisingly, most of the core methods employed by the Development Network State in the United States were pioneered by one particular office in the Pentagon—the Advanced Projects Research Agency (ARPA).[20] ARPA was initially created in the aftermath of the Soviet success with Sputnik to push the technological frontier of Pentagon procurement efforts. The intention was to provide funding for "beyond the horizon" technologies, since the rest of the Pentagon's budget for research and development was linked to immediate procurement of weapons for the various military services.

ARPA initiatives occurred across a range of technologies, but it was the offices that supported technological advance in the computer field that established a new paradigm for technology policy. ARPA's computer offices carefully cultivated a model that was quite distinct from the standard practice of other government agencies that fund research. The National Science Foundation, for example, has relied very heavily on peer review of research proposals, which leaves most of the initiative in the hands of the research community. Since ARPA's computer initiatives began at a time when the established computer science research community was very small, ARPA was far more proactive in shaping the direction of research. From the start, it engaged in targeted resourcing.

ARPA made a practice of hiring visionary technologists and giving them a very high degree of autonomy to give out research funds. The organizational structure was extremely lean with very small staffs and a minimum of paperwork. ARPA's Information Processing Techniques Office (IPTO) was initially established in 1962 and played a central role in the advance of computer technology in the 1960s and 1970s. IPTO provided the resources to create computer science departments at major universities and funded a series of research project that successfully pushed forward advances in the human-computer interface. In fact, many of the technologies that were ultimately incorporated into the personal computer were developed by ARPA-funded researchers.[21]

Of course, the Internet itself began as an ARPA project in the late 1960s that encouraged communication among computer researchers funded by the agency. While responsibility for the early Internet was eventually shifted from ARPA to NSF, it was in the ARPA period that the technological barriers to networked communication among computers were overcome.

The key features of the ARPA model can be described as follows:

1. A series of relatively small offices, often staffed with leading scientists and engineers, are given considerable budget autonomy to support promising ideas.
2. These offices are proactive rather than reactive and work to set an agenda for researchers in the field. The goal is to create a scientific community with a presence in universities, the public sector, and corporations that focuses on specific technological challenges that have to be overcome.

3. Funding is provided to a mix of university-based researchers, start-up firms, established firms, and industry consortia. There is no dividing line between "basic research" and "applied research," since the two are deeply intertwined.[22] Moreover, ARPA personnel are encouraged to cut off funding to groups that were not making progress and reallocate resources to other groups that had more promise.
4. Since the goal is to produce usable technological advances, the agency's mandate extends to helping firms get products to the stage of commercial viability. This can involve the agency in providing firms with assistance that goes well beyond research funding.
5. Part of the agency's task is to use its oversight role to make constructive linkages of ideas, resources, and people across the different research and development sites.[23]

In short, the ARPA model encompassed targeting of resources, technological and business brokering, and a certain amount of facilitation. Moreover, ARPA's computer offices also opened windows for scientists and engineers—who had good network ties—to propose ideas for funding.

PARALLEL DEVELOPMENTS: BIOTECHNOLOGY

The ultimate political impact in the United States of the ARPA model was magnified by a second and largely independent technological transformation that occurred in the 1970—the emergence of genetic engineering under the wing of the National Institutes of Health (NIH). In the aftermath of Watson and Crick's discovery of the structure of DNA in 1953, substantial funding from NIH made possible rapid advances in molecular biology by U.S. scientists. Their achievements included understanding the genetic code and figuring out how DNA replicates itself. These breakthroughs paved the way for the creation of new organisms by combining DNA from different sources.

As early as 1967, experiments were underway to splice genes together, and the first success was achieved in 1971. When a team at Stanford led by Paul Berg successfully created a DNA molecule that combined fragments from different organisms, genetic engineering moved from the realm of science fiction into practicality. In 1977, Herbert Boyer's team at UCSF successfully created a new organism designed to produce a particular protein—somatostatin.[24]

Well before Boyer's important achievement, the biotechnology gold rush was underway. Both established and new firms recognized the extraordinary commercial importance of this new technology. Deliberately engineered organisms could be turned into factories to produce large supplies of proteins that were far more difficult and expensive to obtain in other ways. Moreover, bioengineering also created the potential for the discovery of new blockbuster medications that could cure human illnesses as well as new variants of plants and animals engineered to have particular qualities that were rare or nonexistent in nature. U.S. firms have remained in the forefront in exploiting these possibilities for the last thirty years.

Officials at NIH did not follow the kind of model that ARPA had pioneered with computer technology. There is no evidence for the 1970s of NIH officials setting technological goals in the way that ARPA routinely did. On the contrary, NIH continued to rely heavily on the peer review model in which funds were distributed for the research projects that were deemed most worthy by other scientists. Moreover, the timeline on NIH research projects was very different from the way that ARPA worked. In the computer field, ARPA would often expect to see significant results in a year and would decide to either continue or stop funding after twelve months. At NIH, in contrast, grants were usually for five years, reflecting the far slower progress when work in the laboratory involves the manipulation of actual living organisms.

Nevertheless, NIH operated from a developmental logic of its own that ended up paralleling ARPA's achievements. NIH's funding mandate rested on progress in fighting human disease, so as NIH officials grasped the disease fighting possibility of genetic engineering, they were aggressive in advancing the technology, both with the grants they provided and with the research going on within their own labs. The rapid growth in funding for genetic engineering reflects this enthusiasm. In 1975, NIH supported only two recombinant DNA research projects. In 1976, this rose to 123 projects with $15 million dollars of support. By 1980, this had increased to 1,061 projects funded with $131 million of funding. Moreover, as early as April 1976, one of the constituent institutes announced a contract program designed to accelerate the development of organic chemicals required for recombinant DNA research.[25]

NIH officials in this critical period were also supportive of efforts by scientists to commercialize their discoveries. Some of his colleagues were scandalized when the UCSF scientist Herbert Boyer helped found Genentech in 1976, the first of the biotech startups specifically created to commercialize genetic engineering. However, NIH raised no objections when Boyer continued to use his NIH-funded lab at UCSF for Genentech's first commercial project—the development of a bacteria that would synthesize human insulin. This sent an important signal to other scientists that the relevant government agency was encouraging the closest possible collaboration between scientists and business firms.

Most importantly, NIH did the difficult facilitation work of running political interference for the new technology. In the mid-70s, there was considerable public anxiety around the perceived dangers involved with scientists creating new life forms. Proposals were introduced in Congress for new regulatory agencies that would closely supervise this type of research. The leadership at the NIH skillfully outmaneuvered the opponents by holding public hearings, issuing guidelines, and promoting self-regulation by the scientists themselves. As a consequence, the agency successfully held on to its jurisdiction as the key responsible governmental authority, even though NIH was neither equipped nor authorized to serve as a regulatory agency.[26]

The NIH leadership anticipated that public anxieties would diminish once the new technologies produced valuable medical breakthroughs. And once this happened, they moved quickly to relax the strictness of the initial guidelines. Most importantly, their maneuvering meant that biotechnology firms faced no additional regulatory barriers in pursuing this new type of research. Private firms were urged to self-police in the same way as university scientists by creating internal safety committees that would review proposed research in advance. Private firms that were developing pharmaceuticals or other human therapies would ultimately have to go through the complex FDA approval process, but avoiding new forms of regulation before human trials was quite significant for the rise of this new industry. The resulting growth in biotechnology firms was spectacular: "32 in 1978, 42 in 1979, 52 in 1980, and 100 in 1981. . . ."[27] Genentech went public in October 1980, and its shares, initially priced at $35, soared to $89 on the hopes for rapid therapeutic advances. The reality, of course, was that some of these startups failed, and the drawn out process of testing and approving new pharmaceuticals has meant that the industry's performance has consistently disappointed the expectation of investors looking for overnight results. But in recent years, most of the successful new pharmaceuticals are products of these new technologies.[28]

The point, however, is that NIH's role in the genetic engineering revolution in the 1970s had important consequences both within the agency and within the government more broadly. Just as with ARPA earlier, NIH leaders came to see the nurturing of new firms as part of their agency's mission. Moreover, the centrality of ARPA to the computer industry and NIH to biotechnology persuaded many policy makers that the Federal government had a role to play in nurturing the industries of the future.[29]

WINNING WHILE LOSING: THE INDUSTRIAL POLICY DEBATE AND ITS AFTERMATH

This new understanding was a key part of the industrial policy debate that took place in the early 1980s. The standard history of the U.S. industrial policy debate has been provided by Otis Graham.[30] He shows how industrial policy ideas developed within Democratic Party policy circles at the end of the 1970s were widely debated during Ronald Reagan's first term, becoming a central axis of discussion within the Democratic primaries in 1984. He argues that the critical turning point came when the Democratic nominee in that year, Walter Mondale, repudiated the idea that the government should play an active role in "choosing winners." Mondale focused his campaign instead on well-established Keynesian ideas that had been part of the party's repertoire since the 1930s. With that choice, Graham argues that the industrial policy debate basically ended with clear victory for those advocating reliance on markets.

The reality, however, is significantly more complex. It was anxieties about the ability of U.S. firms to compete successfully in the global economy that had forced industrial policy ideas onto the political agenda in the first place. The U.S. trade deficit in goods worsened significantly in the second half of 1970s, improved slightly during the years of belt tightening and recession from 1979 to 1982, and then dramatically worsened as the Reagan economic boom unfolded. Japan at this time appeared to be a highly effective juggernaut that had successfully captured much of the U.S. market for automobiles and electronic goods and was threatening U.S. leadership in computer chips, computers, and other emergent technologies. Old line U.S. industrial firms, exemplified by the auto companies and big steel, were seen as rusty dinosaurs, thick with bureaucracy, pretty much incapable of adapting to a new environment.

