JUNE 2020

Taking Stock of Government Involvement in Research and Development

Assessing Public R&D Effects

William Alan Reinsch, Jonathan Lesh, Lydia Murray, and John Hoffner

The public sector undoubtedly has a role to play in funding research and development (R&D). The more difficult questions to answer are: How much, when, and where should the government contribute? Looking historically and cross-nationally, what examples of successes and failures of government-funded projects can be found?

R&D funding, regardless of its source, expands the economy. In their 2009 paper, Hall, Mairesse, and Mohnen articulate two types of benefits from R&D: rent and knowledge spillovers.[1] Rent refers to the tendency for R&D-incorporated goods or services to be sold on the market at a price below their true value, as the value of R&D is often underassessed. Knowledge spillover points to the evolutionary nature of innovation, as basic research opens up new fields of discovery, which again demands further R&D funding. Their paper mentions a few case studies regarding various industries that estimate the social and private rates of return. These examples mention a perpetual annuity of $7 for each dollar spent on hybrid corn technology in the early-1900s and a 12 percent internal rate of return to poliomyelitis research. However, the authors stress that it is often difficult to quantify the full social returns on R&D given the infinite timeline for gains, although the full cost of R&D failures is also poorly understood.

In discussing impacts on productivity, the Congressional Budget Office states that:

1 Bronwyn H. Hall, Jacques Mairesse, and Pierre Mohnen, “Measuring the Returns to R&D,” National Bureau of Economic Research, Working Paper no. 15622, December 2009, http://www.nber.org/papers/w15622.

> R&D (as well as federal investment more generally) increases aggregate economic output mainly by gradually boosting private-sector productivity in the longer term. (Federally-funded R&D has other effects as well: It increases output in the short term by increasing overall demand for goods and services in the economy, and as part of its intended purposes, it produces public benefits that are not fully captured in measures of economic growth, such as improvements in life expectancy and public health.)[2]

Federal investment into R&D has spillover effects leading to greater business R&D and greater productivity, more employment, and increased competitiveness.3 Every federal dollar spent on R&D spurs an additional 30 cents of business R&D. Spending on R&D can also increase productivity. When firms increase R&D investment by 1 percent, their productivity increases by 0.05 to 0.25 percent, which translates to a 20 to 30 percent return on investment. Additionally, a 1 percent increase in R&D stock increases employment by 0.8 to 0.9 percent.

However, increased R&D funding is not a panacea; it can create more problems than it solves if improperly managed. R&D can lead to corporate favoritism and corporate capture, which can distort the market and crush innovation from smaller companies or competitors out of favor with the government. Governments can invest in the wrong programs, which generates two risks. First, political interests may make it difficult to change course, resulting in wasteful spending. Second, opponents with a broader agenda may seize on one bad project to sour spending on similar projects in the future, which would foreclose government investment in wide areas of the economy. As a result, well-intentioned R&D is not enough, and, as a guiding principle, innovation policy needs to be results-oriented.

White House R&D Budget Priorities

Annual White House R&D budget priorities offer one glimpse into how the U.S. government thinks about public R&D spending. The White House outlined its FY 2019 budget priorities regarding R&D in a memo.[4] Military and security R&D is prioritized, with the administration aiming to invest enough to maintain U.S. superiority in weaponry and to increase investment to combat cybersecurity threats. The White House also calls for research funding for projects that will lead to job creation and boost the economy, including autonomous systems, biometrics, energy storage, gene editing, machine learning, and quantum computing. The memo prioritizes energy and health technologies as key areas for R&D funding.

In order to support these research areas, the White House aims to increase the efficiency of government research spending, invest in early-stage and basic research projects, and improve interagency collaboration on R&D. The administration calls for improving access to technical training for U.S. workers so that the workforce can modernize with technology. The administration also voices a priority of working with updated research infrastructure.

Government R&D Versus Corporate R&D

Between government and corporate contributions, the United States has spent more than any other country on R&D for many decades. In 2017, the United States continued to lead spending at $483 billion, fol-

---

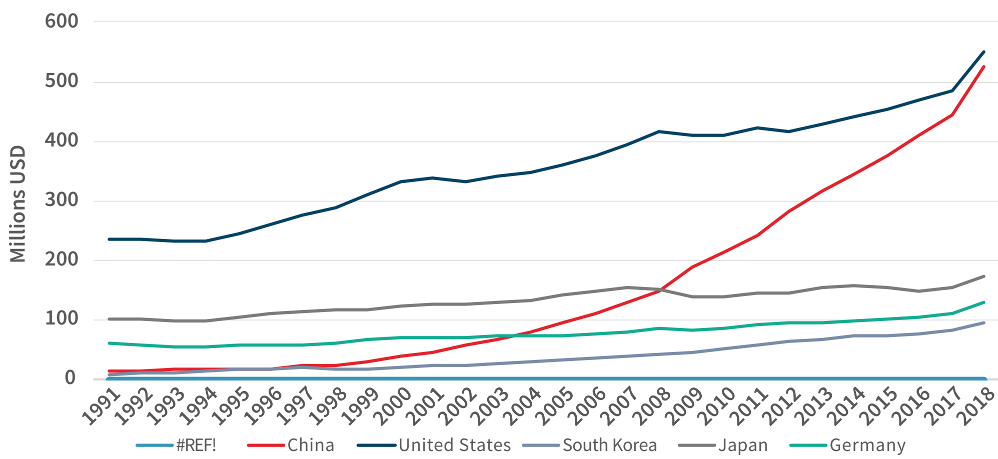
2 Congressional Budget Office, *The Macroeconomic and Budgetary Effects of Federal Investment* (Washington, DC: June 2016), https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/51628-Federal_Investment-OneCol.pdf.

3 J. John Wu, "Why U.S. Business R&D Is Not as Strong as It Appears," Information Technology & Innovation Foundation, June 2018, http://www2.itif.org/2018-us-business-rd.pdf.

4 Michael Kratsios and Michael Mulvanet, "FY 2019 Administration Research and Development Budget Priorities," Executive Office of the President, August 17, 2017, https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2017/m-17-30.pdf.

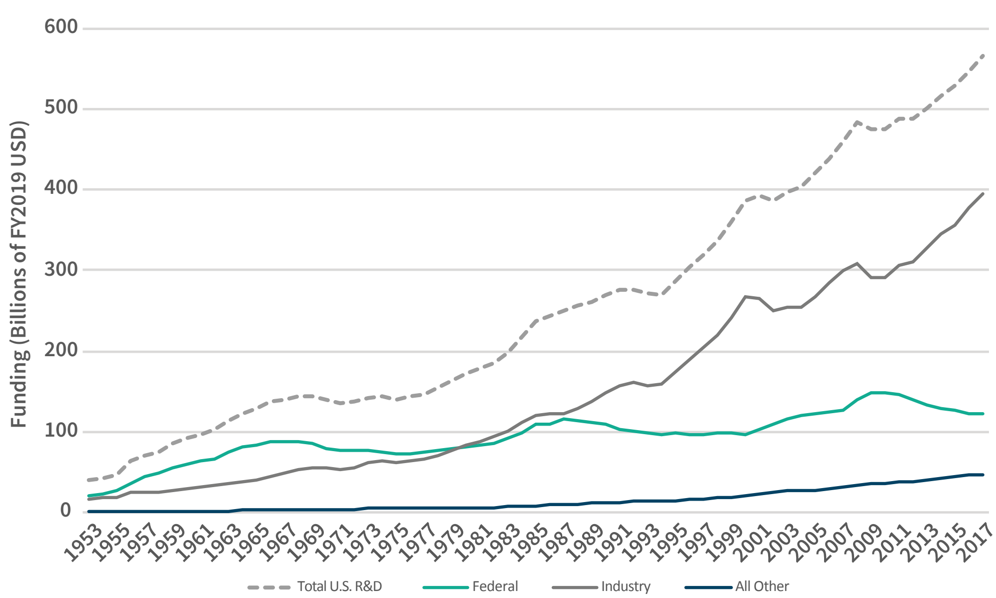
lowed by China at $444 billion and Japan at $366 billion. However, China has had the most dramatic R&D growth trends, with high increases in R&D spending over the past several years. This pace averaged 20.5 percent annually over 2000 to 2010 and 13.9 percent for 2010 to 2015. While the United States remains the largest investor in R&D, its pace of growth in R&D performance is much lower than China's, averaging 4.3 percent over 2000 to 2010 and 4.0 percent for 2010 to 2015. The balance of R&D spending has also shifted. The U.S. share of global R&D declined from 37 percent in 2000 to 26 percent in 2015. From 2012 to 2017, China's R&D sums grew by almost 70 percent.5 During the same period, U.S. R&D grew only 25 percent. If current trends remain unchanged, China is on track to be the dominant spender on R&D, outpacing the United States within the next decade.

Figure 1: Total Spending on R&D by Country



Source: "Gross domestic spending on R&D", OECD Main Science and Technology Indicators, March 2020, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm.

