Country Study: USA

William B. Bonvillian | Suzanne Berger | Thomas Kurfess

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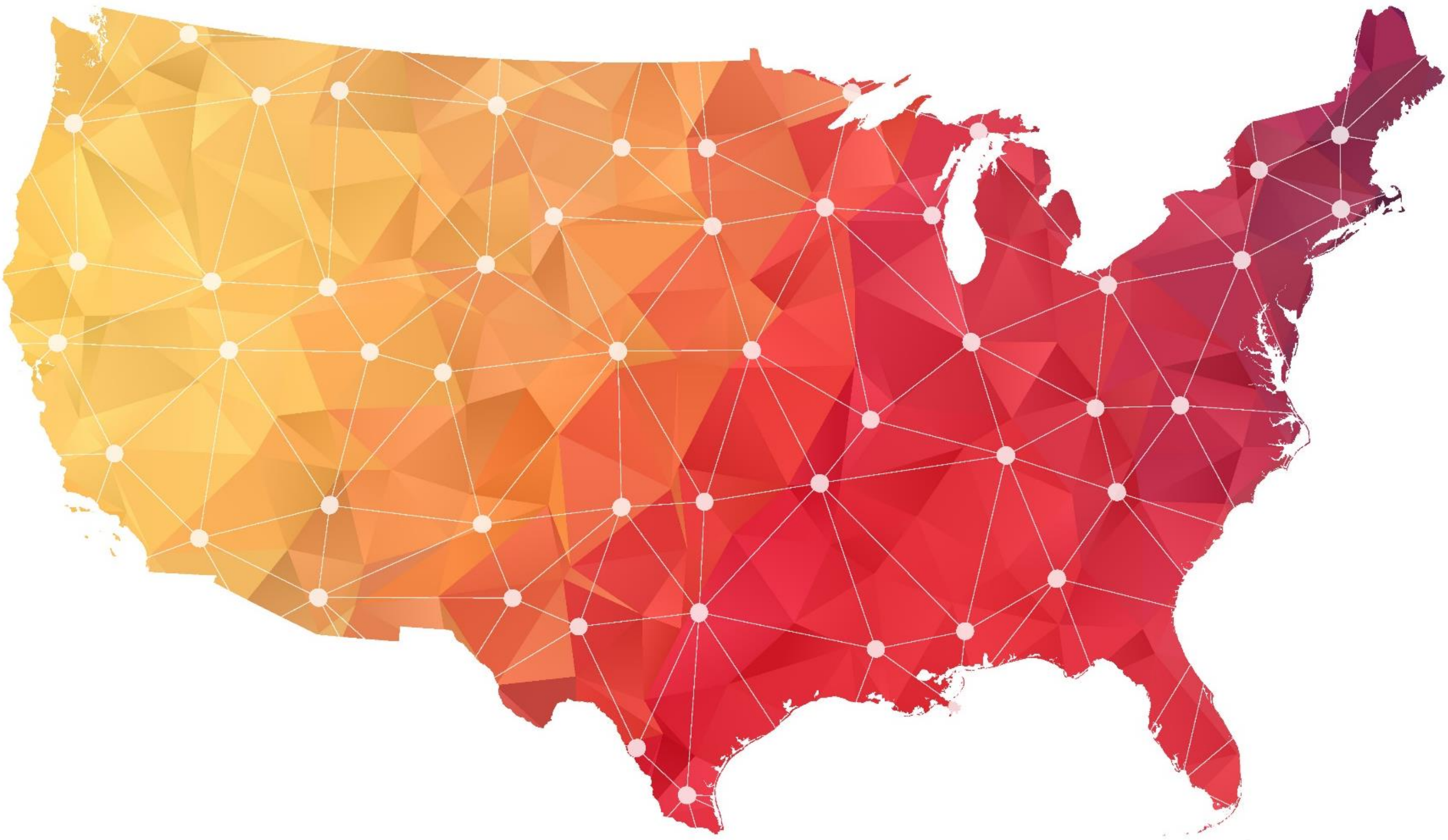

Cambridge Industrial Innovation Policy

Contents

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Introduction

Overall, the United States (U.S.) rated well in international indexes of innovation, competitiveness, and entrepreneurship performance, despite growing international competition, as illustrated in Table 1, below. The results vary based on the emphasis different indexes give to different categories of inputs as well as different ways of applying data, so are not consistent across the different reports. But overall, although its leadership has been in some decline in each of these three areas, it continues to be one of the world leaders in each.