For politicians in both parties, anxieties about U.S. competitiveness translated directly into the issue of jobs. They were concerned whether new jobs were going to open up for their constituents as older manufacturing jobs disappeared. So during the same period that proponents of an explicit and open industrial policy were politically defeated, politicians of both parties nevertheless supported a series of measures that were designed to translate the nation's scientific and technological leadership into commercially viable products that would be produced in the United States.[31]

Taken together, these initiatives can be seen as efforts to build on the successes of ARPA and NIH in nurturing new industries. So despite public declarations that industrial policy was wrong because government should not try to pick winners, initiatives were taken that created a decentralized system through which public agencies would, in fact, invest in potential winners. Some of these initiatives simply facilitated the privatization of publicly funded intellectual property, but others significantly expanded the government's role in directing technological change. The initiatives mentioned here begin at the end of the Carter Administration and end before Bill Clinton started his presidential term in 1993.[32] In other words, the vast majority of these actions occur during the free-market administrations of Ronald Reagan and George H. W. Bush.[33]

Stevenson-Wydler Technology Innovation Act of 1980

This act encouraged the network of Federal laboratories to engage in direct collaboration with state and local governments, universities, and private industry on research efforts. It also mandated that the laboratories spend funds on technology transfer activities.

1980: Bayh-Dole Act

This act was passed by Congress in 1980 to encourage universities and small businesses to pursue commercial exploitation of technological breakthroughs that resulted from Federally funded research. There is some dispute as to how much difference this legislation has actually made, since previous law allowed universities to gain property rights over key technologies developed with Federal support. Nevertheless, the new legislation served an important symbolic function in legitimating close cooperation between university researchers and industry.[34]

1982: Small Business Innovation Development Act of 1982

This legislation created the Small Business Innovation Research Program, which was a consortium between the Small Business Administration and government agencies with large research budgets such as Department of Defense, Department of Energy, and Environmental Protection Agency (EPA). The agencies were required to devote a fraction, initially 1.25 percent of their research funding, to support initiatives that came from small, independent, for-profit firms. Small Phase I awards of $50,000 could be followed by larger Phase II awards of $500,000.[35]

1984 National Cooperative Research Act

This act created a blanket antitrust exemption for private firms to engage in cooperative research efforts to develop new products. It created the legal foundation to establish industry-wide research consortia that shared funding and information on "pre-competitive" research.

1985: NSF Establishes Program for Engineering Research Centers

These university-based centers were designed to create a decentralized network of researchers working on concrete problems of translating scientific breakthroughs into usable technologies.[36]

1986: Federal Technology Transfer Act

This created the legal framework for Cooperative Research and Development Agreements (CRADA's) between Federal laboratories and private firms that would give firms the right to commercially exploit research findings that originated at those laboratories.

1988: Advanced Technology Program (ATP), Department of Commerce

Originally authorized in the Omnibus Trade and Competitiveness Act of 1988, ATP is a program that provides a Federal matching grant for private sector research efforts designed to commercialize promising new technologies. Potential recipients include both big businesses and small.

1988: Manufacturing Extension Program

The same piece of trade legislation also authorized funding for a network of manufacturing extension projects. These were developed on the analogy with agricultural extension programs—a widely decentralized program that would provide locally available expertise to help manufacturers make use of advanced technologies.[37]

1991 Defense Industrial and Technology Base Initiative

The Defense Authorization Act authorized Critical Technology Institutes to "advance the development of technologies deemed critical to U.S. national security and economic competitiveness." The legislation also authorized manufacturing extension programs that would help diffuse advanced manufacturing technologies developed under DOD auspices to small firms.[38]

1991 High Performance Computing and National Research and Education Network Act

This legislation was intended to protect the U.S. international lead in high performance computing and networking. It was also explicitly intended that the technological developments would enhance productivity and industrial competitiveness. It initially allocated $654 million in support of research at the Department of Defense and the National Science Foundation.[39]

1992 Small Business Research and Development Enhancement Act of 1992

This act created a program on the model of the SBIR called the Small Business Technology Transfer Program (SBTTR). The basic design of the program is the same as SBIR, except the research effort must involve a collaboration between a small business and a non-profit research institution such as a hospital, university, or government laboratory.

These initiatives all began at the Federal level, but many of them were designed to coordinate with state and local initiatives. During this same period, driven by concerns about employment creation, most states launched new initiatives to expand their established economic development programs. Many of these initiatives provided technical assistance and some provided startup capital to new firms. Staff at these state agencies could educate the firms about the different types of available Federal assistance. Similarly, both universities and Federal laboratories were also encouraged to take on the task of assisting businesses—both established and startups—with technological problems. The most dramatic instance of this decentralization was the Manufacturing Extension Program that provided services through literally hundreds of locations across the country.

Three of the Reagan era initiatives are of particular importance because they represented significant advances in the scale of Federal developmental efforts. The first was ARPA's Strategic Computing Initiative. In the face of aggressive Japanese initiatives in the computer industry, Congress voted additional funds to ARPA in 1983 to support a ten-year Strategic Computing initiative intended to achieve major breakthroughs in Artificial Intelligence. While the program's architects were far too optimistic about the short-term potential for major breakthroughs in developing thinking machines, the initiative provided an opportunity to further refine the ARPA model of industrial policy. The SCI's leaders identified what they saw as the key technological barriers that had to be overcome, and they then funded competing groups that had different strategies for surmounting the obstacles. When a group demonstrated progress, they were given additional resources, sometimes in the form of procurement contracts, to facilitate the transformation of their ideas into commercially viable products.

ARPA's managers served as public sector venture capitalists for those developing more advanced computer technologies. They facilitated the transfer of key ideas from one research group to another, so that innovations could diffuse more quickly. They also were able to link start-up firms with private venture capital firms, potential customers, and other key resources that would help make them more successful.[40]

A second key ARPA initiative of this period was the creation of Sematech in 1987 after years of pressure by the U.S. semiconductor industry for a response to intensifying Japanese competitive pressures.[41] SEMATECH began as a consortium of twelve semiconductor firms and was initially financed with $100 million per year of ARPA money that was combined with contributions from the consortium members. Its ambitious mission was to both upgrade technological capacity all along the "semiconductor manufacturing food chain" and create an ongoing research and education infrastructure "for sustained U.S. leadership in semiconductor technology."[42]

By most accounts, the Federal investment in SEMATECH was successful. The collaboration between government and industry was able to target resources at key industry bottlenecks, particularly the firms that produced the equipment used for manufacturing semiconductors. The initiative helped U.S. firms to regain significant market share from foreign competitors. The funds also helped to build an academic community around the design of chips making it possible for the industry to maintain the geometric expansion of chip capacity. After ten years, Sematech became self-supporting, relying on industry contributions alone, although ARPA continued to fund key academic work in chip design.

SEMATECH became a model for subsequent industrial policy efforts. Over the next twenty years, there are repeated efforts by government officials to assemble similar types of industrial consortia to accelerate technological development up and down the supply chain. The core idea is that putting some Federal money into the mix gives industry participants an incentive to begin cooperating to identify shared research and logistical challenges that might be solved through joint efforts. The hope is that once industry officials see the benefits of this kind of cooperation, they will continue to finance the consortium efforts without government funds.

Another important initiative of this period was the Human Genome Project that was launched somewhat improbably by the Department of Energy (DOE). DOE's budget included the funding for the system of Federal laboratories that had grown out of weapons programs in the early years of the Cold War. As Cold War tensions eased in the second half of the 1980s, DOE's leadership recognized that the protection of the agency's budget required establishing the commercial value of the Federal laboratories. Hence, DOE became one of the first civilian agencies to embrace parts of the new ARPA model of industrial policy and it seized on mapping the genome as an ideal opportunity.

From the start, the logic of the Human Genome Project was to mobilize the energies of the scientific community around the specific task of mapping the genome as a way to accelerate the discovery of commercially viable products. At NIH, there was initial resistance to the idea because of fear that embracing this kind of top down model would divert resources from the traditional peer reviewed granting process. But these objections were overcome, and the Human Genome Project was formally launched in 1991 as a joint effort of the NIH and DOE, with annual funding of $135 million. NIH, as well, was now in the business of directing scientific and technological development down one particular track.[43]

KEEPING THE DEVELOPMENTAL STATE HIDDEN

From its origins in the Reagan years up to the present, the play of partisan politics has been the key factor in keeping this developmental activity largely hidden from public view. To be sure, the various components of the developmental state are not covert or secretive; agencies that provide assistance for technological innovation advertise their services broadly to the business community, and they brag about their success stories on their Web sites. Like the purloined letter, the hidden developmental state is hidden in plain view. But it has been rendered invisible by the success of market fundamentalist ideology. Since that ideology insists that the private sector is efficient and dynamic while the state is wasteful and unproductive, there is simply no conceptual space for the idea that government plays a critical role in maintaining and expanding the private sector's dynamism.

It is here that the contrast with Europe's experience is most dramatic. There is ongoing debate about European developmental policies, but the arguments are generally pragmatic rather than ideological. They focus on whether particular initiatives are accomplishing their stated objections, not whether it is appropriate for the state to play an active role in driving technological innovation.

To be sure, in the United States, a small scholarly community has been trying to make the workings of the U.S. developmental state more visible since the 1980s,[44] and there are important studies showing the centrality of the state role in a series of different technologies. But this body of work has had little influence on the society's common sense understandings or the way that journalists report on technologies and technological breakthroughs. As late as 2007, a Google search for the phrase, "U.S. developmental state" found no entries beyond the Ford Foundation grant that funded the research for this article.