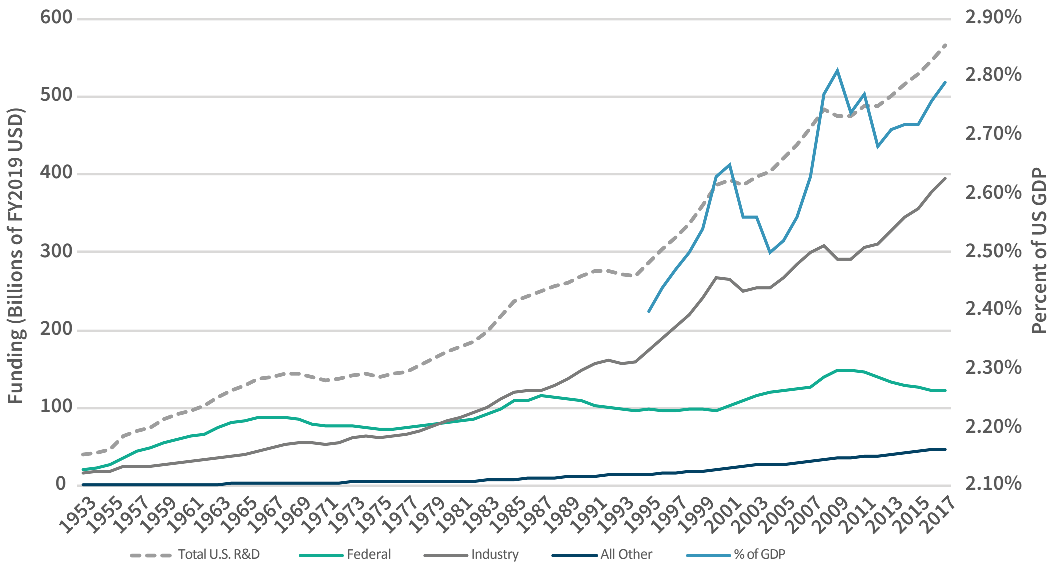
Figure 2: United States R&D Funding by Source (Billions ofFY2019 USD)



Source: "Historical Trends in Federal R&D," The American Association for the Advancement of Science, June 2019, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

---

5 "Science, Technology and Innovation," UNESCO Institute for Statistics, http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en.



Source: "Historical Trends in Federal R&D," The American Association for the Advancement of Science, June 2019, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

Looking specifically at U.S. government R&D spending, the U.S. government spent $116 billion in 2017, equal to about 0.6 percent of GDP.6 Federal funding for R&D, in comparison to private spending, goes primarily toward basic and applied scientific research rather than projects directly aimed at commercial success. For example, 64 percent of government spending goes toward basic and applied research. Basic research seeks to discover scientific principles, while applied research investigates a specific practical objective.

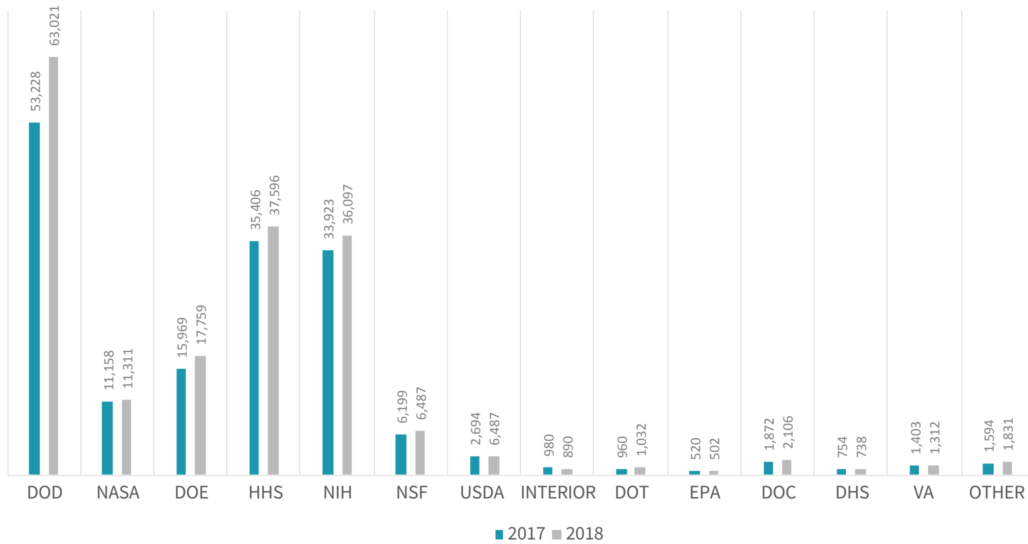
In 2017, U.S. government spending was divided such that $51 billion (40 percent) of federal R&D spending went to defense projects. Federal spending on health R&D accounted for $34 billion, with the National Institutes of Health (NIH) receiving the bulk of those funds, directing it to research on cancer, infectious diseases, and other health problems. Another $20 billion went to R&D on general science, space, and technology, mostly to the National Aeronautics and Space Administration (NASA) for projects such as observatories and space missions, and to the National Science Foundation (NSF), for research in areas such as physical sciences and engineering. The remainder of the R&D spending went to areas including transportation, agriculture, natural resources and the environment, and energy.

Government investment in R&D, as a share of GDP, has stagnated since 1980, whereas corporate R&D investment has nearly tripled.[7] Businesses fund 65 percent of all U.S. R&D today, compared with a nearly equal split between government and the private sector in the 1980s. However, while businesses have increased their investments into R&D, most of that increase has gone toward applied research rather than basic or applied. Most applied research focuses on the commercial application of a product and therefore has fewer spillover benefits. Companies tend to invest more in applied research than basic because it is considered a safer option. While basic research can lead to large breakthroughs, in many cases the results are not commercially viable in the short term. The risk associated with investing in R&D has also led to concern that the government is focusing on funding projects that are considered doable rather than riskier

---

6 Congressional Budget Office, *Estimating the Long-Term Effects of Federal R&D Spending: CBO's Current Approach and Research Needs* (Washington, DC: June 2018), https://www.cbo.gov/publication/54089.
7 Wu, "Why U.S. Business R&D Is Not as Strong as It Appears."

Figure 3: U.S. Government R&D Spending by Agnecy
Millions of Constant FY2019 Dollars



Source: "Historical Trends in Federal R&D," The American Association for the Advancement of Science, June 2019, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

projects that could have greater rewards.[8] One review found that NIH grants were scored based more on "doability" than innovation. DARPA has also become more risk adverse in recent years. Corporations are also concerned that if they invest in basic research, their discoveries could be used and developed by competitors who could reap the rewards of the initial research without having to spend on it. The benefits of investment in basic research take on different forms than that of applied research, often involving social or other positive impacts. Without government funding or incentives, companies will choose to spend most of their R&D money on applied research that can be turned into profits more immediately.

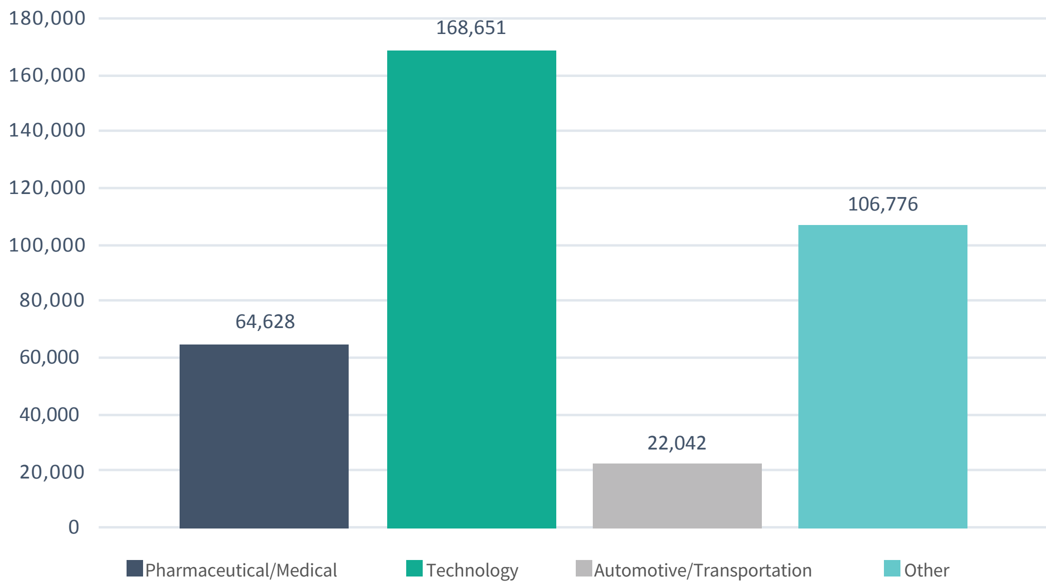
Much current private R&D spending comes from technology companies, pharmaceutical companies, and automakers. This R&D centers on autonomous and electric vehicles, semiconductors, health, and other technology-based projects. In 2018, Amazon spent the most on R&D of any firm, investing in Amazon Web Services, Alexa, and computer vision projects. Many automobile companies make the list, investing in autonomous vehicles and electrification research. Companies such as Intel and Qualcomm offer investments into 5G technology and new semiconductors.