Box 1. U.S. performance in Innovation Related Indexes[1]

Index	Ranking	Description	Comment on China's Position
Innovation			
GII - Global Innovation Index	3 (of 132)	81 indicators are grouped into 7 pillars (Institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology output, and creative outputs), as well as 21 sub-pillars. The GII is published by WIPO in partnership with the Portulans Institute, the Confederation of Indian Industry (CII), the Brazilian National Confederation of Industry (CNI), Ecopetrol (Colombia), and the Turkish Exporters Assembly (TİM).	The U.S. is rated the third most innovative economy in the 2021 Index. It shows strengths, particularly in categories of market sophistication, business sophistication, and knowledge and technology outputs. It has strengths in human capital and research, and creative outputs, but a lower ranking in infrastructure.
Bloomberg Innovation Index	11 (of 60)	Less comprehensive and open to analysis than the GII, it analyses numerous criteria using seven equally weighted metrics, including research and development spending, manufacturing capability and concentration of high-tech public companies. The index is prepared by Bloomberg drawn from various international data sources.	The U.S. dropped out of the top 10 innovators for the first time, with 7 of the top 10 listed from Europe. The US had problems in categories of productivity, and manufacturing capability and declining scores in higher education (in part because of gov't attitudes to int'l students) although it was the world leader in high-tech public companies and in patenting.

[1] Sources: EIS: See https://ec.europa.eu/info/research-and-innovation/statistics/performance-indicators/european-innovation-scoreboard_en#european-innovation-scoreboard-2021, GII: https://www.globalinnovationindex.org/Home ; Bloomberg: https://www.bloomberg.com/news/articles/2021-02-03/south-korea-leads-world-in-innovation-u-s-drops-out-of-top-10 and https://worldpopulationreview.com/country-rankings/most-innovative-countries; IMD: https://www.imd.org/centers/world-competitiveness-center/rankings/world-competitiveness/ , GCI 4.0: https://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf; GEI: http://thegedi.org/tool/ ; GEM;: https://www.gemconsortium.org/reports/latest-global-report

Competitiveness			
GCI (2019)	2 (of 141)	Global Competitiveness Index 4.0 measures national competitiveness—defined as the set of institutions, policies and factors that determine the level of productivity. The overall GCI 4.0 score is the average of the scores of the 12 pillars identified within the overall categories of enabling environment, human capital, markets and innovation ecosystem. In total, there are 103 indicators distributed across these 12 pillars. GCI's last full update in 2019 (there have been topical reports since then). The Index is prepared by the World Economic Forum and participating researchers.	US is ranked number 2 (it was ranked 1 in the last index). It performed particularly well in the innovation capability, business dynamism and financial systems pillars but faced declines in the human capital health pillar.
IMD World Competitiveness index	10 (of 63)	Based on statistics and survey the capacity of countries to create and maintain an environment which sustains the competitiveness of enterprises are ranked based on 255 criteria and categorized 20 sub-factors and in four main factors: Economic Performance, Government Efficiency, Business Efficiency and Infrastructure. The International Institute for Management Development (IMD) ihas centers in Switzerland and Singapore and its World Competitiveness Center is directed by Prof. Auturo Bris.	The US is rated number 10 in overall competitiveness, 1 in digital competitiveness, and 16 in talent rankings. It is ranked number 3 in economic performance, 27 in gov't efficiency, 12 in business efficiency, and 7 in infrastructure.
Entrepreneurship			
GEDI (2019)	1 (of137)	The Global Entrepreneurship Development Index GEDI is an index that measures the performance of entrepreneurship ecosystems in 137 countries with measurement grouped in 14 pillars. It was founded by entrepreneurship scholars from LSE, George	The US ranked no. 1 overall. It ranked 1 in the category of entrepreneurial attitudes (pillars: opportunity perception, start-up skills, risk acceptance and cultural support), 2 in entrepreneurial abilities (opportunity start-up, technology absorption, human capital and competition), and 2 in entrepreneurial aspirations

		Mason Univ., Univ. of Pecs, Imperial College London.	(product innovation, process innovation, high growth, internationalization).
GEM (2021)	3 (of 19 Level A economies for TEA)	The Global Entrepreneurship Monitor (GEM) is survey and expert interview-based, from research on entrepreneurship and entrepreneurship ecosystems world-wide. Among the indicators is TEA: "Total early-stage Entrepreneurial Activity". It was developed by academic teams from a number of nations, originated by Babson Univ. (US) and London Bus. Sch. (UK) researchers, and sponsored by the UAE Ministry of Economy and two others.	The US is no. 3 among Level A (developed) economies in the factor of Total Entrepreneurship Activity (TEA). Although a number of its scores were below other Level A economies, US entrepreneurs were found to be generally able to access financing options particularly in technology and digital media. The commercial and professional infrastructure category was strong as was legal and financial services accessible to entrepreneurs.

However, these categories of innovation, competitiveness, and entrepreneurship are by no means identical to the "*industrial innovation policy*" focus of this Babbage project. The above ratings generally capture U.S. strengths in creating strong international firms in the information technology and biopharma sectors, in research-based innovation capacity, and in forming entrepreneurial companies. However, they miss the industrial innovation challenges the U.S. faces such as in scaling up technologies into implementation and production, and in innovating in production technologies and processes.