This invisibility has been maintained through a long history of partisan conflict over the ARPA model of industrial policy. This conflict first came into the open during the administration of George H. W. Bush and has erupted repeatedly since then. The conflict is rooted in the unusual political coalition that has dominated the Republican Party from the mid-1970s onward. That coalition unites social and religious conservatives with business conservatives around a political agenda that centers on market fundamentalism. However, big business support of market fundamentalism is not principled, but strategic, since large firms are heavily dependent on government providing them with subsidies, a favorable regulatory environment, research support, protection of their "intellectual property," and reliable backing overseas. Nevertheless, they find market fundamentalism useful as a way to resist unwanted regulations and to win ever more favorable tax treatment.[45]

The problem is that some parts of the Republican coalition take market fundamentalist ideas seriously, so Republican presidents periodically have to demonstrate their loyalty to the doctrine. The Cato Institute, for example, expresses the views of libertarians by routinely denouncing many of the programs analyzed here as "corporate welfare." Hence, Republican presidents have periodically played to this part of their base by publicly repudiating programs that go too far in the direction of "picking winners."

An early episode in this ongoing drama occurred in 1990 when the administration of George H. W. Bush fired the head of ARPA for being too aggressive in his industrial policy initiatives.[46] One possible precipitant of Field's ouster was "a decision the agency made this month to invest $4 million in Gazelle Microcircuits, Inc., a Silicon Valley electronics company that is working on high-speed circuits of gallium arsenide."[47] In that case, ARPA was acting openly as a public sector venture capitalist. Shortly before, Fields had also been repudiated in his efforts to use ARPA funding in support of high definition television technology. But even though the Bush Administration publicly reined in ARPA in 1990, it still supported in 1991 the Congressional passage of the High Performing Computing Initiative that provided enhanced support for ARPA's initiatives in this arena. In short, it seems that Fields was sacrificed not because he was engaging in developmental policies, but because he was making those policies too visible.

The complexity is that Democratic politicians have seen technology policy as an opportunity to separate parts of the business community from their loyalty to the Republican coalition. They think that if their party provides aggressive support for technology funding, key business groups could be persuaded to enter into a durable alliance with the Democratic Party.[48] Republican administrations, therefore, have to walk a kind of tightrope. On the one side, they have to provide a high enough level of support for developmental policies to keep key business constituencies from defecting to the Democrats who are promising them a better deal. But at the same time, they have to make a certain number of gestures to prove their support for the idea that market competition, by itself, is the ultimate guarantor of technological progress.

For George W. Bush, the key public gesture has been joining in the right wing's attack on the ATP that has been housed in the Department of Commerce since the late 1980s. The program provides matching grants to business firms, both large and small, that are seeking to overcome a technological barrier. While the program's track record has been excellent, it is particularly despised by market fundamentalists because it supports big businesses that could easily raise funds for their R&D efforts in the capital markets. So George W. Bush has obligingly zeroed out the program in the budgets he has submitted to Congress.[49]

But even when the Republicans controlled both Houses of the Congress, they allowed the ATP to survive at the $150–160 million per year level, since the program was popular with the businesses that it supported. But this repeated dance allowed Bush to appease the most ideological market fundamentalists and reinforce the narrative that the U.S. government does not engage in developmental state activities.

But the real story was that George W. Bush used his dogged opposition to ATP funding as political cover to provide significant funding for much larger technology initiatives. For example, the Bush Administration has enthusiastically embraced the National Nanotechnology Initiative, begun under Clinton, which, like ATP, provides funding to both big business and small business at funding levels of $1 billion per year.[50] Since nanotechnology encompasses research at the atomic and molecular scales, it includes everything from material sciences, chemistry, and energy efficiency to computers and biotechnology. While the Cato Institute is contemptuous of this spending as “pork barrel research,” the Bush Administration has moved full speed ahead with this and other developmental initiatives.[51]

In fact, the White House’s own Web page reveals the administration’s ambivalence. In January 2006, President Bush announced a new competitiveness initiative with requests for additional funds to support technologies policies. Right on the White House Web page for that effort (http://www.whitehouse.gov/stateoftheunion/2006/aci/), there is a graphic of Apple’s IPod, showing how Federally funded research produced some of the key technologies on which that commercial product depends. In a word, an administration that is unswervingly ideological on many other policy fronts has pursued a more pragmatic path in maintaining the hidden developmental state and even occasionally bragging about its accomplishments.

When Bill Clinton was in the White House, the dynamic was completely different. His administration was unequivocal in its support for increasing funding for a range of different technology policies. He campaigned on a public investment platform that involved ambitious outlays in support of technological development.[52] But the Republicans in the Congress fought fiercely to limit funding for most of these initiatives. Republican opposition served two functions; it provided an opportunity to press their case that Democrats were unreconstructed supporters of big government while also making it more difficult for Democrats to woo business allies with expanded R&D programs.[53]

Clinton, for example, sought to expand the ATP from its relatively small size under George H. W. Bush. In fact, he brought in an experienced ARPA hand to ramp up the agency’s efforts. But this initiative made ATP a particularly attractive target for the Republican Right. They relentlessly attacked Clinton as an advocate of big government who had failed to learn Ronald Reagan’s key lesson that “government is not the solution, government is the problem.” They used this rhetoric to oppose Clinton’s entire public investment agenda. Moreover, the attack was intended to keep Clinton from getting Congressional approval for the resources he wanted to outbid the Republicans for business support.

As soon as the Republicans gained control of Congress in the 1994 mid-term elections, they sought to cut off all funding for ATP. The agency’s budget for FY 1996 was slashed to $19 million, but the Clinton Administration was ultimately able to push funding back up to $150 million per year. The new Republican majority also used their budgetary power to limit the Clinton Administration’s pursuit of other new technology initiatives such as the Partnership for a New Generation of Vehicles. They also dismantled the Congressional Office of Technology Assessment that had carefully cultivated bipartisan support through its twenty three-year history. Over the years, its staff had developed considerable expertise and had produced a series of important reports on some of the different programs of the hidden developmental state. In closing it down, Gingrich and his allies appear to have calculated that if they killed the messenger, the news about the hidden developmental state was less likely to get out.[54]

In sum, partisan conflict during both Republican and Democratic administrations has worked to keep the U.S. developmental state hidden and the ideology of market fundamentalism in place. Nevertheless, the various programs passed in the 1980s and early 1990s have gradually matured into a Developmental Network State with considerable breadth and effectiveness. While defense and national security remain central concerns of this DNS, its activities now extend into every corner of the civilian economy.

CHANGES IN THE ORGANIZATION OF INNOVATION

Over the past twenty years, despite deep partisan conflicts and budgetary fluctuations, a quite elaborate Developmental Network State has emerged in the United States. One of the key mechanisms of this maturation has been organizational learning; officials within various agencies of the Federal government have learned from the ARPA model and have become effective at supporting and advancing new technologies. But the organizational learning has not been confined to the Federal government. Deep changes have also occurred at the state and local level, universities, Federal laboratories, and in the private sector itself.

The changes outside of the Federal government can only be touched on briefly here, but the basic idea is that commercializing new technologies has become a major preoccupation of university administrators, Federal lab administrators, and networks of state and local economic development officials. When Herbert Boyer created Genentech in 1976, he was challenging the norms of the academic community. Thirty years later, the situation has reversed. An academic or Federal laboratory scientist who refuses to take action to commercialize his or her discovery is likely to be seen as deviant. Moreover, in many parts of the country, there are now networks of supportive institutions designed to help the scientist or engineer with the project of commercialization. These institutions provide technical, business, and moral support as well as network connections.

The two most relevant private sector changes have been the dramatic growth of private sector venture capital and shifting corporate strategies around innovations. The apparatus of private sector venture capital firms in the United States has grown enormously in recent years. These investors usually wait to support firms until they have developed a commercial prototype of a product. Nevertheless, founders of new firms recognize that if they can manage to get past that hurdle with a product with growth potential, they have a reasonable chance of attracting venture financing. Moreover, the venture firms have developed considerable expertise in nurturing and supporting new technology firms.[55]

Changing strategies—even in the largest corporations—means that many firms now pursue innovations through partnerships rather than primarily through their own laboratories. The model that began in the pharmaceutical industry where the largest firms seek partnerships in drug development with small, biotech start-ups has spread to many other sectors of the economy.[56]

Taken together, these shifts have radically changed the national innovation system in the United States. A generation ago, a large portion of innovations could be traced to the autonomous and self-financed work that went on in the laboratories of Fortune 500 companies. Now, however, most innovation occurs among networks of collaborators that cross the public-private divide. A snapshot of this shift can be seen by looking at the R&D 100 Awards.

For forty-five years, *R&D Magazine* has been recognizing the one hundred most innovative commercial products introduced in the previous year. In 1975, forty-seven out of eighty-six domestic innovations were produced by Fortune 500 companies, and forty of these involved no outside partners. By 2006, the big firms were responsible for only six out eighty-eight innovations, and in most cases, they had partners. In 2006, fifty of these innovations were the products of researchers at U.S. government laboratories, universities, or other public agencies, working alone or in collaboration with private firms. Another thirteen innovations came from "supported spin-offs," relatively new firms started by scientists or technologists that had received considerable Federal funding both before and after the firm's founding. Of the remaining twenty-five innovations that belonged to private sector organizations, at least another fourteen involved Federal dollars. In short, all but eleven of the prize winning innovations in 2006 depended on some public financing. Since these recognized innovations ranged over every sector of the economy, there is reason to believe that the pattern revealed in the awards reflects the broader trends in innovation in the U.S. economy.[57]

Another indicator of the importance of the government role has been provided in a recent analysis of the "valley of death"—the often daunting transition between a new scientific or engineering discovery and its successful transformation into a commercial prototype. Funds for Early Stage Technology Development (ETSD) that help firms through this valley are estimated to represent only between 2 percent and 14 percent ($5–$36 billion) of total R&D spending in the United States. The authors then calculate that Federal spending—across many different programs—account for 20–25 percent of these total ESTD outlays with another 6–7.5 percent coming from state governments and universities. Significantly, they argue that venture capital firms play a relatively minor role (2.3–8 percent), while the remaining funding comes from industry and "angels"—individual investors.[58]

By showing the relatively small amounts of funds that go to ETSD, this finding helps demonstrate that Federal programs that might spend as little as $50 million or $150 million per year could still be making a significant difference for overall rates of innovation. Moreover, the DNS also seeks to increase the efficiency with which ETSD funds are used. One means is to provide in-kind assistance such as access to the most sophisticated laboratory equipment and highly skilled technicians. Another is by effective technology brokering; helping to connect groups of scientists and engineers with other researchers who can provide important leverage for solving their problems.