The companies spending the most on R&D globally in 2018 were[9]:

- Amazon (United States): $22.6 billion.
- Alphabet (Google's parent company) (United States): $16.6 billion
- Volkswagen (Germany): $15.8 billion
- Samsung (South Korea): $15.3 billion

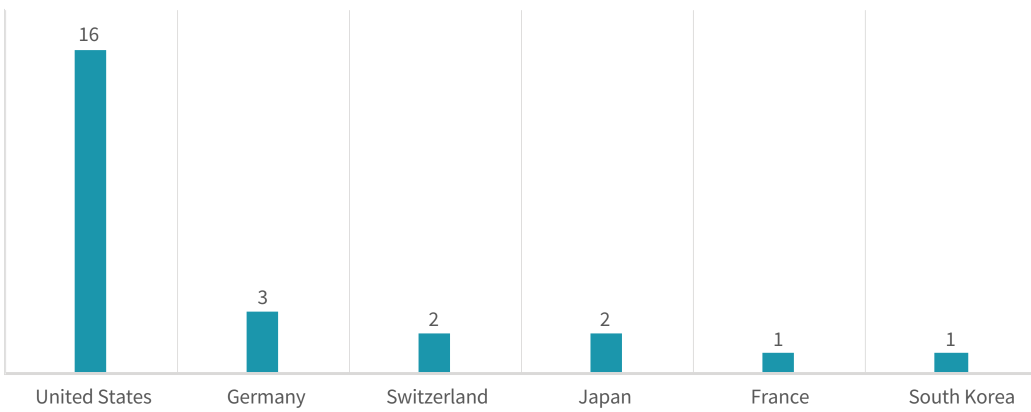
8 Jonathan Gruber and Simon Johnson, *Jumpstarting America: How Breakthrough Science Can Revive Economic Growth & the American Dream* (New York: Public Affairs Books, April 2019).
9 "Ranking of the 20 companies with the highest spending on research and development in 2018," Statista, October 2018, https://www.statista.com/statistics/265645/ranking-of-the-20-companies-with-the-highest-spending-on-research-and-development/.

Figure 4: Private R&D Spending by Industry
Millions of USD



Source: Raymond Wolfe, "Business R&D Performance in the United States Reached $400 Billion in 2017, a 6.8% Increase from 2016," National Science Foundation, September 2019, https://www.nsf.gov/statistics/2019/nsf19326/nsf19326.pdf.

Figure 5: Number of Top 25 R&D Spending Companies by Country



Source: Ranking of the 20 companies with the highest spending on research and development in 2018," Statista, October 2018, https://www.statista.com/statistics/265645/ranking-of-the-20-companies-with-the-highest-spending-on-research-and-development/.

- Intel (United States): $13.1 billion
- Microsoft (United States): $12.3 billion
- Apple (United States): $11.6 billion
- Roche (Switzerland): $10.8 billion
- Johnson & Johnson (United States): $10.4 billion
- Toyota (Japan): $10 billion

- Merck (United States): $9.6 billion
- Novartis (Switzerland): $8.5 billion
- Ford (United States): $8.0 billion
- Facebook United States): $7.8 billion
- Pfizer (United States): $7.6 billion
- General Motors (United States): $7.3 billion
- Honda (Japan): $7.1 billion
- Daimler (Germany): $7.1 billion
- Sanofi (France): $6.6 billion
- Oracle (United States): $6.2 billion
- Siemens (Germany): $6.1 billion
- Cisco (United States): $6.1 billion
- Celgene (United States): $5.9 billion
- Qualcomm (United States): $5.5 billion
- IBM (United States): $5.4 billion

THE BAYH-DOLE ACT

One piece of legislation which dictates how federal spending on R&D functions is the Bayh-Dole Act of 1980.[10] The legislation deals with intellectual property produced by government-funded research. Prior to Bayh-Dole, researchers operating with federal funding were obligated to assign patent ownership of their inventions to the government.[11] The passage of the bill allowed for universities, small businesses, and non-profit institutions to retain the title of a patent for inventions made with federal funding. The passage of Bayh-Dole accelerated the diffusion of innovation from public researchers to private firms for development. Before the law, government-owned patents provided for non-exclusive licenses which companies had the opportunity to purchase, but corporations were reluctant to purchase said licenses, as their competitors could just as easily use the same technology. The Bayh-Dole Act incentivized both the transfer of technology and the development of new inventions. Since universities and other entities could retain the rights to their inventions, they also had the decisionmaking power on licensing, which can generate revenue for the entity. Companies would also be able to purchase inventions with exclusive agreements, which incentivizes them to develop the inventions.

Following the passage of the Bayh-Dole Act, the number of patents granted to universities increased substantially. Universities engage in patenting research at an estimated rate 10 times higher than in 1980. Estimates also suggest that $30 billion of economic activity per year can be attributed to technologies born

10 “Bayh-Dole Regulations,” National Institute for Health, https://grants.nih.gov/grants/bayh-dole.htm.

11 David Levenson, “Consequences of the Bayh-Dole Act,” Massachusetts Institute of Technology, December 12, 2005, http://web.mit.edu/lawclub/www/Bayh-Dole%20Act.pdf.

in academic institutions. Studies have also shown that the industries surrounding university research also grew and increased employment by up to 1 percent following the passage of the Bayh-Dole Act.[12]

Some have criticized the Bayh-Dole Act, saying that its passage has led to universities electing to pursue applied research rather than basic research in order to gain greater royalties from patenting.[13] Other criticism involves biomedical, government-funded research. Since the passage of Bayh-Dole, biomedical research investment has increased significantly. Critics argue that allowing universities or other entities to retain the patents for biomedical inventions discourages the final production of the invention, as the final product would likely require additional R&D by the company and payment for the licensing of a patent.

PATENTING BY RESEARCH INSTITUTIONS IN THE OECD AND CHINA

A study by the OECD found that among OECD countries and China, patent applications have increased substantially since 1992.[14] The paper attributed much of the initial rise to the passage of the Bayh-Dole Act in the United States. The study also noted that the share of science-industry joint inventions also grew between 1992 and 2014, making up 29 percent of all patent applications from universities and public research institutions in 2014, up from 17 percent in 1992. However, research institutions' relative share of total patent applications remains low compared to industry.

Results from the same paper also suggest that geographic proximity of industry to universities is positively associated with patent applications in Europe. The paper used econometric methods to capture the correlation. This implies that proximity to a university positively influences local industry patenting.

FOREIGN DIRECT INVESTMENT

U.S. affiliates of majority foreign-owned companies spent $62.6 billion on R&D in 2017.[15] With its Open Investment Policy, the United States attracts high amounts of foreign investment in R&D, and it is the top destination for FDI.[16] In 2018, the five largest sources of FDI stock in the United States were the United Kingdom ($597 billion), Canada ($588 billion), Japan ($489 billion), Germany ($474 billion), and Ireland ($385 billion). The fastest-growing sources of FDI among markets with at least $1 billion in investment were Argentina (57.9 percent five-year compound annual growth rate, $4.9 billion), China (35.2 percent, $60.2 billion), Thailand (35.0 percent, $2.1 billion), Ireland (34.2 percent, $385 billion), and Chile (23.9 percent, $3.5 billion). Though current FDI inflows remain higher than the years following the financial crisis, annual FDI inflows have experienced a 46 percent decline since 2015. While the United States continues to incentivize American companies to divest from overseas ventures, this has not carried over to foreign investors.[17]

---

12 Naomi Hausman, "University Innovation, Local Economic Growth, and Entrepreneurship," U.S. Census Bureau, Center for Economic Studies, June 2012, https://www2.census.gov/ces/wp/2012/CES-WP-12-10.pdf, and Ibid. Jonathan Gruber and Simon Johnson, *Jumpstarting America: How Breakthrough Science Can Revive Economic Growth & the American Dream*.

13 "Impact of Bayh–Dole Act on Scientific Research," Enago Academy, May 24, 2018, https://www.enago.com/academy/impact-of-bayh-dole-act-on-scientific-research/.