The discussion below is focused on industrial innovation policy. If industrial policy entails the extent of the governmental role in various sectors of the economy, industrial innovation policy is particularly focused on the government's role in fostering innovation approaches within that industrial policy context. This includes its role in not only research but later stage development and implementation of technology innovations.

Organisations

DARPA and its Clones

DARPA is generally considered the most successful U.S. technology development agency and has been the model, for now, three other comparable U.S. agencies: ARPA-E in energy, IARPA in intelligence-related IT technologies, and the recently authorized and funded ARPA-Health. A number of countries have or are looking to the DARPA model, including the UK (ARIA), Germany (SPRIN-D), and Japan (Moonshot/advanced R&D). Because DARPA projects have led to numerous significant technological advances, it is a leading example of an institutional organization for industrial innovation policy.

Focus: The DARPA model for organizing innovation is distinct from other U.S. research and development agencies in its rejection of 'pipeline' and technology 'hand-off' approaches used by most agencies. Concerning the "pipeline," as an innovation organization, DARPA takes responsibility not simply for basic research at the beginning of the pipeline but seeks to bring about technological breakthroughs and nurture them toward final products. Using the concept of Technology Readiness Levels discussed above, DARPA operates across research stages, from basic research to applied research and advanced technology development, then connects to military procurement programs to implement its technologies. In contrast, other leading U.S, R&D agencies operate at the basic research level. Concerning "handoff," while other R&D agencies focus on making the initial research award through a committee-based peer review system, handing off an award to researcher applicants, DARPA places award responsibility on program managers not peer review. After awards, its program managers work in close collaboration with their research teams throughout the project, providing assistance and resources as it progresses toward a prototype.

Basic ruleset: At the heart of the DARPA ruleset is what one analyst has termed a technology visioning process. It uses a right-left research model – its program managers contemplate the technology breakthroughs they seek to have emerged from the right end of the innovation pipeline, then go back to the left side of the pipeline to look for proposals for the breakthrough research that will get them there. It uses a challenge-based research model – seeking research advances that will meet significant technology challenges. It looks for revolutionary breakthroughs that could be transformative in the technology sector. All of these elements go into a process where agency program managers develop a vision of a technology advance that could be transformative, then work back to understand the sequence of R&D advances required to get there. If these appear in a range of accomplishments, DARPA's administrative processes allow very rapid project approval by the agency's director and a prompt start. Strong program managers are the key organizational element in the agency and are empowered in their 4- to 5-year terms to develop a breakthrough technology concept, obtain signoff from DARPA's leadership, seek out and contract with the best technology development teams in the nation, whether at universities or industry, and create a technology prototype. The empowered program managers aim to select the best research groups for the work; DARPA has no labs of its own and has, as noted, no peer review process.

Other elements of the DARPA ruleset include:

- Small and flexible—DARPA consists of only 100 program managers and office directors; some have referred to DARPA as "100 geniuses connected by a travel agent."

- Flat—A flat, non-hierarchical organization, with empowered program managers.
- Entrepreneurial—Emphasis on selecting highly talented, entrepreneurial program managers, willing to press their projects toward implementation, often with both academic and industry experience. They serve for limited (3–5 years) terms, which sets the time frame for DARPA projects and assures that new ideas are always coming into the agency.
- Work with the researchers—Program managers aren't just involved in the initial research award, they work on an ongoing basis with their researchers to help them progress, linking them to resources, talent and ideas.
- No laboratories—Research is performed entirely by outside performers, with no internal research laboratory.
- Focus on impact, not risk—Projects are selected and evaluated on what impact they could make on achieving a demanding capability or challenge.
- Seed and scale—Provides initial short-term funding for seed efforts that can scale to significant funding for promising concepts, but with a clear willingness to terminate non-performing projects.
- Autonomy and freedom from bureaucratic impediments—DARPA operates outside the civil-service hiring process and standard government contracting rules, which gives it unusual access to talent, plus speed and flexibility in contracting for R&D efforts.
- Hybrid model—DARPA often puts small, innovative firms and university researchers together on the same overall project, so firms have access to breakthrough science, and researchers see pathways to implementation.
- Teams and networks—At its best, DARPA creates and sustains highly talented teams of researchers, that is highly collaborative and networked to be "great groups," around the challenge model.
- Acceptance of failure—DARPA pursues a high-risk model for breakthrough opportunities and is tolerant of failure if the payoff from potential success is high.
- Orientation to revolutionary breakthroughs in a connected approach: DARPA is focused not on incremental but on breakthrough/radical innovation. It emphasizes high-risk investment, moves from fundamental technological advances to prototyping, and then attempts to hand off the production stage to the armed services or the commercial sector.

Scale-up: A crucial question facing any APRA-like entity is how will its technology scale-up. DARPA's position within the Defense Department enables it to make use of the Department's major procurement budget to scale up and implement its prototype projects, and the DOD often becomes the initial market creator. Most of its technologies are "dual use" so have business sector applications, so spin-off is frequent. Alternatively, DARPA can launch its new technologies directly into the business sector if scale-up there is preferable, which is the way it launched most of its information technology-related technologies. DARPA in 2022 had a $3.8 billion budget.