MAPPING THE U.S. DEVELOPMENTAL STATE

While considerations of space make it impossible to describe all of the key agencies that play an important role in the U.S. developmental state, it is still important to provide some kind of overview of how this system works. By returning to the four key functions of a developmental network state, it is possible to identify some of the key locations within the Federal government where these activities are carried out.

Targeted Resourcing

ARPA continues to push technologists to overcome certain key hurdles. ARPA funds a variety of initiatives to advance supercomputing and to overcome the barriers that potentially limit the ability of semiconductor designers to double the number of circuits on a chip. But ARPA is also playing an active role in biological science and nanotechnology.[59] But ARPA initiatives have been copied from the early 1990s onward in the Department of Energy that has carried out hundreds of programs in collaboration with industry that focus on overcoming specific technological barriers.

One particularly ambitious and successful program involved partnering with General Electric and Westinghouse in the 1990s to develop a new generation of gas turbines to produce electricity with significant increases in efficiency and comparable decreases in pollution. The idea was to burn the gas at extremely high temperatures without melting the turbines themselves. DOE covered half the cost of this project and created at Georgia Tech University a new academic specialty focusing on the issues of constructing high temperature turbines.[60] This model is being used today to create collaborations between universities and industries to discover cost-effective techniques for turning agriculture waste products and fast growing weeds into ethanol.

The ATP at the National Institute of Standards of the Department of Commerce has elements both of resource targeting and opening windows. Proposals are reviewed for both their technological merits and their business potential. ATP has funded both smaller start-up firms and the largest corporations, sometimes working in consortia. For example, ATP worked with the big U.S. auto companies and their major suppliers in a multi-year initiative that was designed to make a significant improvement in the accuracy with which metal parts are machined.[61]

Similarly, the National Science Foundation and a wide variety of other government agencies have pursued a strategy that can be called micro-targeting. The core idea is to fund the creation of a university research center that is focused on a particular set of technological challenges. The funded university is then expected to build networks with other scholars doing related research and build connections with business firms with an interest in solving such problems.

As early as 1978, the National Science Foundation expanded a pilot program to create the Industry University Cooperative Research Centers program. NSF provides seed money for these centers with the expectation that they will find ongoing support from industry and other government agencies. A program for Engineering Research Centers was established in 1984 with more generous funding for the individual centers to cover large equipment costs. By 2007, NSF was supporting fifty of these Industry-University centers involving many universities and more than 500 cooperating business firms. For each dollar that NSF contributed, firms were providing $10 to keep these centers going. Moreover, a number of these NSF-originated centers had “graduated” and no longer received any NSF funding.[62]

These NSF programs provided other government agencies with a model of how to organize the collaboration among university-based researchers and multiple business firms. DOD and DOE followed this model when they were trying to accelerate the development of particular technologies. Moreover, Congress itself has funded many of these centers as part of the earmarking process; it is a way that members can deliver resources to their districts with the hope that centers might actually generate some economic development activity. While some of these fall squarely within the category of Congressional pork, others have proven to be productive.

Finally, an increasingly important form of targeting follows a model that ARPA used in the Strategic Computing Initiative. ARPA realized that the fabrication of computer chips represented a major bottleneck in the effort to design faster and more powerful chips. Since fabrication was costly and required elaborate equipment, it was difficult for outsiders to test their chip designs. So ARPA funded a lab called MOSIS, affiliated with the University of Southern California, which would fabricate at no charge a small number of chips from designs that were sent in via e-mail. This relatively small expenditure broke the logjam because start-ups and even graduate students could now pursue their ideas for radical new chip designs.[63]

So across the whole system, the government has been actively building sophisticated laboratories that can be used by scientists and engineers to attack particular types of problems. This strategy lies at the heart of the National Nanotechnology Initiative. Since working at the atomic or molecular level requires elaborate machinery and instruments, the government has built a series of nanotechnology laboratories at major universities with the idea that such laboratories would run experiments for technologists working both in nonprofit and for profit settings.[64] NIH is doing something similar in using its laboratories to test promising compounds that are submitted by researchers who lack the equipment to run such tests.[65] And increasing numbers of businesses—both small and large—are turning to the Federal laboratories for assistance because of the equipment and technological expertise that has been assembled there.[66]

OPENING WINDOWS

The most important and largest open windows are organized through the Small Business Innovational Research and the Small Business Technology Transfer programs.[67] The first provides funds to small businesses alone, and the second supports collaborations between small businesses and public researchers at universities or government laboratories. Both programs are organized as Federal set-aside programs. All of the government agencies that fund a significant amount of R&D are required to reserve a certain percentage of their budgets to fund initiatives by small business. The percentage started at a tiny .2 percent but was gradually raised to 2.5 percent in the 1997 Fiscal Year. Both programs involve Phase I and Phase II grants: the smaller Phase I awards of up to $100,000 support investigations into the feasibility of an idea, and then larger Phase II awards—up to $750,000—are designed to develop the idea into a prototype. (These are current funding levels; they have increased over time.) Phase III, the actual commercialization of the product, is to be financed outside of this program.

These awards do not have to be re-paid, and the small businesses retain full control of the resulting intellectual property. By 2004, the government was making 4,304 phase one awards and 2,044 phase two awards for total funding of $2 billion and another $200 million of SBTTR grants.[68] While the program is loosely coordinated by the Small Business Administration, the actual funding decisions are made within each of the eleven participating Federal agencies. A firm that is turned down by the Department of Defense can turn around and apply to NASA or the Department of Energy.[69]

Some agencies initially saw the set aside as an encumbrance on their capacity to spend research dollars.[70] After all, agencies like DOD and NASA were accustomed to working entirely in a top-down manner, but with SBIR, the agency has to choose among the proposals made by the grantees. However over time, it appears that most agencies have come to see considerable advantages to this program. It provides a kind of ear-to-the-ground through which agency personnel can stay abreast of what cutting edge researchers are doing. It also links the agency with firms that might be willing to take on tasks that existing contractors lack the interest or capacity to pursue. Finally, the program provides the obvious political advantage of a dispersed set of beneficiaries for the agency's research budget that has obvious advantages in discouraging Congress from cutting these funds.[71]

Most of the agencies involved now have an SBIR honor roll on their Web sites, where they list "success stories"—firms that got their start on a particular technology with SBIR funds from that agency. In some cases, these firms began as tiny start-ups and eventually grew into substantial firms, sometimes continuing to specialize as contractors for one or two agencies in particular. Moreover, many of the initiators of these new firms began, and sometimes continue to be, scientists or engineers employed in universities or government laboratories. Starting in the 1980s and continuing down to the present, there has also been increasing coordination between the SBIR programs and initiatives within the fifty states to encourage high technology growth. State governments have created networks of technology development programs that provide small business with advice about accessing the SBIR process as well as other forms of technical assistance.[72] Many states have also created public venture capital funds to invest resources in particularly promising businesses that have successfully maneuvered through the SBIR process. A survey in 2006 by the National Association of Seed and Venture Funds showed that forty-four states had invested $5.8 billion in venture capital funds with $2.2 billion still available for new investments.[73]

In recent years, there is a growing recognition that the SBIR program doesn't support firms long enough for them to bring new technologies to the marketplace.[74] A number of agencies have experimented with ways to provide funding in "Phase III." The most radical experiment began with the Central Intelligence Agency (CIA) in 1999 when it was given the green light to charter and fund its own not-for-profit venture capital firm called In-Q-Tel**.** According to its website, In-Q-Tel has invested in ninety different organizations that are developing new technologies that the agency needs.[75] The U.S. Army quickly followed this model, creating its own parallel organization called OnPoint in 2003, with an initial endowment of $25 million. OnPoint now includes ten small firms in its investment portfolio. NASA followed in 2006 with the creation of Red Planet Capital that plans to invest in the neighborhood of $20 million per year. The DOE has launched its venture capital fund in partnership with Battelle, the large nonprofit research organization that runs several of the DOE laboratories.[76]

But SBIR is not the only open window option. The decentralized network of state business development programs and technology incubators operate as a parallel set of windows, linking firms to SBIR and other Federal programs. Many of the Federal laboratories and university-industry research centers also operate as screening mechanisms where firms, large and small, that have successfully identified a relevant group of experts, can come to test ideas and possibly find collaborators. Finally, the Manufacturing Extension Program has worked through a highly decentralized network to provide thousands of small businesses with assistance in adopting new production technologies.[77]

BROKERING

Effective technology brokering that links scientists and engineers to others who have the ideas and techniques that they need to solve their problems is probably the most central developmental task, but it is notoriously difficult to increase the frequency with which such brokering activity occurs. The problem is that the universe of people with both sufficient technological understanding and broad enough networks is always small, and those people also tend to be very busy with multiple demands on their time. Nevertheless, the Federal initiatives have sought to expand the number of places where these critical brokering conversations might occur.

As suggested earlier, the program officers within the Federal agencies are one key locus, particularly those who are following the ARPA model of targeted resourcing. Such officials can use what they learn from reading proposals and research reports from a wide variety of laboratories to make key linkages. Many of them also organize periodic meetings of their grantees to exchange ideas to accelerate possible synergies. University researchers who are at the center of university-industry collaborative research centers are a second key locus. They are in a structural position where they can move key ideas from one part of the network to another. Third are some of the SBIR program officers at Federal agencies and the technology transfer officers at the larger Federal laboratories. If these individuals gain enough mastery over a particular technological area, they might be able to make some of these key connections. Fourth are the industry consortia that the Federal government has often supported, following the SEMATECH model that hope to bring together researchers from a range of different firms.