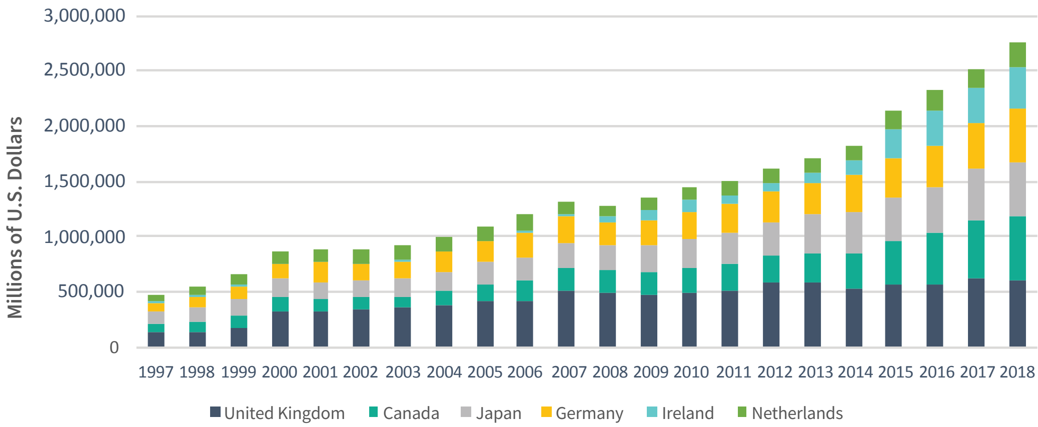
14 Caroline Paunovi, Martin Borowieckii, and Nevine El-Mallakhi, "Cross-country evidence on the contributions of research institutions to innovation," OECD, September 24, 2019, https://www.oecd-ilibrary.org/science-and-technology/cross-country-evidence-on-the-contributions-of-research-institutions-to-innovation_d52d6176-en.

15 U.S. Department of Commerce, *Foreign Direct Investment (FDI): United States* (Washington, DC: 2019), https://www.selectusa.gov/servlet/servlet.FileDownload?file=015t0000000LKSn.

16 U.S. Office of the Press Secretary, "Statement by the President on United States Commitment to Open Investment Policy," The White House, June 20, 2011, https://obamawhitehouse.archives.gov/the-press-office/2011/06/20/statement-president-united-states-commitment-open-investment-policy.

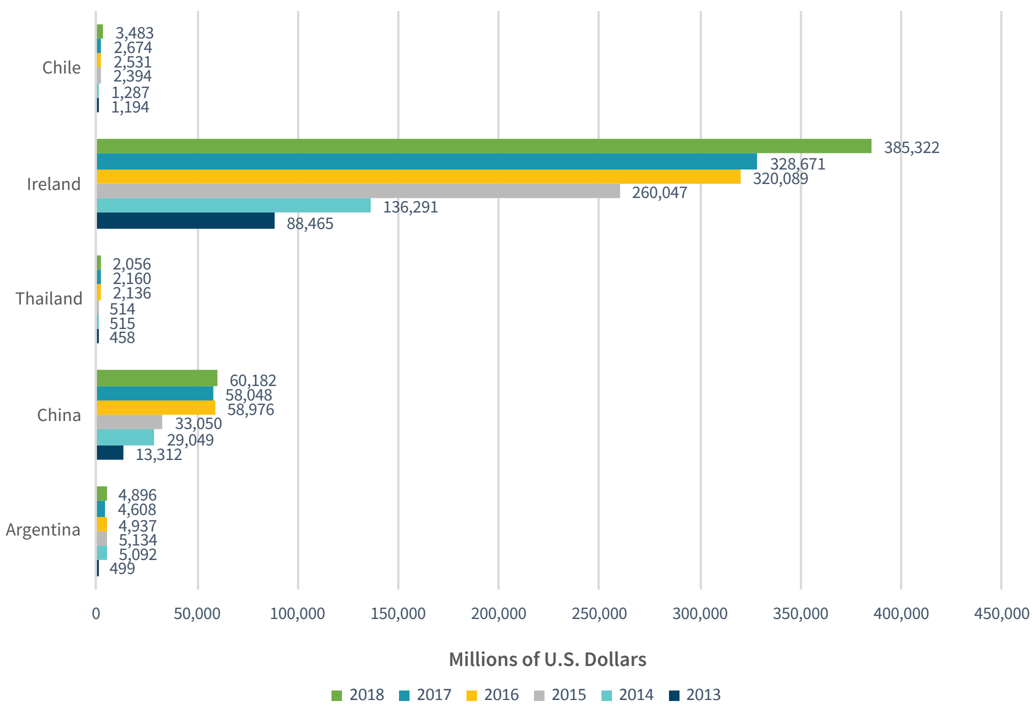
17 U.S. Department of Commerce, *Foreign Direct Investment (FDI): United States*.

Figure 6: FDI Stocks by Selected Country of Ultimate Beneficial Owner, 1997-2018



Source: "Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data," Bureau of Economic Analysis, July 2019, https://www.bea.gov/international/di1fdibal.

Figure 7: Fastest-growing Sources of FDI by Ultimate Beneficial Owner, 2013-2018

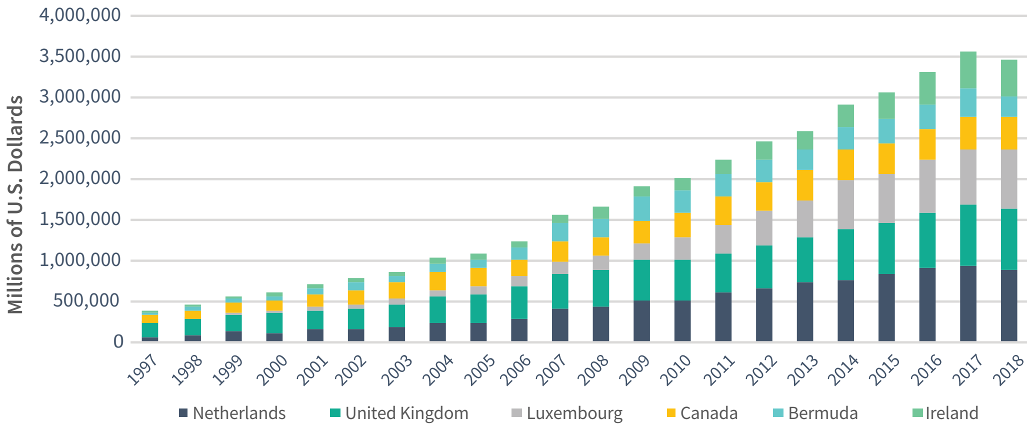


Source: "Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data," Bureau of Economic Analysis, July 2019, https://www.bea.gov/international/di1fdibal.

The Trump administration's attempts to divest overseas ventures have been most evident in outward FDI losses. While typically the world leader in outward FDI, in 2018 U.S. outflows were net-negative $64 billion. This was the first time since data was collected that outward FDI from the United States was negative. It was also the sharpest decline recorded, with outward FDI in 2017 totaling a net-positive $300 billion.[18] This decline has been primarily attributed to the tax reforms which took place in late 2017 and

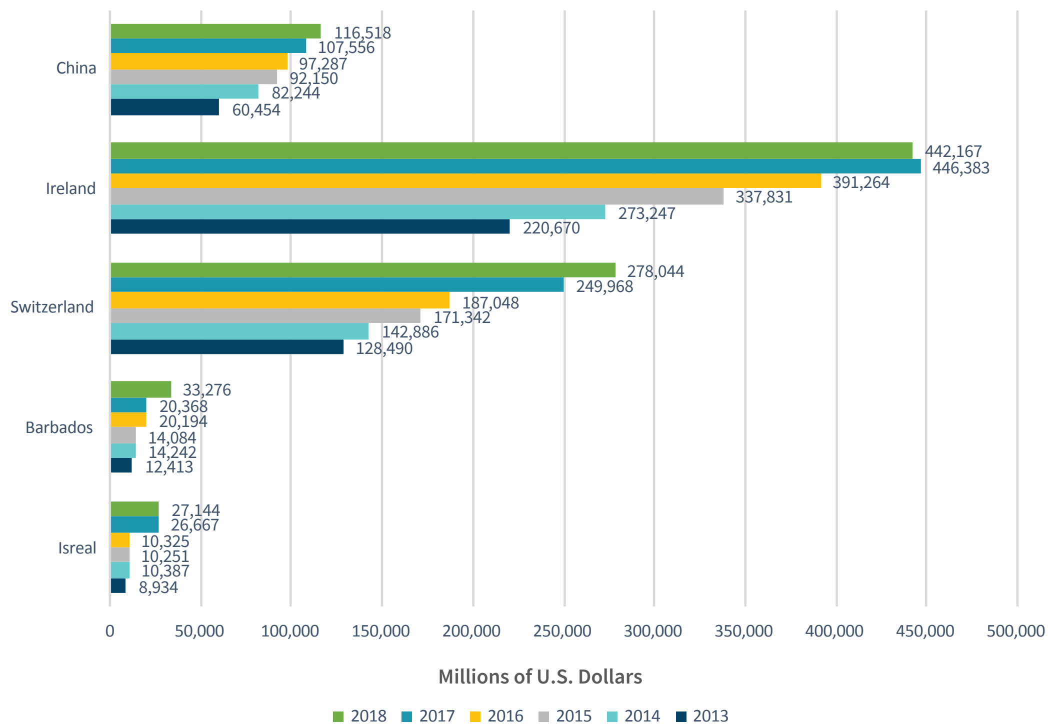
18 United Nations Conference on Trade and Development, *World Investment Report 2019* (New York: United Nations Publications, June 12,

Figure 8: Outward FDI Stocks by Selected Country from the United States, 1997-2018



Source: "Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data," Bureau of Economic Analysis, July 2019, https://www.bea.gov/international/di1fdibal.