Island-Bridge: DARPA reports, in effect, to the Secretary of Defense, so can call on the Secretary for help in having other parts of DOD implement its projects. DARPA is placed on an "island," protected from bureaucratic pressures, but it has a "bridge" to key decision-makers, particularly the Secretary, to enable the implementation of its technologies. This is key to its scale-up capability.

Technology Accomplishments: DARPA-backed R&D has led to major technological accomplishments in a series of fields, including: the internet, wireless transmission advances, microelectromechanical systems (MEMS), microprocessor advances, personal computing, supercomputing, the Global Positioning System (GPS), lightweight collaborative robotics, the "revolution in military affairs" (precision strike, stealth, and drones), synthetic biology, computer simulations and gaming for training, the driverless car challenge and development of mRNA.

Although DARPA is part of the U.S. Defense Department, the DARPA model has had extensive non-defense applications. Only a modest portion of its research is classified, so is accessible, and the great majority of its technological advances have had commercial sector applications, sometimes helping launch major technologies. The U.S. has successfully applied the DARPA model to energy technology development, through ARPA-Energy, which reports to the Secretary of Energy, as well as to information technology for intelligence through IARPA. It will now be applied to health technologies, through the new ARPA-Health, which has now been authorized and funded. Further application of the DARPA model outside of the defense may continue to prove relevant to policymakers.

Processes

Context: During the Second World War the United States built a substantial science and technology capability, adding this to its then world-leading, mass production-oriented, manufacturing industrial base. At the close of the war, seeking to retain some of this new capability, the President's science advisor (Vannevar Bush) recommended that the federal government pull away from its wartime support of applied research but support basic research. In addition, he recommended a single federal science agency (the National Science Foundation) to oversee and offer research awards. The first proposal for federal government backing of basic research was successful, which led to a network of federally-funded research universities, but the proposal for a single science organization, independent of other government agencies was unsuccessful.

Decentralized Science and the Problem of Cross-Agency R&D Coordination: These postwar decisions have played a significant role in determining the subsequent framework and processes for U.S. science and technology. The National Science Foundation was not created until 1950 and did not receive significant funding until the "Sputnik" crisis of 1957; in the interim, a plethora of R&D organizations either expanded or was created, generally attached to larger mission-based agencies. This meant that the U.S. would have decentralized science agencies independent of each other, where coordination across agencies would be difficult and complex. While an Office of Science and Technology Policy was created in 1976 within the White House for such coordination, as well as to provide the President with science advice, this office does not control science budgets so has had limited coordination authority.

The Problem of Technology Transition*:* In significant part due to the federal focus on basic research, as well as the decentralization of science policy, federal innovation policy has long faced a problem in the transition between research and the later stages of development into technology implementation. This "valley of death" has been a major subject of U.S. science and technology policy for some three decades. However, the U.S. Defense Department, when faced with the Cold War required both research and technology, has proved the exception to this general organizational rule. It has long supported a connected system for research, development, and innovation (RDI) that stretches from basic research support through technology market creation, while this generally has not been the case for science in non-defense sectors.

Increasing Mix of Frameworks: To summarize, against an overall framework of federal support for the research stage, as opposed to the applied and implementation stages, a growing series of exceptions have arisen. Thus, a separate framework has arisen for defense technology development, which has spilled over into extensive civilian economy benefits. In addition, modest programs that move further down the innovation pipeline past research into development, prototyping, testing and demonstration, and product development have arisen as pragmatic responses to policy challenges. These include programs in energy and manufacturing technologies. This provides us with three frameworks:

- The *standard model* and process for federal government industrial innovation, then, has been to support research, with the expectation that businesses would pick it up and undertake the follow-on stages.
- An alternative framework and process developed in the *defense sector* where the federal government supports research through product acquisition stages.

- Also, *additional frameworks and processes* have developed in response to policy challenges, particularly in the *energy* technology and *manufacturing* technology sectors. These are enumerated in the next section on Content.

Framework and Process "Owners": The agency owners that pursue the "standard" framework of basic research support include a mix of R&D agencies, the largest being the National Science Foundation (NSF), the National Institutes for Health (NIH), and the Office of Science at the Department of Energy.

The alternative applied Defense sector framework, of course, is dominated by the Department of Defense, with some additional involvement from the Department of Homeland Security. The Agriculture Department and NASA pursue a comparable applied approach, although at a much more limited scale.

Additional frameworks for a range of applied and implementation policies are "owned" by the Energy Department (including through its Energy Efficiency and Renewable Energy office, ARPA-E, energy innovation hubs, and technology transition office) and the Commerce Department (including through its National Institute for Standards and Technology (NIST)). Lately, manufacturing institutes are managed through three agencies, the Departments of Defense, Energy, and Commerce (through NIST).