As for economic brokering, this is increasingly likely to occur both at the targeted agencies and at many of the open windows. It has always been part of the ARPA model to worry about the economic viability of enterprises, and as the ARPA model has spread to other agencies, so has the emphasis on economic brokering. Testimony from SBIR program officers suggest that many of them see their role as "public sector venture capitalists" who are trying to provide recipients with network connections to other government agencies, major government contractors, venture capitalists, or particular consultants who can provide needed managerial assistance.[78]

FACILITATION

Across many new technologies, the understudied National Institutes of Standards and Technology has performed critical work in establishing technical standards that have accelerated commercialization of new technologies.[79] And, as we have seen earlier, NIH and the FDA continue to play a key role in establishing public confidence in new medical technologies, although there have been increasing questions as to whether FDA has had sufficient independence from the firms that they are supposed to be regulating.

It is, however, in the larger scale forms of facilitation that the U.S. developmental state has proven weakest over the past twenty years. There are a number of significant cases where new technologies required considerable sponsorship at higher levels of government, but this did not happen, either because of the weight of market fundamentalist ideology, the power of entrenched corporate interests, or some combination of the two.

Probably the most dramatic failure has been the slow rate in the United States of transition of households to high speed, broadband connections to the Internet.[80] The decision in the United States to rely almost entirely on private firms and households to bear the cost of these connections has meant that the percentage of households with high speed connections has lagged behind the connectivity rates achieved by Japan, Taiwan, and a number of European nations as well. A recent Organization for Economic Co-operation and Development (OECD) report showed the United States falling to fifteenth place internationally after being in fourth place as recently as 2001. Moreover, the infrastructure being developed in other countries also allows for significantly higher speeds of connection and greater possibilities for later upgrading.[81]

Similar problems of high level facilitation are reported by Galperin in his study of high definition television in the United States. Both under George H. W. Bush and Bill Clinton, the government failed to get the various industry representatives to agree on standards that might have allowed the United States to leapfrog over the European and the Japanese in making the transition from analog to digital delivery of television signals. Had this effort been successful, the United States might once again have had an onshore industry for producing television receivers. As it happened, the United States will ultimately make a transition to high definition, but producers in other nations will reap many of the benefits.[82]

Energy conservation technologies tell a similar story. The single most egregious example has been the failure of the United States to emulate Japanese and French investments in high speed, passenger rail lines connecting major cities. The DOE has nurtured a wide range of energy-saving technologies, but there has been a long-term failure in the Executive Branch to expand the scale of these efforts enough to reduce the economy's dependence on fossil fuels. The Clinton Administration, for example, tried with the highly publicized Partnership for a New Generation of Vehicles to collaborate with the big auto firms to achieve major advances in fuel efficiency, but the initiative's results were disappointing.[83] And even this effort was canceled by the Bush Administration that has been ideologically opposed to major efforts to reduce the economy's dependence on oil and coal.

The U.S. health care system represents yet another example of this failure of facilitation. While the U.S. DNS is extremely successful at rolling out new medications and new medical instruments, translating these into improvements in public health has proven an elusive goal. The weakness of facilitation is reflected in the highly uneven quality of health care and steadily rising costs.

LIMITS OF THE HIDDEN DEVELOPMENTAL STATE

The dilemma in analyzing the U.S. developmental state is whether the proverbial glass is half empty or half full. The optimistic version emphasizes how remarkable it is that an institutional structure that is hidden or has developed against the current has had such a profound impact on the way innovation occurs in the economy. The pessimistic version stresses that because this institutional structure grew up in the shadows, it has deep flaws that limit its ability to support and accelerate desirable innovations. Five flaws are particularly significant.

1. Democratic deficit and ineffectual facilitation.

Since these developmental state activities are hidden, the whole system lacks democratic legitimation, and the public exercises little voice in determining the Federal government's R&D priorities.[84] Without public participation, the military and the national security apparatus continue to exert disproportionate influence on the direction of technological advance. Similarly, certain entrenched corporate interests have been able to put their needs ahead of the public interest. The relatively low level of DOE spending on alternative fuels relative to oil and coal based technologies is one example. Another is Federal support for the agrochemical industry to develop seeds that actually increase the use of chemical pesticides.

Moreover, during these thirty years of market fundamentalism, the idea that there is such a thing as the public interest has atrophied. This makes it very difficult for political leaders to frame arguments that certain policies will contribute to the common good. The result is a kind of structural bias against any significant domestic policy initiatives other than those that attempt to increase individual self reliance.

Without democratic legitimation and a vigorous concept of the public good, there is a real danger of a public backlash against the "triple helix" formed by the universities, business, and government. Elements of such a backlash are already present in a range of different social movements. It is obvious in the religious right's opposition to the teaching of Darwinian evolution and their successful campaign to limit Federal support for embryonic stem cell research. But it is also an element in the environmental movement's critiques of bioengineered organisms and widespread fears that manmade toxins are responsible for a rising share of human disease. The anti-science thrust of the current administration in its muzzling of climate scientists and its dissemination of misinformation on reproductive issues could be early indicators of an even more intense attack on science and technology by a future administration.[85]

But even putting aside the issue of potential backlash, the democratic deficit and atrophied notion of the public interest makes it very difficult for government to be effective at the more complex tasks of facilitation. In cases such as broadband Internet access, high definition television, and a number of large scale, energy saving technologies, there have to be coordinated investments by a range of different market participants. In these cases, government facilitation by investing in infrastructure, creating confidence among market participants, and helping them to coordinate the timing of their outlays, are indispensable.

But under the current circumstances, the U.S. government's capacity to perform those tasks is quite limited. It is not just that certain corporate interests have been able to exercise veto power on government action that challenges their entrenched position. It is also that the democracy deficit has left the Federal government with very limited reserves of legitimacy for anything beyond national security initiatives. If, for example, a newly elected U.S. president saw global climate change as a true emergency and was able to silence the entrenched energy firms, he or she would still encounter fierce opposition to a large scale program to address the problem. Almost thirty years of ideological claims that government is the problem and not the solution have taken a toll on public confidence in governmental initiatives.

2. Unstable funding.

To make matters worse, the hidden developmental state lacks a sound fiscal foundation. It grew up in a period when the ideas that the benefits of these Federal initiatives need to be shared with the public was either absent or marginalized. The problem is most obvious in the areas of biotechnology, where, despite huge Federal outlays to support the development of new drugs and new medical instruments, the firms that ultimately market these products have resisted any restrictions on their right to charge whatever the market will bear. Even when drugs have been explicitly developed under a Cooperative Research and Development Agreement with the government, there are no requirements for profit sharing or even limits on pricing.[86] But the problem is much more general. If it was DOE spending that helped GE and Westinghouse to develop a new generation of gas turbines, why aren't they paying a share of their profits on those turbines back to the public?

The problem is so serious because corporations have used the rhetoric of market fundamentalism to win continuous declines in the effective rate of taxation on corporate profits. So at the same time that profits are increasingly dependent on Federal R&D efforts, corporate tax effort has been declining. This puts the whole developmental state at continuous budgetary risk since Federal R&D spending must compete with all of the other claims on the Federal budget.

This particular problem could be solved relatively easily because the developmental state has repeatedly proven effective in creating vast amounts of private wealth. Google, for example, emerged out of academic research at Stanford that was funded by the National Science Foundation. A law requiring that Google and other firms that emerged with Federal support would be required to put 5 percent of their shares in a public sector trust fund would create a powerful mechanism for financing future DNS spending as well as other government programs.[87]

3. Commoditization of Knowledge.

The Developmental Network State in the U.S. has been shaped by the ideology of market fundamentalism in treating knowledge as nothing more than a commodity. This is the presumption that underlies an increasingly restrictive regime of "intellectual property rights" through which the government organizes and enforces private monopolies over certain types of knowledge both at home and abroad. But knowledge is not a commodity, and aggressive ownership claims threaten the open debate and discussion on which scientific communities depend.[88]

There are two deep problems that result from the commoditization of knowledge. First, it erects barriers to the inter-organizational research collaborations that are indispensable for technological advance.[89] Fear that one of the other collaborators might gain ownership of any knowledge that is produced can act as a powerful deterrent to launching such efforts. Second, when firms gain durable monopolies over certain avenues of technological development by virtue of patent or copyright protection, the result can slow further technical progress to a crawl.[90]

There are policy solutions that minimize these problems while also rewarding innovators for their breakthroughs. But in the United States, in the era of market fundamentalism, the policy regime has been heavily tilted in the other direction by the political influence of powerful incumbent corporations seeking to maximize the return on their intellectual property portfolios. For the Developmental Network State to achieve its full potential, significant reforms of the intellectual property regime are necessary.

4. Lack of Coordination.

The absence of coordination in the U.S. version of the DNS means that four different Federal agencies could be providing resources to five or six different groups of technologists to solve the identical problem without any of them knowing about the other's efforts. Some duplication of efforts is desirable, but only if different groups are able to learn from each others successes and failures. But an excessive lack of coordination and information sharing across agencies prevents such learning and makes it less likely that effective technology brokering will happen. Without strong coordinating mechanisms, agencies engage in turf warfare and unproductive forms of duplication, and it is difficult to establish serious government-wide priorities. It also leaves more room for various interest groups to colonize R&D budgets for their own particularistic ends.

Finally, without coordination, there is little in the way of systematic evaluation that compares the effectiveness of different DNS initiatives and allows program officers in one agency to learn from the successes and failures of other agencies. Despite all of the difficulties with evaluation procedures, they are still essential if the DNS is to have the capacity for self-correction and the ability to learn from its mistakes.