Figure 9: Fastest-growing Recipients of FDI Outflows, 2013-2018



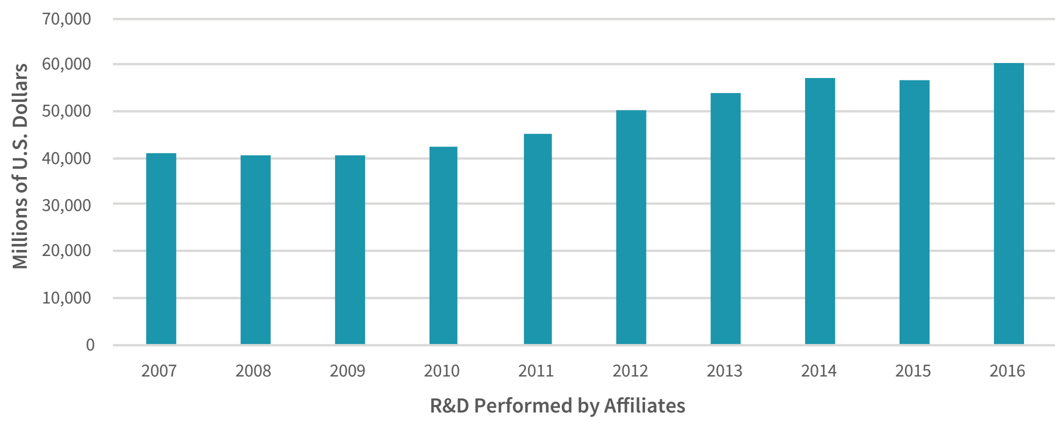
Source: "Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data," Bureau of Economic Analysis, July 2019, https://www.bea.gov/international/di1fdibal.

subsequent reinvestments of earnings within the United States.[19] Looking at outward FDI stocks in 2018, the six largest markets for U.S. investors have been the Netherlands ($883 billion), the United Kingdom ($758 billion), Luxembourg ($714 billion), Ireland ($442 billion), Canada ($402 billion), and Bermuda

2019), https://unctad.org/en/PublicationsLibrary/wir2019_en.pdf.

19 Cora Jungbluth, "Tracing three decades of foreign direct investment booms and busts and their recent decline," Global Economic Dynamics Project, September 27, 2019, https://ged-project.de/allgemein-en/foreign-direct-investment/.

Figure 10: R&D by Majority-owned U.S. Affiliates, 2007-2017



Source: "Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data," Bureau of Economic Analysis, July 2019, https://www.bea.gov/international/di1fdibal.

($249 billion). The fastest-growing sources of FDI outflows from the United States with at least $1 billion in investments were Israel (24.9 percent five-year CAGR, $27 billion), Barbados (21.8 percent, $33 billion), Switzerland (16.7 percent, $278 billion), Ireland (14.9 percent, $442 billion), and China (14 percent, $117 billion). A 2019 IMF report found that only seven countries, which represent only 3 percent of the global economy, account for 40 percent of the world's FDI. U.S. outflow data reflects similar findings, as five of the seven countries—the Netherlands, Luxembourg, Ireland, Bermuda, and Switzerland—were all top FDI recipients from the United States.[20]

Examples of Government Involvement in Business

Governments have a variety of levers to influence business within their country. As previously discussed, governments can support pre-commercial activities such as R&D. Governments can use tax policy and other incentives to shape the general business environment or to support specific sectors, industries, or companies. Governments can also play a more direct role in business operations in their country. They can act as a facilitator of industry cooperation in response to foreign competition, ensure innovative small businesses are not overlooked, and take risks and carry companies that are working on promising but unproven ideas across the so-called "Valley of Death" when private capital is otherwise unavailable. Ostensibly those functions serve a greater good, such as improving national security or bolstering public health. Governments, however, can also play a more market distorting role by establishing cozy relationships and favoring certain companies.

The following section examines a range of government programs to support specific businesses, some more successful than others.

SMALL BUSINESS ADMINISTRATION

The Small Business Administration (SBA) was established in 1953, following concerns about underemployment after World War II, with the goal of enhancing competition in the private market.21 The SBA offers

20 United Nations Conference on Trade and Development, *World Investment Report 2019*.

21 U.S. Small Business Administration (SBA), *FY 2020 Congressional Justification and FY 2018 Annual Performance Report*, (Washington, DC: April 2019), https://www.sba.gov/sites/default/files/2019-04/SBA%20FY%202020%20Congressional%20Justification_final%20508%20%204%2023%202019.pdf.

a variety of programs to support small businesses, including: loan guarantee and venture capital programs to enhance small business access to capital; contracting programs to increase small business opportunities in federal contracting; direct loan programs for businesses, homeowners, and renters to assist their recovery from natural disasters; and small business management and technical assistance training programs to assist business formation and expansion.[22]

ENTREPRENEURIAL DEVELOPMENT PROGRAMS

Entrepreneurial development programs are non-credit-bearing education programs often found at community colleges which provide management and training services to small businesses. These programs include: Small Business Development Centers; the Microloan Technical Assistance Program; Women Business Centers; the Program for Investment in Microentrepreneurs; Veteran programs; the Native American Outreach Program; the Entrepreneurial Development Initiative; and the Entrepreneurship Education Initiative. In FY 2019, funding for these programs totaled $220 million.

CAPITAL ACCESS PROGRAMS

Capital access programs work to provide funding for small businesses. The SBA has authority to make direct loans but has not exercised that authority except for disaster loans and loans to Microloan Technical Assistance Program intermediaries since 1998. The SBA stopped issuing direct loans because the subsidy rate was 10 to 15 times higher than that of loan guarantee programs. Instead of making direct loans, the SBA guarantees loans issued by approved lenders to encourage those lenders to finance small businesses. In FY 2018, the SBA approved 60,353 7(a) loans, totaling nearly $25.4 billion. In FY 2018, there were 1,810 active lending partners providing 7(a) loans.

One category of loan guarantees includes International Trade and Export Promotion programs, which offer loan guarantees to firms looking to begin exporting or expanding current exporting operations. Within that, the Export Express loan program provides working capital or fixed-asset financing for firms that will begin or expand exporting. It offers a 90 percent guarantee on loans of $350,000 or less and a 75 percent guarantee on loans of $350,001 to $500,000. The Export Working Capital loan program provides financing to support export orders or the export transaction cycle, from purchase order to final payment. It offers a 90 percent guarantee of loans up to $5 million. Finally, the International Trade loan program provides long-term financing to support firms that are expanding because of growing export sales or have been adversely affected by imports and need to modernize to meet foreign competition. It offers a 90 percent guarantee on loans up to $5 million.

Another loan program, the Microloan Technical Assistance Program, provides direct loans to qualified non-profit intermediary lenders which then provide microloans of up to $50,000 to small businesses. In FY 2018, 5,459 small businesses received a microloan from the program, totaling $76.8 million. The average microloan was $14,071, and the average interest rate was 7.6 percent.

CAPITAL INVESTMENT PROGRAMS

Capital investment programs aim to improve small business access to venture capital and support innovation and research. Within this category is the Small Business Investment Company program (SBIC), the Small Business Innovation Research program (SBIR), and the Small Business Technology Transfer program (STTR).

---

22 Robert Jay Dilger and Sean Lowry, *Small Business Administration: A Primer on Programs and Funding*, CRS RIL33243 (Washington, DC: Congressional Research Service, August 2019), https://www.everycrsreport.com/files/20190829_RL33243_242c1347757a3f8f9df6aeb5f-ec4677db42f7ff5.pdf.

Founded in the 1960s, the Small Business Investment Company (SBIC) paved the way for the modern private venture capital industry. With the SBIC, the government not only invests in traditional R&D but also acts as a venture partner with the private sector. The SBIC raises private capital to provide small businesses with guaranteed loans. In FY 2018, the SBA committed to guarantee $2.52 billion in SBIC small business investments. SBICs invested another $2.98 billion from private capital for a total of $5.50 billion in financing for 1,151 small businesses.

The Small Business Innovation Research program (SBIR) is designed to increase the participation of small, high-technology firms in federal R&D endeavors, provide additional opportunities for the involvement of minority and disadvantaged individuals in the R&D process, and expand commercialization of the results of federally-funded R&D. SBIR is the largest federal spending program supporting R&D. SBIR aims to finance 4,500 projects each year in conjunction with STTR. According to congressional testimony, SBIR/STTR funding lets companies hire people to do research on a project that is "high risk, high reward." Current law requires that every federal department with an R&D budget of $100 million or more establish and operate a SBIR program. SBIR funding comes in two phases, the first grants up to $150,000 for preliminary work, while Phase II awards grants of up to $1 million for later-stage research.

The Small Business Technology Transfer program (STTR) provides funding for research proposals that are developed and executed between a small firm and a nonprofit research organization, with certain mission requirements. Funding is available in two phases. Phase I financing is available up to $163,952, and Phase II funding awards up to $1.09 million.