All of these owners of the several frameworks generally must work in government-business sector collaborations in implementing most of the industrial policy approaches briefly summarized above. Although mission agencies exercise ongoing control of these frameworks with budgeting and the scope of their authority approved by Congress, new policy directions are set through the combined executive branch and Congressional action, with the White House Office of Management and Budget, National Economic Council, and Office of Science and Technology Policy playing a key role in executive branch policy overall development.

The U.S. has developed a standard description of the processes required to bring new technologies into markets at scale, known as "Technology Readiness Levels" (TRL). While basic research agencies largely operate at TRL levels 1 through 2, undertaking basic research and proof of concept work, applied agencies and programs move from those stages to TRL levels 4 through 7, from applied development to prototype demonstration. Implementation agencies, particularly at the Department of Defense, work at TRL levels 8 through 9 of actual system completion and deployment.

In summary, the U.S. has a complex mix of processes and frameworks that vary across agencies, generally falling into quite different defense and non-defense categories. The non-defense agencies tend to be limited to basic and early-stage development while defense agencies stretch to full implementation and creation of initial markets for new technologies. In recent years, however, as set out in Section 3 on Content, non-defense programs, like the defense programs, have increasingly included applied elements, moving down a pathway toward industrial innovation policies.

Content

The U.S. has long pursued industrial policies in various economic sectors, including transport infrastructure, health subsidies for the elderly and poor, energy infrastructure for hydropower, electrification, and nuclear power, and agriculture irrigation infrastructure and price supports. It has also pursued through its Defense Department advanced technology development to meet national security needs. However, U.S. policymakers have often faced ideological controversy over industrial policy approaches in the R&D area that extend beyond early-stage technology development, outside of defense and agriculture sectors. Generally speaking, as noted in the previous section, the federal government's R&D role in the postwar period in non-defense innovation has been to undertake the support of basic research and early-stage development, with an assumption that economically meritorious technologies would be taken up and implemented by the business sector.

As noted, the exception to this assumption about the federal role has been the U.S. Department of Defense (DOD) which has been willing to support the full panoply of technology development and implementation for defense-related technologies, from basic to applied research, prototyping, testing and demonstration, support for initial production and creation of the initial market for the new technology. The agriculture sector is another exception, where the government has supported applied research at "land grant" universities, extension programs to bring new practices and technologies to farmers, as well as infrastructure and price supports. However, the size of the agriculture interventions pales in comparison to the defense innovation system. In addition, the National Aeronautical and Space Administration (NASA) has similarly followed an industrial innovation pathway in its space missions, although these also are of much smaller scale and more limited focus than Defense efforts. Any evaluation of U.S. industrial innovation frameworks and processes has to account for these two different and parallel systems, defense and non-defense.

Defense: The Defense supports all stages of innovation, from research to market creation. led to the creation of major innovation waves in *aviation, electronics, space, computing, and the internet*. Each has its history and particular program elements, but the DOD role in initiating these fields was critical. While technologies developed in these areas were based on defense needs, they were often "dual use" with extensive spillover into the non-defense civilian economy.

Non-defense: While not without controversy, there have been industrial innovation policies In non-defense sectors, although far more limited than on the defense side. Major non-defense initiatives in the past two decades include:

- ***Competitiveness Period of the 1980s-1990s**:* When Japan out-competed the United States in industries such as autos, steel, consumer electronics, and machine tools, where U.S. companies had been leaders, a government response evolved. One cause for the U.S. competitiveness problems was seen to be the "valley of death," where too many newly-invented technologies failed to move past the research stage. As a result, a series of bridging mechanisms across this valley was developed for improving this transition in areas outside defense. These include the Bayh Dole Act, a system for vesting intellectual property rights from federal research in universities and researchers that perform the research; the Manufacturing Extension Partnership to bring "lean" manufacturing practices to small manufacturers; the R&D Tax Credit to encourage companies to undertake more R&D; the Small Business Innovation and Research Act to competitively award R&D funds to small firms for innovative technologies; and Sematech, a five-year program to recapture technology leadership in semiconductors.

- ***Energy Technologies***: Starting around 2000, significant efforts to support new energy technologies in light of the climate challenge emerged, adding additional program elements to the Department of Energy. The Department of Energy formed ARPA-E to spur breakthrough energy technologies; a loan program office for financing innovative new energy technologies; innovation hubs with public-private collaborations to focus on later-stage development of energy technologies; and a technology transition office to move the results of federal energy R&D into the business sector.
- ***Advanced Manufacturing***: Starting in 2012, the U.S. created sixteen manufacturing innovation institutes, as discussed in more detail in section 4 below, to promote the implementation of new manufacturing technologies and processes through government-business sector collaborations, with funding from three agencies. The institutes were competitively selected and obtained matching funding from industry and states. This program, known as Manufacturing USA, is still evolving with the most recent institute launched in November 2020, and funding for several more institutes pending. The program supports applied research at Technology Readiness Levels 4-7, including testing and prototyping, for new advanced manufacturing technologies and processes in collaborative efforts between industry and universities. The institutes also support workforce education for a skilled advanced manufacturing workforce.