5. Low road labor practices.

Since it emerged in the epoch of market fundamentalism, the U.S. developmental state grew up with almost no attention to issues of labor in high technology industries. To be sure, policy makers concern themselves with the production of PhD scientists and engineers and facilitating the immigration of individuals with technological expertise. But virtually no attention is paid to the question of who will make the computer chips and other high tech products. It has simply been assumed that the market fundamentalist policies that have weakened labor unions, increased the use of contingent workers, and led to wage and benefit stagnation for production workers are desirable for all employers.

However, this is not the case. High technology production often requires higher levels of worker skill and new forms of cooperation between employees and management. Research has shown that "high road" management strategies often are often more effective in these settings than the "low road" alternative.[91] Moreover, as compared to its rivals in both Europe and Asia, the United States is unusual in how few public resources are devoted to creating the skills needed by high technology firms. Such firms are usually left to their own devices to recruit the set of skills they need.

In explaining the decision of U.S. firms to move production overseas, most discussion centers on labor costs. But since labor costs constitute such a small proportion of overall costs for high technology production, it is just as likely that some of these movements occur because of the greater availability of pools of trained production workers in some of these overseas locations. For example, U.S. firms, with government support, played a key role in developing the technologies that made possible the enormous growth of the market for flat panel displays. Nevertheless, production of these displays moved to South Korea and Taiwan where governments were not shy to help firms with the task of recruiting and training the necessary labor force of skilled workers.[92]

In short, the institutionalization of low road labor practices can make it harder for new high tech firms to attract the skilled labor force they need to ramp up production levels and also increases the likelihood that when the shift to large-scale production occurs, firms will move production overseas. The Manufacturing Extension Program that has grown steadily since the late 1980s has had successes in helping small firms train their employees and master cutting edge technologies. But with Federal funding of only about $100 million per year, the program is nowhere near the scale that is needed to impact labor force development for a high tech economy. The budgeting comes out to about $6 per manufacturing production worker nationally when it takes tens of thousands of dollars of investment in training to make significant increases in employee earnings.

Some of the United States' competitors use a tripartite system of cooperation among government, labor unions, and business to organize much larger investments in skill development for production workers. The United States' neglect of this key dimension of developmental policies is a major weakness that can undercut the effectiveness of its other initiatives.

CONCLUSION

This article has argued that legislative and executive branch decisions made in the U.S. between 1980 and 1992 significantly expanded the capacity of the U.S. state to accelerate technological development in the business economy. Since then, this capacity has grown into a highly decentralized Developmental Network State, and this DNS has transformed the way many businesses operate and has successfully focused a large cadre of publicly funded researchers on the task of turning new technologies into commercially viable products and processes. Essentially, Daniel Bell's postindustrial vision of a knowledge society built around government-university-industry has been largely realized.

The existence of this hidden developmental state has important political implications both domestically and internationally. The international implications are immediately apparent, but the domestic implications are potentially transformative and could ultimately have deep global ramifications.

The hidden developmental state in the United States suggests that developing nations have more room for active industrial policies than has generally been assumed. Within the WTO framework on Subsidies and Countervailing Measures, developing nations could use governmental R&D support to launch domestic startup firms that would initially produce for the home market and ultimately compete in overseas markets.[93] These start-ups could be structured as partially state-owned enterprises that raise capital from both public and private venture capital funds and international development banks. With appropriate technical and financial support from global aid agencies, complementary initiatives across the Global South could generate hundreds of thousands of new jobs and generate much needed foreign exchange.

More generally, this research highlights the deep disconnect between what the United States does at home and the economic policies that it has sought to impose on the rest of the world.[94] The constant message of the Washington Consensus has been that other nations must pull the government back from playing an active role in the economy. But as we have seen, the real Washington has become ever more deeply immersed in its own business economy through its technology policies. Moreover, U.S. foreign economic policy always insists that foreign governments must treat both foreign and domestic firms identically. Yet at home, the DNS is heavily focused on supporting domestic industries. Exposing this kind of systematic hypocrisy could and should empower those who are challenging Washington's market fundamentalist agenda.

Domestically, the Hidden Developmental State has critical implications because ever since the decay of the New Deal Democratic coalition in the 1970s, progressives in the United States have lacked a persuasive story of how an egalitarian and democratic turn in social and economic policies could assure prosperity for the nation. However, the pressing need to expand and reform the Developmental Network State creates an unprecedented opportunity for progressives to lead a transformation of U.S. politics.

This project would have four central emphases. The first would be creating a new partnership model for organizing and managing the relationship between business firms and government. Society would continue to invest heavily in measures to support business innovation, but firms would be expected to act as social partners to help achieve environmental protection, improved employee welfare, and the creation of more resilient communities. Within this framework, government would use a combination of carrots and sticks to discourage firms from using "low road" strategies of blocking effective regulation, lobbying to avoid a fair tax burden, or discouraging socially beneficial technologies.

This is hardly a utopian vision because the partnership already exists; U.S. firms are already heavily dependent on publicly provided resources to innovate. Thus far, however, market fundamentalist ideology has allowed business firms to escape the ordinary expectations of reciprocity between partners. The task facing progressives is to define and justify these expectations and develop a strategy that would gradually isolate those firms who insist on their right to behave badly.

The second emphasis would be on the need for policies of social inclusion to make a high technology society function effectively. It is essential to raise the level of technological literacy of the population so people can fulfill their tasks both as citizens and as employees and to expand the potential pool of technological innovators. This calls for improvements in the educational system, efforts to assure universal access to high- capacity, broadband Internet services, and significant new investments in programs for training and retraining employees. But all of these efforts will quickly confront the reality of deep poverty and racial division in U.S. society that leaves a significant segment of the population on the wrong side of the digital and educational divides. Hence, a major effort to eliminate poverty is required to overcome these divides and create the full social inclusion that is necessary for a high-functioning knowledge society.[95]

The third emphasis is on expanding the space for public deliberation on the direction of technological change. This is necessary to overcome the democratic deficit of the existing developmental efforts and to reduce the vested power of the military and entrenched industries. This broader participation in technological decision making would pave the way for a fairer system for financing the DNS, improved coordination of developmental initiatives, and significant improvements in the government's capacity for high level facilitation.

The final emphasis would be to redeploy U.S. research and development dollars away from military missions such as space-based weaponry towards initiatives that could address the global climate crisis and diminish disease, hunger, and lack of access to information in the developing world. While developmental initiatives in the United States gathered strength under the auspices of the military, these same tools can be used as part of an effort to redefine U.S. national security to focus on global cooperation and poverty reduction.

This agenda could both overcome the current weaknesses of the Developmental Network State in the United States and fundamentally realign U.S. politics. It would also open up new opportunities for activists around the world who have mobilized around the slogan: "Another World is Possible." It is far too late to have illusions that advanced technologies will by themselves reduce global poverty and diminish international conflict. But it is hardly utopian to imagine that new technologies in combination with the conscious and determined exercise of political agency can create another, better world for all of the world's people.

NOTES

1. Fred Block, "Understanding the Diverging Trajectories of Europe and the United States: A Neo-Polanyian Analysis," *Politics & Society* 35, no. 1 (2007): 1–31.

2. Evelyne Huber and John Stephens, *Development and Crises of the Welfare State* (Chicago: University of Chicago Press, 2001); Jonas Pontusson, *Inequality and Prosperity: Social Europe vs. Liberal America* (Ithaca: Cornell University Press, 2005). On rising insecurity in the United States, see Jacob Hacker, *The Great Risk Shift* (New York: Oxford 2006).

3. On developmental policies in Europe see Sean O' Riain's important study of Ireland—*The Politics of High-Tech Growth: Developmental Network States in the Global Economy* (Cambridge: Cambridge University Press, 2004). European efforts are also understudied, but see Thomas Lawton, ed., *European Industrial Policy and Competitiveness: Concepts and Instruments* (New York: St. Martin's, 1999); Jakob Edler, Stefan Kuhlmann, and Maria Behrens, eds., *Changing Governance of Research and Technology Policy: The European Research Area* (Cheltenham, UK: Edward Elgar, 2003). On the United States, the evidence will be provided in the body of the paper.

4. The argument here is an extension of Daniel Bell's pioneering work, *The Coming of Post-Industrial Society* (New York: Basic Books, 1973). See also Fred Block, *Postindustrial Possibilities: A Critique of Economic Discourse* (Berkeley: University of California Press, 1990). For an overview of the debate, see Howard Brick, *Transcending Capitalism: Visions of a New Society in Modern American Thought* (Ithaca: Cornell University Press, 2006).

5. For example, the European Community speaks openly about engaging in industrial policy, see http://ec.europa.eu/enterprise/enterprise_policy/industry/index_en.htm.

6. The best account is Kent Hughes, *Building the Next American Century: The Past and Future of Economic Competitiveness* (Washington: Woodrow Wilson Center Press, 2005). The most recent piece of legislation passed with little press coverage was the America COMPETES Act of 2007 that reconfigured some of the programs described below.

7. New York: Harcourt Brace and Jovanovic, 1980.

8. For the persistence of these legacies in Europe, see Stefan Berger and Hugh Compston, eds., *Policy Concertation and Social Partnership in Western Europe: Lessons*

for the 21st Century (New York: Bergahn Books, 2002). A comparison of the strengths and weaknesses of the United States and European developmental efforts is well beyond the scope of this paper, but I am arguing that the European efforts are more durably institutionalized.

9. The classic studies are Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy 1925–1975* (Stanford: Stanford University Press, 1982); Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization* (Princeton: Princeton University Press, 1990).