SBIR/STTR funds have existed since 1977 but are subject to continual renewal. Industry advocates have recommended making funding permanent as well as expanding SBA funding to enable them to more quickly manage the grant programs. SBIR has been found to support five to seven times as many early-stage start-ups as venture capital funding. Funding by SBIR, which is a competitive process, serves as a signal to VC firms of the viability of a start-up since SBIR includes a vigorous peer-review process. SBIR winners represent 3 percent of VC funding recipients for information technology, 20 percent for life sciences, and 10 percent of the energy and industrial sector.

GROWTH ACCELERATOR INITIATIVE

The Growth Accelerator Initiative provides $50,000 matching grants to university and private-sector accelerators to support start-ups which lack traditional access to capital. The initiative aims to increase the number of small businesses in the high-tech economy. It has awarded 223 projects in 45 states over the last five years and made awards to 20 entities in FY 2018.[23]

Alternative Models

ZAIBATSU AND CHAEBOL: GOVERNMENT-INDUSTRY RELATIONSHIPS LEADING TO CORPORATE CAPTURE

The Japanese Zaibatsu

Zaibatsu refers to any of the large capitalist enterprises in Japan before World War II, similar to cartels or trusts but typically organized around one family. The four main groups were Mitsui, Mitsubishi, Sumitomo, and Yasuda. The zaibatsu developed after the Meiji Restoration in 1868, which restored practical imperial rule to Japan and reconsolidated the political system under the emperor. The Samurai class, which

23 SBA, *$3 Million for High Sech, Small Business Focused Accelerators in 2019* (Washington, DC: U.S. Small Business Administration, September 2019), https://www.sba.gov/offices/headquarters/ooi/resources/1428931.

previously received benefits such as a rice stipend, was phased out by Emperor Meiji and replaced with one-time government bonds. The government also privatized various small industries. Many of the former Samurai used their bonds to start businesses which would later develop into the zaibatsu. The rising groups capitalized on limitless demand and cheap sources of labor and raw goods.[24]

High economic growth followed the Meiji Restoration. During this time, the first Japanese banks were established, which helped finance new businesses and issue stock for corporations. The formation of the new financial institutions provided a foundation for the zaibatsu to grow. Unlike American moguls, the zaibatsu did not specialize in one industry but rather held a spectrum of enterprises.

The zaibatsu opened 49 percent of shares to public purchase to expand capitalization, and corporations shielded themselves from risk because their subsidiaries were independently incorporated. The lower an entity was on the corporate pyramid, the greater its public ownership, and therefore the least damage incurred by zaibatsu leadership. The goal of the zaibatsu was to capture market share before capturing profits.[25]

The zaibatsu held significant economic and political influence in Japan. They were heavily involved in the industrialization of Japan and the domestic and foreign policy decisions made at the time. Outside of the main four zaibatsu, there existed a "second tier," which consisted of many other thriving business families. The reign of the zaibatsu ended after World War II when the surrender of Japan effectively dissolved the zaibatsu.

Korean Chaebol

In Korea, the chaebol offers many similarities to the Japanese zaibatsu.26 The mostly-family run conglomerates were developed after the Korean War. However, unlike the zaibatsu, the chaebol still holds massive economic and political power in South Korea. More than 40 conglomerates meet the definition of a chaebol in Korea, but the top five hold the most power. Those five represent nearly half of the South Korean stock market value and include Samsung, Hyundai, SK Group, LG Corporation, and Lotte Group.[27]

The chaebol emerged in the 1950s when U.S. and international aid allowed the Korean government to provide hundreds of millions of dollars in special loans to support efforts to rebuild the economy.[28] The companies flourished under General Park Chung-Hee, who led the country from 1963 to 1979. He developed an export-driven strategy which prioritized preferential loans to export businesses and protected domestic industries from foreign competition. Exports grew from just 4 percent of GDP in 1961 to more than 40 percent by 2016.[29] Over roughly the same period, the average income of South Koreans rose from $120 per year to more than $27,000 in today's dollars.[30]

---

24 David A. C. Addicott, "The Rise and Fall of the Zaibatsu: Japan's Industrial and Economic Modernization," *Global Tides* 11, no. 5 (January 1, 2017), https://digitalcommons.pepperdine.edu/globaltides/vol11/iss1/5/.
25 Robert J. Crawford, "Reinterpreting the Japanese Economic Miracle," *Harvard Business Review*, January/February 1998, https://hbr.org/1998/01/reinterpreting-the-japanese-economic-miracle.
26 Eleanor Albert, "South Korea's Chaebol Challenge," Council on Foreign Relations, May 4, 2018, https://www.cfr.org/backgrounder/south-koreas-chaebol-challenge.
27 Carlos Tejada, "Money, Power, Family: Inside South Korea's Chaebol," *New York Times*, February 17, 2017, https://www.nytimes.com/2017/02/17/business/south-korea-chaebol-samsung.html.
28 Sang-young Rhee, "The Origins of the Korean Chaebols and Their Roots in the Korean War," *Korean Journal of International Relations* 45, no. 5, (2005): 204-230, doi:10.14731/kjis.2005.12.45.5.203.
29 "Exports of goods and services (% of GDP) - Korea, Rep.," World Bank, https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS.
30 "GNI per capita, Atlas method," World Bank, https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=KR.

The South Korean government and the chaebol have a longstanding relationship. However, in recent years the closeness has resulted in what critics call corruption, including embezzlement, bribery, and tax evasion. Politicians seeking money in return for political favors with the chaebol was considered the norm until more recently, when these practices became unpopular with the public. Tensions recently erupted in 2016 and 2017 with protests ending in the ousting of President Park Geun-hye, who was later sentenced to 24 years in prison for charges related to corruption.

It is a common issue for industrial policies, such as the one in Korea, to lead to political capture by powerful groups who then attempt to manipulate the policies for their own gain.[31] The risk of political capture can be minimized in more transparent societies where criticism of cronyism can help prevent such an issue.[32] One example of such capture occurred in Tunisia, where the former president's family accounted for 1 percent of private-sector output and 3 percent of employment but held 21 percent of the country's profits.[33]

U.S. SEMATECH: Government-Industry Partnership Pays Off

In the mid-1980s, the U.S. chip industry was at risk of falling behind Japanese producers. This spurred the U.S. government and corporations to work together to accelerate the U.S. chip-making industry between the 1980s and 1990s. Semiconductor Manufacturing Technology (SEMATECH) was a group of 14 U.S. chip manufacturers formed with the goal of revitalizing the U.S. semiconductor industry.[34]

The original members of SEMATECH were IBM, Intel Corporation, Motorola, Texas Instruments, National Semiconductor, Advanced Micro Devices, Lucent Technologies, Compaq Computer Corporation, Hewlett-Packard Technology, Conexant Systems, NCR Microelectronics Corporation, Harris Semiconductor, LSI Logic Corporation, and Micron Technology.

SEMATECH set a goal in the early-1990s to decrease the miniaturization cycles of chips from three years to two. This goal sped up innovation in the electronics industry and the entire economy. In the unique arrangement, the group won a five-year contract of $100 million in annual funding from the U.S. Defense Department's Defense Advanced Research Projects Agency (DARPA), which the companies matched. The program lasted eight years, and by the end the government invested a total of $850 million. The group succeeded and overtook Japan in market share for semiconductors worldwide in 1992.[35]

One of the reasons the consortium worked was government legislation which allowed companies to openly communicate without antitrust concerns.[36] Though the National Cooperative Research Act (NCRA) of 1984 already provided sufficient coverage for joint research and development projects, the House Judiciary Committee approved a bill to amend the NCRA in 1990 to affirm further protections for joint ventures, specifically written with SEMATECH in mind. This communication allowed companies to better identify

---

31 Shanta Devarajan, "Three reasons why industrial policy fails," Brookings Institution, January 14, 2016, https://www.brookings.edu/blog/future-development/2016/01/14/three-reasons-why-industrial-policy-fails/.

32 Erik Berglof and Vince Cable, *Back in Business: Industrial Policy for Emerging Economies in the New Globalisation* (London: London School of Economics Institute of Global Affairs, October 2017), http://www.lse.ac.uk/iga/assets/documents/publications/2017/Berglof-Cable-report.pdf.

33 Antonio Nucifora, Bob Rijkers, and Caroline L. Freund, "All in the Family: State Capture in Tunisia," World Bank, March 1, 2014, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2415016.

34 Robert D. Hof, "Lessons from Sematech," MIT Technology Review, July 25, 2011, https://www.technologyreview.com/2011/07/25/192832/lessons-from-sematech/.

35 Chris McFadden and Dewey Ballantine, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry* (Washington, DC: National Academies Press, 2003), 95-121.