In the last two years, the pace of industrial innovation policies has been accelerating, driven by three factors: technology competition from China, the need to accelerate new energy technologies because of climate change, and because of the pandemic. Recent industrial innovation policies, largely outside of continuing defense efforts, include:

- ***Operation Warp Speed*** led the development and distribution of vaccines, particularly the mRNA vaccines, for the coronavirus pandemic in 2020-2021, and is discussed in Section 4.
- ***The CHIPS Act*** was authorized in 2020 and funded in 2022 with $52 billion for R&D and production facilities for the semiconductor industry. Added to that were an additional $11 billion investment tax credit for new foundries and fabs and $200 million for semiconductor workforce education.
- ***The Innovation and Competition Act*** passed in 2022 (along with the CHIPS Act) authorizes applied R&D support for ten advanced technologies including artificial intelligence, quantum computing, robotics, and biotechnology. Support includes the creation of new applied university-industry development centers, testing and demonstration facilities, and regional innovation hubs for regional technology development efforts.
- ***Demonstration projects for new energy technologies*** passed in 2021 and provided $20 billion in funding for carbon management, clean hydrogen, renewable energy, and advanced nuclear technologies, as well as a new Energy Department technology demonstration office to support the effort.
- ***Assuring domestic supply chains*** is an Executive Branch-led effort for pharmaceuticals and ingredients, advanced batteries, critical minerals and materials, and semiconductors, and applies a range of tools from applied R&D to tax subsidies, expedited regulatory approvals, and use of federal procurement.

Good Practices

a) Operation Warp Speed

Background: Operation Warp Speed (OWS) was a 2020-21 partnership between the Department of Health and Human Services (HHS), the Department of Defense (DOD), and other health agencies to develop, manufacture, and distribute effective vaccines against Covid-19. It was a major public health effort, playing an important role in delivering hundreds of millions of doses of new vaccines that had never been approved and delivered before, in nine months, not a decade, saving millions of lives, both in the U.S. and worldwide. Operation Warp Speed was a governmental, cross-agency partnership, but directed at and with participation and collaboration with the business sector.

The role of the federal government in the development and delivery of vaccines against Covid-19 began with decades of investment in fundamental research in genomics and RNA by the National Institutes of Health (NIH) and at university research laboratories. The shift of this research into the private sector was powerfully assisted by DARPA funding for mRNA vaccine development at Moderna and other firms a decade ago. Without the large and long investment in basic research and the DARPA vaccine development support, Operation Warp Speed would not have been possible.

The Case: Operation Warp Speed (OWS) was a top-down effort by the federal government which selected a group of participating firms and then funded the dramatic acceleration of the late-stage development, production, and distribution of Covid-19 vaccines. It involved a number of innovation program features, outlined below:

Team: OWS was a strong cross-agency leadership group, including health research and regulatory agencies and the military, and was led by a former pharmaceutical executive fluent in both development and production and a U.S. Army logistics general. This group in turn interacted closely with industry teams, both for vaccine development and manufacturing. It relied on active, engaged companies. For the critical mRNA technology, there was committed leadership at Moderna and the Pfizer-BioNTech joint effort.

Portfolio approach: OWS surveyed over 100 pending vaccine projects, decided on four different types of vaccine technology platforms, some new like mRNA and others more established, then picked two companies to support each platform approach. So it developed a portfolio to manage the technology risk, selecting a range of technologies and firms.

OWS applied a series of tools for its industrial innovation approach:

> ***Guaranteed Contracts****:* Once the portfolio of firms was selected, OWS began targeting them with support. The Key was the issuance of contracts for the production of their vaccines even though the vaccines had not yet received emergency use approval from the FDA. The OWS concept was that further vaccine development and clinical trials would proceed in parallel to actual vaccine production so that doses would be ready for distribution as soon as they were approved.
>
> ***Flexible Contracting Mechanisms***: OWS made extensive use of "*Other Transactions Authority*" (OTA) first developed by DARPA and used by DOD agencies and offered a much faster and more

flexible way to contract, outside of the glacial processes of normal federal procurements. The *Defense Production Act* dates from the Korean War and allows the federal government in national emergencies to require suppliers to meet security needs, superseding other customers. It proved key to lining up supplies and resources for vaccine makers to avoid production delays.

Technology Certification*:* FDA's *Emergency Use Approval* (EUA) was another key to speed – FDA could use this approval to meet emergency health needs, as opposed to a full and permanent approval that often took years of reviews. This FDA step was vital: it amounted to certification and validation of the technology, assuring instant market acceptance.

Mapping Supply Chains*:* The Defense Production Act enabled OWS to intervene in supply chains, but the key to that was understanding every facet of relevant supply chains in depth. DOD had a strong emergency logistics capability and knew the importance of supply chain reliability and flexibility and how to map them. It helped the companies with these supply issues, working to manage the application of the Defense Production Act to get key supplies to vaccine makers but also to avoid disruption in other needed markets.