10. The key distinction between a Developmental Bureaucratic State and a Developmental Network State is elaborated in O'Riain, *Politics of High-Tech Growth.*

11. The use of the DNS is hardly exclusive to the United States and Europe as O'Riain argues, but the global diffusion of the DNS is beyond the scope of this paper.

12. Product and process innovations are closely intertwined, since finding markets for new products requires figuring out how to produce the new product at much lower cost. In the discussion that follows, "product innovation" should be read as shorthand for "product and process innovations."

13. The resources on which a DNS based are addressed in the literature on "national systems of innovation." See Richard Nelson, ed., *National Innovation Systems: A Comparative Analysis* (New York, Oxford University Press, 1993); Philippe Laredo and Philippe Mustar, eds., *Research and Innovation Policies in the New Global Economy* (Northampton, MA: Edward Elgar, 2001).

14. The early development of Silicon Valley provided the paradigm for this approach. Scientists and engineers both at Stanford and at large firms set out on their own to create a series of new firms to pursue promising technological ideas. Ever since, replicating Silicon Valley's success has become central to economic development strategies. On the history, see Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, MA: Harvard University Press, 1996); Martin Kenney, ed., *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region* (Stanford: Stanford University Press, 2000).

15. The concept of technological brokering is elaborated by Andrew Hargadon, *How Breakthroughs Happen: The Surprising Truth About How Companies Innovate* (Boston: Harvard Business School Press, 2003). See also Richard Lester and Michael Piore, *Innovation—The Missing Dimension* (Cambridge, MA: Harvard University Press, 2004). Hargadon's emphasis on the incremental sources of "breakthroughs" is also elaborated in John Alic, David Mowery, and Edwards Rubin, *U.S. Technology and Innovation Policies: Lessons for Climate Change* (Arlington, VA: Pew Center for Global Climate Change, 2003).

16. Peter Evans, *Embedded Autonomy: States and Industrial Transformation* (Princeton: Princeton University Press, 1995).

17. Richard Bingham, *Industrial Policy American Style: From Hamilton to HDTV* (Armonk, NY: M. E. Sharpe, 1998); Hughes, *Building the Next American Century.*

18. The tension is an important theme in Frank Dobbin, *Forging Industrial Policy: The United States, Britain, and France in the Railway Age* (New York: Cambridge University Press, 1994).

19. John Alic, *Trillions for Military Technology: How the Pentagon Innovates and Why It Costs So Much* (New York: Palgrave Macmillan, 2007). The importance of the military in biotechnology is elaborated by Shelley Hurt, "Patent Law, Biodefense, and the National Security State, 1945–1972," paper presented at the International Studies Association Conference, March 2006.

20. The agency's name shifts a number of times between ARPA and DARPA (Defense Advanced Research Projects Agency) as later administrations sought to emphasize the defense mission. For simplicity, it will be referred to consistently as ARPA here.

21. On ARPA, I have relied heavily on Alex Roland with Philip Shiman, *Strategic Computing: DARPA and the Quest for Machine Intelligence 1983–1993* (Cambridge, MA: MIT Press, 2002). See also National Research Council, Committee on Innovations in Computing and Communications, *Funding a Revolution: Government Support for Computing Research* (Washington, DC: National Research Council, 1999); Glenn Fong, "ARPA Does Windows: The Defense Underpinnings of the PC Revolution," *Business and Politics* 3, no. 3: 213–237; Nathan Newman, *Net Loss: Internet Prophets, Private Profits, and the Costs to Community* (University Park, PA: Pennsylvania University Press, 2002).

22. The now classic discussion of the limitations of the basic/applied science distinction is Donald Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington: Brookings, 1997).

23. For a similar mapping of the agency's procedures, see William Bonvillian, "Power Play: The DARPA Model and U.S. Energy Policy," *The American Interest* II, no. 2 (November-December, 2006): 39–48.

24. Sheldon Krimsky, *Genetic Alchemy: The Social History of the Recombinant DNA Controversy* (Cambridge, MA: MIT Press, 1982); Susan Wright, *Molecular Politics: Developing American and British Regulatory Policy for Genetic Engineering, 1972–1982* (Chicago: University of Chicago Press, 1994).

25. Steven Collins, *The Race to Commercialize Biotechnology: Molecules, Markets and the State in the United States and Japan* (New York: RoutledgeCurzon, 2004). The *NIH Guide for Grants and Contracts* is available at http://grants.nih.gov/grants/guide/historical/index.html#1976.

26. Krimsky, *Genetic Alchemy*; Wright, *Molecular Politics.*

27. Collins, *Race to Commercialize,* 100.

28. Walter W. Powell, Douglas R. White, Kenneth W. Koput, and Jason Owen-Smith, "Network Dynamics and Field Evolution: The Growth of Interorganizational Collaboration in the Life Sciences," *American Journal of Sociology* 110 (2005): 1132–1205.

29. Hughes, *Building the Next American Century.*

30. Otis Graham, Jr., *Losing Time: The Industrial Policy Debate* (Cambridge, MA: Harvard University Press, 1992). Graham makes clear that since Japan was the model, industrial policy advocates were generally calling for a DBS—a centralized effort to jump start new industries.

31. Hughes, *Building the Next American Century.*

32. Some of these initiatives grew out of a Domestic Policy Review that the Carter Administration completed in October 1979. James Turner, "The Next Innovation Revolution: Laying the Groundwork for the United States," *Innovations* (Spring 2006): 123–144.

33. For a similar list, see Sheila Slaughter and Gary Rhoades, "The Emergence of a Competitiveness Research and Development Policy Coalition and the Commercialization of Academic Science and Technology," in *Science Bought and Sold,* eds. Mirowski and Sent, 69–108. Slaughter and Rhoades point out that most of the relevant pieces of legislation passed with large bipartisan majorities.

34. Robert A. Lowe, David C. Mowery, and Bhaven N. Sampat, *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer before and after the Bayh-Dole Act in the United States* (Stanford: Stanford Business Books, 2004).

35. Josh Lerner, “The Government as Venture Capitalist: The Long-Run Impact of the SBIR Program,” *The Journal of Business* 72, no. 3 (July 1999): 285–318.

36. Ernest Steinberg, *Photonic Technology and Industrial Policy: U.S. Responses to Technological Change* (Albany: SUNY Press, 1992).

37. On both ATP and MEP, see Paul Hallacher, *Why Policy Issue Networks Matter: The Advanced Technology Program and the Manufacturing Extension Program* (Lanham, MD: Rowman and Littlefield, 2005).

38. Erik Pages, *Responding to Defense Dependence: Policy Ideas and the American Industrial Base* (Westport, CT: Praeger, 1996). See also Hallacher, *Policy Issue Networks.*

39. Glenn Fong, “Breaking New Ground or Breaking the Rules: Strategic Reorientation in U.S. Industrial Policy,” *International Security* 25, no. 2 (August 2000): 152–186.

40. Roland, *Strategic Computing.*

41. Pages, *Responding to Defense Dependence*; Corey, E. Raymond, *Technology Fountainheads: The Management Challenge of R&D Consortia* (Boston, Harvard Business School Press, 1997); Fong, “Breaking New Ground”; Andrew P. Cortell, *Mediating Globalization: Domestic Institutions and Industrial Policies in the United States and Britain* (Albany, SUNY Press, 2006).

42. The mission statement is cited in Fong, “Breaking New Ground,” 175–176.

43. Daniel Kevles, “Out of Eugenics: The Historical Politics of the Human Genome,” in *The Code of Codes: Scientific and Social Issues in the Human Genome Project*, eds. Daniel Kevles and Leroy Hood (Cambridge, MA: Harvard University Press, 1992), 3–36. To be sure, NIH is still criticized for not engaging in enough targeted research. See, for example, Robert Cook-Deegan, “Does NIH Need a DARPA ?” *Issues in Science and Technology* 13, no. 2 (Winter 1996): 25–29.

44. Among the most important early studies have been Martin Kenney, *Biotechnology: the University-Industrial Complex* (New Haven: Yale University Press, 1986); National Research Council, Committee on Science, Engineering, and Public Policy, *The Government Role in Civilian Technology: Building a New Alliance* (Washington: National Academy Press, 1992); John Alic, Lewis Branscomb, Harvey Brooks, Ashton Carter, and Gerald Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston, MA: Harvard Business School Press, 1992). More recently, Glenn Fong has made important contributions that have already been cited here. See also, the work of Henry Etzkowitz, particularly, “Innovation in Innovation: The Triple Helix of University-Industry-Government Relations,” *Social Science Information* 42, no. 3 (2003): 293–337.

45. Block, “Diverging Trajectories.”

46. Fields went on to be the chief executive at SEMATECH, so he continued to play a critical role in diffusing the ARPA approach to technology commercialization.

47. John Markoff, “Pentagon’s Technology Chief is Out,” *New York Times*, April 21, 1990.

48. For an amusing account of Democratic efforts to build support among Silicon Valley businesses in the 1990s, see Sara Miles, *How to Hack a Party Line: The Democrats and Silicon Valley* (Berkeley: University of California Press, 2001).

49. See, for example, Robert Pear, “Applying Breaks to Benefits Gets Wide GOP Backing,” *New York Times,* January 9, 2005.

50. For more information and funding levels, see http://www.nano.gov.

51. Clyde W. Crews Jr., “Washington’s Big Little Pork Barrel: Nanotechnology,” Cato Institute Web page, May 29, 2003 at http://www.cato.org/pub_display.php?pub_id=3110.

52. For an account of the Clinton plan, its fate in Congress, and the eventual retreat from the public investment agenda, see James Shoch, "Bringing Public Opinion and Electoral Politics Back In: Explaining the Fate of 'Clintonomics' and Its Contemporary Relevance," *Politics & Society* 36: 1(2008): 89–130.