36 U.S. International Trade Commission, *Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries: Semiconductor Manufacturing and Testing Equipment* (Washington, DC: September 1991), https://www.usitc.gov/publications/332/pub2434.pdf.

and tackle industry-wide issues. It is also important to note that SEMATECH itself did not actually make anything—the companies manufactured without competition from the government. For the U.S. government, the deal also worked well because the firms that it helped would later pay taxes on earnings. For example, Intel now pays more in taxes every quarter than the entire government investment in SEMATECH.[37] Government support helped because it allowed the companies to focus on long-term, high-risk research rather than short-term projects with predictable results. It is in the broader, riskier projects that government-led innovation lies.[38]

The United Kingdom's Concorde: The Wrong Bet

The Concorde was a joint project between the United Kingdom and France launched in 1962 to create a computer-controlled, supersonic passenger aircraft. The aircraft featured carbon-fiber brakes and fly-by-wire controls, which are typical in aircraft design today but were new innovations at the time. The plane was able to cut transatlantic flight times in half.[39]

The Concorde operated from 1976 until a crash in Paris in 2000 killed 133 people. The aircraft was returned to flight in 2001 after significant safety improvements but was permanently grounded again in 2003.[40] Other problems also plagued the Concorde, which, despite its speed, was highly inefficient. The aircraft burned through jet fuel rapidly and failed to be profitable during a time of high oil prices. The plane could only hold 100 passengers but used the same amount of fuel as the Boeing 747, which could fit four times people. The aircraft also had a short range and was only able to complete trips from the United Kingdom to the United States' East Coast, unable to make it as far as the West Coast.[41]

The cost in current dollars for developing the Concorde reached as high as $2.04 billion by mid-1974, with the United Kingdom's share amounting to $1.20 billion. Due to the inefficiency, British Airways estimated that its fleet of five Concordes would generate $247 million in operating losses over 10 years. In 1974, the British government stated that the cost of producing the aircraft was $808 million, which was $224 million more than they estimated it would cost them to cancel the project. British Airways also invested $202 million.[42]

In the development of the Concorde, the United Kingdom made the wrong bet on what the future of air travel would look like. The plans for development began prior to the oil shocks of the 1970s, which resulted in an era of high oil prices unsuitable for the inefficiency of the Concorde. Additionally, the Concorde prioritized luxury and national prestige over the practicality of the aircraft. During development, the British government knew that the cost of producing the aircraft was higher than the cost of cancelling the project but still carried the project to completion.

Case Studies of Government-funded R&D Creating Breakthroughs

RADAR IN THE UNITED KINGDOM AND THE UNITED STATES

37 McFadden and Ballantine, *Securing the Future*, 95-121.
38 Katie Hafner, "Does Industrial Policy Work? Lessons From Sematech," *New York Times*, November 7, 1993, https://www.nytimes.com/1993/11/07/business/does-industrial-policy-work-lessons-from-sematech.html.
39 Christopher McFadden, "Concorde: The Real Reason Why the Supersonic Passenger Jet Failed," Interesting Engineering, March 5, 2017, https://interestingengineering.com/concorde-the-real-reason-why-the-supersonic-passenger-jet-failed.
40 "Concorde grounded for good," BBC, April 10, 2003, http://news.bbc.co.uk/2/hi/uk_news/2934257.stm.
41 David Kaminski-Morrow, "Retrospective: When Concorde wasn't the UK's cup of tea," Flight Global, April 9, 2019, https://www.flightglobal.com/strategy/retrospective-when-concorde-wasnt-the-uks-cup-of-tea/132222.article.
42 Ibid.

Development of aviation radar technology followed two parallel tracks in the pre-World War II era. In 1922, the United States Naval Research Laboratory (NRL) first observed bistatic radar's effects in an experiment on a ship sailing on the Potomac River. Further research did not progress until 1930, when the principle was applied to aircraft. It was not until monostatic radar—using one antenna as both receiver and transmitter—was developed that military applications were realized, first demonstrated on the USS *New York in 1939.*[43]

Meanwhile, the British started similar research in 1935 with a greater sense of urgency as its security seemed increasingly threatened by Germany. At the UK government's Radio Research Station, Robert Watson-Watt worked to implement the Chain Home system in 1938. This network of radar stations provided integral early detection of German air raids, allowing for the strategic allocation of defense resources by the Royal Air Force.

Without these public investments into the basic research of radar, it is difficult to imagine the same pace of innovation occurring in the United States and other allying countries in aerial and naval defense, navigation, and tracking, not to mention a bevy of non-military applications, such as meteorology, commercial boating, fishing, or new radar systems integrated with camera technology to assist with emergency braking and self-driving cars.[44]

In this case, both U.S. and British authorities identified a national security threat that could be addressed through technical research and made successful investments. External factors, such as the threat of war, oftentimes motivates governments to allot more funds for R&D and guides disbursement to the most relevant technical fields.

NASA Spinoffs

Since the establishment of its Technology Transfer Program in 1964, NASA has played a significant role in bolstering the innovation economy. Sharing the breakthroughs reached by NASA scientists and engineers with the public domain has resulted in thousands of commercially viable products and services. The Technology Transfer Program has shared both patented and formerly patented NASA technology online, available to be licensed for free by the public. These reapplications have become so frequent that since 1973, NASA has published an annual publication, *Spinoff,* cataloging the year's featured innovations. Technologies as diverse as LASIK, cochlear implants, artificial limbs, Thermawing, improved radial tires, landmine removal, fire-resistant material, freeze-drying, and water purification were all pioneered at NASA or associated laboratories.[45]

THE HUMAN GENOME PROJECT

From 1990 to 2003, the Department of Energy (DOE) and the National Institutes of Health (NIH) led the Human Genome Project (HGP) in the United States with the mission of decoding the full set of human genes and thereby make them available to biological and biomedical study and application.[46] After successfully finishing the sequencing, the International Human Genome Sequencing Consortium immediately designated the genome as public domain. The accessibility of HGP's research has not only provided

43 Merrill I. Skolnik, "History of Radar," Britannica Encyclopedia, March 5, 2019, https://www.britannica.com/technology/radar/History-of-radar.

44 Jack Browne, "Radar Grows from Military Tool to Everyday Use," Microwaves & RF, August 18, 2015, https://www.mwrf.com/technologies/systems/article/21846409/radar-grows-from-military-tool-to-everyday-use.

45 "NASA Technology Transfer Program," NASA, 2018, https://spinoff.nasa.gov/Spinoff2018/nttp_1.html.

46 U.S. Department of Energy Human Genome Project, "History of the Human Genome Project," U.S. Department of Energy, June 7, 2019, https://web.ornl.gov/sci/techresources/Human_Genome/project/hgp.shtml.

new tools to disciplines such as genealogy but has also created whole new fields such as genetic health and pharmacogenomics.

Researchers completed the project two years ahead of schedule and $300 million under projected budget. After considering the benefits and spinoffs for biotechnology, it is difficult to overestimate the returns on investment.[47]

Start-up firms such as Celera Genomics, Incyte, and Human Genome Sciences all contributed to the later portions of the sequencing project, but without the $5.1 billion of public investment, the data used by these private partners may have never been produced or made free for public use.[48]

THE GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) has its roots in the U.S. Navy's use of satellites to pinpoint the location of its nuclear submarines in the 1960s. The Department of Defense (DoD) sought to expand this technology's use, launching the first Navigation System with Timing and Ranging (NAVSTAR) satellite in 1978 and forming an operational 24-satellite constellation in 1993. The DoD does reserve its own frequency for secure use, but for the most part, GPS operates as a free, U.S.-government-provided public utility to its direct users. It has allowed for advances in navigation, tracking, data mining, recreation, robotics, and cartography, proving to be an instrumental tool in the information age.[49]

THE ROOTS OF THE INTERNET

Another DoD product was the internet.[50] In 1969, the Department started the Advanced Research Projects Agency Network (ARPANET), designed to ensure the security of government communications and ease the transmission of information between university laboratories. Vint Cerf and Robert Kahn, developers of the now-ubiquitous TCP/IP data protocol, worked through a government grant and contributed to ARPA's architecture. ARPANET could not communicate beyond its network of university computers, but the TCP/IP suite allowed for integrated network communication in today's internet.

ARTIFICIAL INTELLIGENCE

Federally-funded basic research in three main disciplines—robotics, neural networks, and symbolic systems—produced the field of artificial intelligence (AI) as it is known today.[51] Robotics traces its origins to the theories of Isaac Asimov, but NSF-sponsored projects in the 1970s paved the way for industrial robots equipped with computer vision and sensors.[52] Decades earlier, Frank Rosenblatt explored using neural networks to model machine learning methods while backed by the Office of Naval Research.[53] Finally, the concept of symbolic systems, or replicating the logical flow of human decisionmaking, owes its develop-

---

47 National Human Genome Research Institute, "Human Genome Project FAQ," National Human Genome Research Institute, February 24, 2020, https://www.genome.gov/human-genome-project/Completion-FAQ.
48 Ibid.
49 "*Global Positioning System History*," NASA, October 27, 2012, https://www.nasa.gov/directorates/heo/scan/communications/policy/GPS_History.html.
50 Kevin Featherly, "Arpanet – United States Defense Program," Britannica Encyclopedia, November 28, 2016, https://www.britannica.com/topic/ARPANET.
51 Iain M. Cockburn, Rebecca Henderson, and Scott Stern, "The Impact of Artificial Intelligence on Innovation," National Bureau of Economic Research, Working Paper no. 24449, March 2018, https://www.nber.org/papers/w24449.pdf.
52 National Science Foundation, "NSF's 40-year history supporting US robotics research," Robohub, November 27, 2014, https://robohub.org/nsfs-40-year-history-supporting-us-robotics-research/.
53 Frank Rosenblatt, "The Perceptron: A Probabilistic Model for Information Storage and Organization in the Brain," *Psychological Review* 65, no. 6 (1985): 386-408, doi:10.1037/h0042519.

ment to DARPA programs.[54] Without these core, publicly-funded breakthroughs, the U.S. private sector would have been unable to integrate the component technologies into industrial AI applications.