Integration of Federal Personnel with Companies*:* OWS put federal agency personnel into the companies to help them with the complex regulatory approval processes and also to assist with project management and supply access. The Army Corps of Engineers oversaw construction to expand company production facilities.

Distribution Systems*:* OWS took on the task of not only supporting the production of vaccines but also getting the doses shipped to states based on a state population-based formula. Considering that the two mRNA vaccines had to remain frozen and required complex special handling, the logistics were remarkable, with only a tiny amount of vaccine spoiled in shipment.

b) Tesla

Background: Government support for businesses is one of the most politically contentious issues in American policy debates. Opponents on all sides of the political spectrum claim that it provides an unfair advantage to one or a few companies and skews competition and generally, that government is unable to pick winners effectively. Nonetheless, the Department of Energy loan program provided Tesla, the first major electric vehicle maker, with major loan support approved in 2009 and available through 2013. In 2021, Tesla had a market value of $1.06 trillion, overshadowing the combined value of its five largest competitors. It had 2021 revenues of $54 billion and reported $5.6 billion in net income.

The Case: Tesla benefited from a large number of government support mechanisms. They represent an industrial policy approach, undertaken for a climate change mission of promoting electric vehicles (EVs)**.** Unlike the example above of Operation Warp Speed, the government's role was not top-down but instead, in creating a menu of incentives, was more bottom-up, relying on firms to come to the table. The government did not drive the creation of Tesla but created a series of incentives, loans, and regulatory elements that Tesla systematically used to help it overcome barriers and assume leadership in US electric vehicle production. These mechanisms include:

Early-Stage R&D Support - Department of Energy (DoE) R&D support early on for the *development of lithium-ion battery technology.*

Tax incentives to consumers for the purchase of electric vehicles. The EV tax credit was $7500 for consumer purchases of electric vehicles. It was initially created in the Energy Improvement and Extension Act of 2008 and later the American Clean Energy and Security Act of 2009. The tax credit currently only applies to the first 200,000 vehicles sold by a company, so Tesla cars no longer qualify. But, in effect, the cost of Tesla vehicles was reduced by $1.5 billion in federal subsidies to enable them to be more competitive. (There is pending legislation that could continue various incentives for electric vehicles).

Lending - Tesla received a $465.5 million Department of Energy *guaranteed loan* as part of the Advanced Technology Vehicles Manufacturing program (which it paid back in 2013) to build out its production factory in California. This loan helped rescue it from near bankruptcy.

Infrastructure support – the 2021 bipartisan Infrastructure law contains $7.5 billion for the deployment of half a million *charging stations* nationwide, mostly level 2 and DC fast charging ports. Tesla, as the leading US producer of EVs, would be a major beneficiary. Tesla has built its network of charging stations but would gain from this greatly expanded network.

***Subsidies* -** In total, Tesla has received about $2.4 billion in *subsidies* (not including the above-repaid bailout), including about $1.3 billion in benefits for their Nevada Gigafactory from Nevada, $750 million for its New York solar panel factory, and various other subsidies. Tesla laboratories have received about $3.6 million in subsidies and loan guarantees. Tesla has also obtained governmental support from nations where it produces including China and Germany, aside from the U.S.

State regulations and incentives - The state of California's *clean air regulations and incentives* have supported over time substantial subsidies for EVs, of particular benefit to Tesla. Federal environmental law has protected California’s ability to regulate emissions more strictly than federal law and has been protected by federal statute. An *Electric vehicle mandate and offset payment* program in California (and other states) enabled Tesla to obtain $428 million in offsets from other car makers to help finance its scale-up. In addition, California provided significant rebates to purchasers of electric vehicles.

***Federal applied for R&D and technology development support* –** A federal consortium with industry for advanced batteries, major past and upcoming support for advanced battery R&D, and a program to close battery supply chain gaps, have all provided direct and indirect support to Tesla.

In summary, at crucial stages of development and on an ongoing basis, government support for Tesla rescued it from bankruptcy, enabled it to build key production facilities, subsidized consumers to purchase its products, supported a massive upcoming build-out of charging station infrastructure, and supported advances in EV battery technology. Thus, the government (primarily federal but also state) has been an important supporting partner at every stage. It provides an ongoing example of industrial innovation policy.

c) Manufacturing Innovation Institutes

Background: The U.S. faced a 1/3 decline in its manufacturing workforce between 2000 and 2010. It has had low productivity growth in manufacturing over the past two decades compared with that of important foreign competitors, as well as low rates of capital investment. The ecosystem for manufacturing in many regions has declined as large firms cut back their domestic suppliers and reduced their expenditures on internal training, R&D, and support for local and regional workforce education. Although the U.S. has emphasized R&D-led innovation, other countries have supported the process and technology-based manufacturing innovation, including Germany, Japan, Korea, Taiwan, and now China.