53. These conflicts are described in Hughes, *Next American Century* and Hallacher, *Networks Matter.*

54. Hughes, *Next American Century.* In the absence of OTA, the work of evaluating these governmental initiatives has been taken up by the National Academies of Sciences that has produced a valuable stream of reports about the various programs described here.

55. On venture capital firms, see Paul Gompers and Josh Lerner, *The Venture Capital Cycle*, 2nd ed. (Cambridge, MA: MIT Press, 2004). On the reluctance of venture capital to support firms at the early stage, see Philip Auerswald and Lewis Branscomb, "Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States," *Journal of Technology Transfer* 28 (2003): 227–239.

56. On the shift to "networked" firms, see Walter Powell, "The Capitalist Firm in the Twenty-First Century: Emerging Patterns in Western Enterprise," in *The Twenty-First Century Firm: Changing Economic Organization in International Perspective*, ed. Paul DiMaggio (Princeton: Princeton University Press, 2001), 35–68; Raymond Miles, Grant Miles, and Charles Snow, *Collaborative Entrepreneurship: How Communities of Networked Firms Use Continuous Innovation to Create Economic Wealth* (Stanford: Stanford University Press, 2005).

57. Results of an analysis of the R&D Awards over the last four decades are presented in Fred Block and Matt Keller, "Where Do Innovations Come From?" unpublished paper.

58. Auerswald and Branscomb, "Valleys of Death."

59. While some of its programs are top secret, others are discussed with some detail on its Web site, http://www.darpa.mil.

60. On the advanced turbine project, see Vicki Norberg Bohm and Robert M. Margolis, "Reaching Environmental Goals Through R&D Collaboration: Lessons from the U.S. Department of Energy Programs for Gas Turbines and Photovoltaics," *Industrial Transformation: Environmental Policy Innovation in the U.S. and Europe*, eds. Theo de Bruijn and Vicki Norberg Bohm (Cambridge, MA: MIT Press, 2005), 147–173; Mike Curtis, "United States: Advanced Turbine System," *Innovation in Energy Technology: Comparing National Innovation Systems at the Sectoral Level*, OECD (Paris: OECD, 2006), 295–317.

61. Information is available at http://www.atp.nist.gov. See also, Hallacher, *Policy Networks Matter.*

62. Http://www.nsf.gov/eng/iip/iucrc. See also, Etzkowitz, "Innovation in Innovation," and Steinberg, *Photonics.*

63. This is reported by Roland, *Strategic Computing.*

64. For a listing of the university-based centers funded under the National Nanotechnology Initiative, go to http://www.nano.gov/html/centers/nnicenters.html.

65. For example, the National Cancer Institute has a program called Rapid Access to NCI Discovery Resources, see http://dtp.nci.nih.gov/docs/rand/rand_index.html.

66. The scale of this support activity by government funded laboratories is impressive. In 2006, the Department of Energy laboratories alone accounted for 2,416 Work-for-Others Agreements, in which they did research for other agencies and private firms. In addition, they also had 3,474 active user facility agreements in which outsiders were permitted to use laboratory resources. See *Report on Technology Transfer,* Office of Policy and International Affairs, U.S. Department of Energy, March 2007. http://www.llnl.gov/IPandC/news/specialreports/FY2006AnnualReportonTTfinal.pdf.

67. While the SBIR program was passed by Congress in 1982, the program began as a pilot program of NSF during the Carter Administration, see Turner, “Next Innovation Revolution.”

68. Data are from http://www.sba.gov/SBIR/indexsbir-sttr.html#sbirstats.

69. On SBIR and STTR, see Scott Wallsten, “Rethinking the Small Business Innovation Research Program,” *Investing in Innovation: Creating a Research and Innovation Policy that Works*, eds. Lewis Branscomb and James Keller (Cambridge, MA: MIT Press, 1998), 194–220; Josh Lerner, “The Government as Venture Capitalist: The Long Run Impact of the SBIR Program,” *The Journal of Business* 72, no. 3 (July 1999): 285–318; Charles Wessner, ed., *SBIR and the Phase III Challenge of Commercialization: Report of a Symposium* (Washington: National Research Council, 2007).

70. Wallsten, “Rethinking.”

71. However, it has been a persistent problem that 40 percent of all SBIR grants go to California and Massachusetts—the nation’s leading technology centers, Lerner, “Government as Venture Capitalist.”

72. Christopher Coburn and Duncan Brown, “State Governments: Partners in Innovation,” in *Investing in Innovation*, eds. Branscomb and Keller, (Cambridge, MA: MIT Press, 1999), 422–437; Maryann P. Feldman and Maryellen R. Kelley, “How States Augment the Capabilities of Technology-Pioneering Firms,” *Growth and Change* 33, no. 2 (2002): 173–195.

73. See http://www.nasvf.org.

74. Wessner, ed., *SBIR and the Phase III Challenge.*

75. See http://www.inqtel.org.

76. For OnPoint, go to http//www.onpoint.us. On NASA, see Liz Moyer, “Venture Capital’s Space Shot,” *Forbes,* February 21, 2006 at http//www.forbes.com/2006/02/21/nasa-venture-capital-cx_Im_0221redplanet.html. Battelle Ventures is described at http://www.battelleventures.com

77. On MEP, see Hallacher, *Policy Networks Matter;* Josh Whitford, *The New Old Economy: Networks, Institutions and the Organizational Transformation of American Manufacturing* (Oxford: Oxford University Press, 2005).

78. Wessner, ed., *SBIR and the Phase III Challenge.*

79. The key sources are periodic evaluations by the National Academies. See, for example, National Research Council, *An Assessment of the National Institute of Standards and Technology Measurement and Standards Laboratories: Fiscal Years 2004–2005* (Washington: National Academies Press, 2006).

80. Even larger are the problems with the U.S. health care system. The failure to turn medical advances into improved health outcomes is another case of failed facilitation. See John Alic, “Postindustrial Technology Policy,” *Research Policy* 30 (2001): 873–889.

81. S. Derek Turner, “Shooting the Messenger—Myth vs. Reality: U.S. Broadband Policy and International Broadbank Rankings,” *Freepress*, July 2007 at http://www.freepress.net/docs/shooting_the_messenger.pdf.

82. Hernan Galperin, *New Television: Old Politics: The Transition to Digital TV in the United States and Britain* (Cambridge, Cambridge University Press, 2004).

83. Daniel Sperling, “Public-Private Technology R&D Partnerships: Lesson from U.S. Partnership for a New Generation of Vehicles,” *Technology Policy* 8 (2001): 247–256.

84. Arguably, the major exception is the funding priority that Congress and the White House have given to biomedical research. But even in that case, business interests and university-based bioscientists tilt spending towards finding magic bullets rather than improving the delivery of health care.

85. Chris Mooney, *The Republican War on Science* (New York: Basic Books, 2005).

86. One of the most notorious cases is the cancer drug Taxol. See Vivien Walsh and Jordan Goodman, "Cancer Chemotherapy, Biodiversity, Public and Private Property: The Case of the Anti-cancer Drug Taxol," *Social Science and Medicine* 49 (1999): 1215–1225. The General Accounting Office reported in 2003 that NIH received $35 million in royalty payments for Taxol, but Medicare alone had paid $500 million for Taxol treatments. U.S. General Accounting Office, *Technology Transfer: NIH-Private Sector Partnership in the Development of Taxol*, June 2003.

87. John Battelle, *The Search* (New York: Penguin Books, 2005). The idea of a "share levy" has been advocated by Robin Blackburn as a means to restore progressivity to the tax system, "How to Tax the Rich and Live Happily Ever After," *Dissent* (Summer 2007): 63–67. The idea makes even more sense in the framework of a DNS.

88. For the argument that knowledge is a "fictitious commodity," see Fred Block, "Towards a New Understanding of Economic Modernity," *The Economy as Polity: The Political Constitution of Contemporary Capitalism* (London: UCL Press), 3–16; Sean O'Riain, "Time-Space Intensification: Karl Polanyi, the Double Movement, and Global Informational Capitalism," *Theory and Society* 35: 5–6 (December 2006): 507–528. For a powerful critique of the commoditizing of knowledge, see Yochai Benkler, *The Wealth of Networks* (New Haven: Yale, 2006).

89. Hargadon, *How Breakthroughs Happen.*

90. For example, the antitrust suit against Microsoft in the 1990s arose out of fears that the firm would be able to control future technological development in the entire industry. David Bank, *Breaking Windows: How Bill Gates Fumbled the Future of Microsoft* (New York: Free Press, 2001).

91. Eileen Appelbaum, Thomas Bailey, Peter Berg, and Arne Kalleberg, *Manufacturing Advantage: Why High-Performance Systems Pay Off* (Ithaca: ILR Press, 2000).

92. This argument is speculative. For a careful account of the movement of flat panel production to Asia, see Thomas Murtha, Stephanie Lenway, and Jeffrey Hart, *Managing New Industry Creation: Global Knowledge Formation and Entrepreneurship in High Technology* (Stanford: Stanford University Press, 2001). While they stress the centrality of learning by doing in the competition to produce flat panel displays, they do not explore the government's role in work force training in Korea and Taiwan.

93. Elements of this strategy are described in Andrew Schrank and Marcus Kurtz, "Credit Where Credit is Due: Open Economy Industrial policy and Export Diversification in Latin America and the Caribbean," *Politics & Society* 33:4 (2005): 671–702.

94. See Ha-Joon Chang, *Kicking Away the Ladder: Development Strategy in Historical Perspective* (London: Anthem, 2002); Linda Weiss and Elizabeth Thurbon, "The Business of Buying American: Public Procurement as Trade Strategy in the USA," *Review of International Political Economy* 13:5 (2006): 701–724.

95. For a strategy to end poverty, see Fred Block and Jeff Manza, "Could We End Poverty in a Postindustrial Society?: The Case for a Progressive Negative Income Tax," *Politics & Society* 25:4 (1997): 473–511.

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