The U.S. Department of Agriculture Agricultural Research Service's Screwworm Study

In the 1940s, scientists from the United States Department of Agriculture discovered how to use radiation to sterilize screwworms, a livestock parasite that caused tremendous damage to U.S. and world agricultural production. Entomologists Edward Knipling and Raymond Bushland of the Agricultural Research Service observed that x-ray radiation could sterilize screwworms without disrupting their mating behavior. Application of this study led to the eradication of the screwworm fly in North and Central America, much to the benefit of the U.S. agricultural industry. Moreover, radiation sterilization continues to be employed to fight diseases such as Zika and pests such as the tsetse fly in tropical Africa.[55]

SOLAR: A MIXED BAG

The development of solar cell technology is another much discussed example of government intervention in industry. Solar energy technology stands out as a success of research but a failure of deployment.

The cost of solar power has fallen 99 percent since serious research began in the mid-1970s. From 1980 to 2001, most of the cost reductions concerned the cost of the device and its materials. Basic science research contributed to better engineering of panels and higher efficiency, and therefore lower costs. Costs continued to slide after 2001, this time due mainly to increasing plant size. Market-stimulating policies such as feed-in tariffs contributed to the creation of these economies of scale in the solar industry.[56]

Despite these cost reductions partially induced by public R&D, the solar industry has struggled to reach cost competitiveness with fossil fuels. Without adequate price signals, the market for solar energy has struggled, but without government support, it would likely be in a much worse position.[57]

Government intervention in the solar industry became politically toxic after the 2011 Solyndra scandal. Solyndra, a next-generation solar power company, announced it was filing for Chapter 11 bankruptcy and laid off its 1,100 employees in September 2011.[58] The company received a $535 million loan guarantee as part of the 2009 American Recovery and Reinvestment Act, meaning the federal government pledged to pay its private creditors in the case of insolvency.[59] After a media firestorm and a four-year investigation, the inspector general concluded that Solyndra misled the DOE in its loan guarantee application and that the DOE neglected to conduct full due-diligence efforts. Subsequent DOE loan guarantees have targeted mature solar and wind energy companies with secure utility contracts rather than start-ups like Solyndra.[60] Regardless of current DOE practices, the Solyndra case called into question the viability of using taxpayer funds to back clean energy projects.

---

54 Allen Newell and Herbert A. Simon, "Computer science as empirical inquiry: symbols and search," *Association for Computing Machinery* 19, no. 3 (March 1976): 113-126, doi:10.1145/360018.360022.

55 Animal and Plant Health Inspection Service, "A Short History of the Screwworm Program," U.S. Department of Agriculture, February 10, 2020, https://www.aphis.usda.gov/aphis/ourfocus/internationalservices/sterile_fly_release_programs/screwworm/screwworm_history.

56 Goksin Kavlaka, James McNerneya, and Jessika E. Trancik, "Evaluating the causes of cost reduction in photovoltaic modules," *Energy Policy* 123 (December 2018): 700-710, doi:10.1016/j.enpol.2018.08.015.

57 David Roberts, "What made solar panels so cheap? Thank government policy," Vox, December 28, 2018, https://www.vox.com/energy-and-environment/2018/11/20/18104206/solar-panels-cost-cheap-mit-clean-energy-policy.

58 Ucilia Wang, "Solyndra to file for bankruptcy, lay off 1,100," GigaOm Research, August 31, 2011, https://gigaom.com/2011/08/31/solyndra-to-file-for-bankruptcy-lay-off-1100/.

59 Katie Fehrenbacher, "Why the Solyndra mistake is still important to remember," Fortune, August 27, 2015, https://fortune.com/2015/08/27/remember-solyndra-mistake/.

60 Office of Inspector General, "The Department of Energy's Loan Guarantee to Solyndra, Inc.," U.S. Department of Energy, August 24, 2015, https://www.energy.gov/sites/prod/files/2015/08/f26/11-0078-I.pdf.

Recommendations

The United States must reemphasize its commitment to innovation by expanding federal R&D funding to strategic areas. Publicly funded R&D programs must model themselves off "start-up mode" policy experiments. Scalability, deployment, evaluation timelines, and methodology all must be adjustable with limited bureaucratic delay. Without the ability for revolutionary R&D ventures to "fail fast," the United States will fall behind its competitors in developing advanced solutions.

Drawing from the lessons of past funding surges, federal R&D spending, especially on basic research of critical technologies, should not increase all at once. Rather than following a "doubling policy"—aiming to double R&D spending over a given timeframe—it would be more productive to set a goal for R&D to achieve a certain percentage of overall GDP. This approach would limit market disruptions resulting from a rushed influx of capital into the research market. Also, to build a more sustainable innovation workforce, younger researchers should receive a greater share of R&D funding than they do currently. This policy will have the dual effects of recruiting new talent to the industry and investing in human capital that has a longer timeline for return.[61]

Communication between public institutions and private-sector developers is critical. Two international examples—Data61 in Australia and Digital Catapult in the United Kingdom—stand out as effective innovation networks. Data61 uses shared data and network expertise to conduct fundamental and applied research. A subcomponent of Australia's science agency, Data61 is afforded the flexibility to work within a "sandbox" setup, participating in challenge programs that reward creative solutions. Digital Catapult, on the other hand, selects a handful of target technologies and industries while partnering with academia, industry, and investors. In both of these programs, the government stays involved with private-sector innovation without impeding progress by enforcing strict guidelines.

The SBIR and STTR programs require reform. Lerner (2013) advises a few best practices for public involvement in the venture sector. First, funders should more thoroughly consider the entrepreneur's staff of lawyers, marketers, and engineers before throwing money at a merely promising idea. Second, federal authorities should incentivize academic tech transfer offices to play a greater role in fostering young companies rather than opting for partnerships with large corporations. Third, the government should be conscious of the overall venture capital market to avoid cannibalizing funding from private funds.[62]

When possible, the United States must move toward a model of open data access. Some private-sector data sets will remain restricted to protect trade secrets, but public-sector data must be made widely available for public use. This resource will generate a competitive innovation environment where firms will tend to collaborate with peers rather than withhold data from them. It would also allow data to be reused where relevant, increasing its economic utility. Such a model would not be the first of its kind; data from the United Kingdom's open portal has already been used to build online platforms such as TransportAPI.[63] As the government makes data accessible, it must also work to improve public trust around the issues of data privacy and ethics so that the data marketplace can thrive.

---

61 Richard Freeman and John Van Reenen, "What If Congress Doubled R&D Spending on the Physical Sciences?" *Innovation Policy and the Economy* 9, no. 1 (2009): 1-38, doi:10.1086/592419.

62 Josh Lerner, "The Boulevard of Broken Dreams: Innovation Policy and Entrepreneurship," *Innovation Policy and the Economy* 13, no. 1 (January 2013): 61-82, doi:10.1086/668239.

63 UK Government Digital Service, "Find open data," UK Government Digital Service, 2020, https://data.gov.uk.

At the same time, governments must be sensitive to the issue of data territoriality. The fluidity of data makes it difficult to ensure that the benefits of one country's data production are not reaped by its neighbor. The United States should seek out cooperative solutions to ensure countries can share the output of data flows incentivized by national policies. The OECD's Inclusive Framework for Base Erosion and Profit Shifting (BEPS) can provide some insights into how multilateral solutions can address this problem.[64] Without fair arbitration, national policies that facilitate international data flows will fail to capture popular legitimacy and will produce fewer innovative products than otherwise possible.

As a guiding principle, innovation policy should be results-oriented. Setting broad goals of intended outcomes, rather than focusing on development of specific technologies, will foster a more entrepreneurial environment. DARPA stands out as a prime example of this philosophy. Its Challenges initiative led to the development of functional autonomous vehicles in 2005 by university teams. The AV Challenge produced revolutionary breakthroughs in a truly emerging field; other agencies should take note of DARPA's best practices.

William Reinsch *holds the Scholl Chair in International Business at the Center for Strategic and Interna-tional Studies (CSIS) in Washington, D.C.* ***Jonathan Lesh*** *and* ***Lydia Murray*** *are former interns with the CSIS Scholl Chair. John Hoffner is a current intern with the CSIS Scholl Chair.*

This report is made possible by general support to CSIS. No direct sponsorship contributed to this report.

64 "Inclusive Framework on Base Erosion and Profit Sharing, Understanding Tax Avoidance," OECD, 2020, https://www.oecd.org/tax/beps/.