Advanced manufacturing is the application of innovative technologies to improve manufacturing processes and products, adding significant value to the sector through productivity advances and innovation. Scientists and engineers indicate that a series of new advanced manufacturing paradigms may be in a range that could transform manufacturing efficiency, productivity, and returns, from advanced materials to AI and robotics.

The advanced manufacturing innovation initiative that emerged (now called Manufacturing USA) led to forming manufacturing innovation institutes, each focused on a single set of advanced technologies, for example, 3-D printing, robotics, technical fabrics, and photonics. It was a collaborative model bringing together industry, universities, and state and federal government started in 2012 and now includes 16 institutes with programs that reach nearly every state in new technology areas. Each of the institutes receives funding from industrial member participants, from state governments, and through one of three government agencies— the Departments of Defense, Energy, and Commerce.

The Case: The manufacturing institute model is neither top-down nor bottom-up, but collaborative, as noted above. The federal government initiated the effort through a competition for companies, universities, and states to form institutes, with federal funding cost-shared by companies and states. In turn, the institutes invite companies to participate in the institute's programs aimed at later-stage applied R&D, as well as workforce education.

Institute Model: The manufacturing institute model attempts to deal with the weaknesses in U.S. manufacturing by:

- Promoting collaboration among large firms as well as innovating smaller firms in the development and introduction of advanced technologies,
- Linking innovation and production through collaboration between firms, university laboratories, and state and federal government,
- Pursuing production innovations to grow efficiencies and productivity,
- Providing shared facilities for scale-up,
- Building a skilled workforce to implement and disseminate advanced production technologies into companies, and
- Developing collaboration between large and small firms in order to advance technological upgrading in SMEs.

The institutes have thus been trying to address key structural elements missing in the U.S. system. They do not replace traditional industry labs (which have experienced deep funding cuts over the past two decades), but supplement them, and aim to spur collaboration across firms on manufacturing technologies. They each received initial federal support from $50 to $70 million for their initial five years, cost-matched by industry and states at more than a one-to-one ratio.

d) DOE Advanced Manufacturing Office

Background: Over the past fifteen years, the U.S. Department of Energy has significantly reorganized from an agency focused largely on nuclear energy and supporting basic research in the physical sciences, to an agency increasingly focused on energy technologies needed for climate change. With this shift has come a host of new organizations, including an Advanced Manufacturing Office (AMO), with a mission not simply around R&D but the production of new energy technologies and decarbonization of the manufacturing sector. This office attempts to combine the top-down, bottom-up, and collaborative models noted above through a combination of program elements.

The Case: AMO supports R&D projects, R&D consortia, and technical partnerships with national laboratories, companies (for-profit and not-for-profit), state and local governments, and universities, through competitive, merit-reviewed funding opportunities designed to introduce new manufacturing technologies and processes. AMO seeks to drive energy productivity improvements by bringing together these organizations to identify challenges, catalyze innovations, to develop cutting-edge materials, with a process focus and incorporation of information technologies, for an efficient and competitive domestic manufacturing sector. Its mission stretches from R&D to technology implementation, embracing an industrial innovation policy approach.

In addition to its R&D and technology development grants noted above, its program elements include:

- ***Manufacturing Innovation Institutes*** – AMO supports seven manufacturing innovation institutes (see discussion in section c above), in the areas of smart manufacturing, chemical process intensification, remanufacturing, advanced composites, power electronics, critical materials, and cybersecurity. Institutes focus on technology development and workforce education.

- ***The National Alliance for Water Innovation*** – This consortium is made up of researchers and scientists in industry, academia, and national labs, alongside stakeholders in federal, state, and local governments, water users, entrepreneurs, investors, and advocacy groups. Its focus areas are process innovation and intensification, addressing novel, autonomous, and adaptable water systems. It also addresses process innovation for water desalination.

- ***Pilot and demonstration facilities*** – The *Manufacturing Demonstration Facility*, established in 2012, is one of the Department of Energy's designated user facilities focused on performing early-stage research and development to improve energy and material efficiency, productivity, and competitiveness for American manufacturers. It is located at DOE's Oakridge National Laboratory (ONRL) in Tennessee. The *Carbon Fiber Technology Facility*, established in 2013, is the Department of Energy's user facility for carbon fiber innovation, also located at ONRL. It identifies high-potential, low-cost raw materials, including textile, lignin, polymer, and hydrocarbon-based precursors for new composites. Industry and researcher users have access to both facilities.

- ***Engaging Small and Medium-Sized Manufacturers*** – AMO's Better Plants program is a voluntary partnership focused on significant energy efficiency improvements across energy-intensive industrial companies and organizations.

About us

Cambridge Industrial Innovation Policy (CIIP) is a global, not-for-profit policy group based at the Institute for Manufacturing (IfM), University of Cambridge. CIIP works with governments and global organisations to promote industrial competitiveness and technological innovation. We offer new evidence, insights and tools based on the latest academic thinking and international best practices.

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