Data Brief

Bayh-Dole Patent Trends

Charting Developments in Government-Funded Intellectual Property Through Time

Authors
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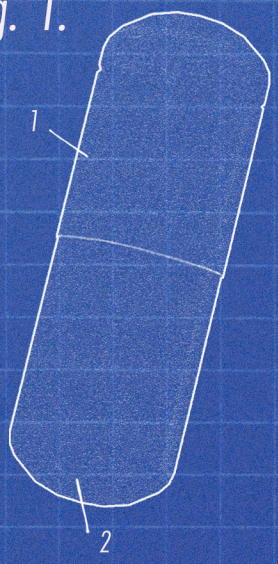
Fig. 1.



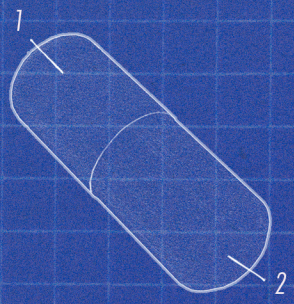


Fig. 2.

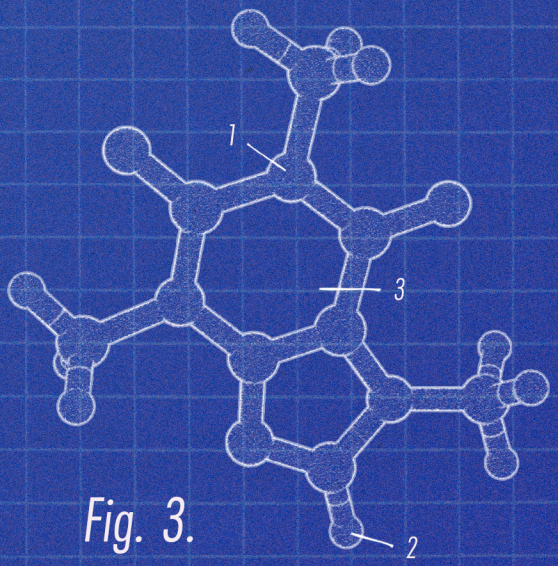


Fig. 3.

CSET CENTER for SECURITY and EMERGING TECHNOLOGY

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Executive Summary

In the last half century, few policies have done more to transform U.S. patenting than the Patent and Trademark Act Amendments of 1980, known as the Bayh-Dole Act. By allowing private entities—rather than the U.S. government—to retain ownership of patents developed through federally funded research, the law altered incentive structures within the U.S. innovation ecosystem. Since its passage, the law has been praised for laying the foundation for academic technology transfer, allowing universities to benefit financially from moving technologies from the lab to the private sector. Others, however, have criticized the law for privatizing the rewards of taxpayer-funded research.

Despite the Bayh-Dole Act's prominence in the U.S. innovation ecosystem, little research has attempted to characterize the publicly-funded, privately-owned IP produced under the law. In this data brief, we shed light on this under-explored corner of the U.S. patent landscape by analyzing declassified Bayh-Dole and non-Bayh-Dole patents granted between 1981 and 2020. Our analysis finds:

1. **The number of Bayh-Dole patents increased substantially from 1,635 in 1981 to 7,911 in 2020**. However, they have consistently accounted for a relatively small proportion (1.5 to 2.6 percent) of U.S. patents awarded in any given year.
2. **Bayh-Dole patents make up a larger share of patents in bioscience-related categories, like biotechnology (15 percent) and pharmaceuticals (8 percent), and defense-related categories like weapons manufacturing (10 percent).** They also represent a larger share in select emerging technology categories—AI, robotics, biotechnology—than in the overall U.S. patent landscape.
3. **The share of Bayh-Dole patents funded by different federal agencies has changed substantially over time.** In 2020, the top funders of Bayh-Dole patents included the National Institutes of Health (30 percent), Department of Defense (21 percent) and Department of Energy (15 percent).
4. **A substantial number of Bayh-Dole patents are awarded to universities**. Nine of the top 15 recipients of Bayh-Dole patents were academic institutions.

While our analysis sheds light on major trends in the Bayh-Dole patent landscape, more research is required to understand the law's role in the broader U.S. innovation ecosystem. Future analysis of patent licensing data, technology transfer trends, and the economic effects of march-in rights would help policymakers better understand the law's strengths and weaknesses, and identify potential reforms that would help maximize the social and economic benefits of publicly funded research.

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Introduction

Intellectual property (IP) protections are a foundational component of the U.S. innovation ecosystem. By offering inventors the exclusive right to exploit their creations for a period of time, patents create an economic incentive to pursue cutting-edge research, develop novel ideas, and ultimately produce new technologies.

Over the last half century, few policies have done more to transform the U.S. patenting landscape than the Patent and Trademark Act Amendments of 1980, more commonly known as the Bayh-Dole Act. Among other things, the law shifted ownership of government-funded inventions from the public to the private sector.[1] Previously, patents that resulted from federal research were assigned to the agency that supported the endeavor, which could then license out the IP as it saw fit. Under the Bayh-Dole Act, the recipients of federal funds were allowed to retain ownership of any patents they generated.[2] This change came as a major boon to universities and private companies, which could now generate fresh revenue streams off their government-funded work.[3]

It is still possible for the government to retain ownership of IP generated through federally funded research in certain cases. Patents produced through research conducted wholly by or in partnership with a government entity, such as a national laboratory, typically include that federal entity as an assignee. Funding agencies also acquire ownership of IP that the research "performer"—the organization that received funds and conducted the research—chooses not to retain.[4] The Bayh-Dole Act also permits the government to dictate or amend the terms of patent ownership in other "exceptional circumstances." In 2020, for instance, the Department of Energy declared that it could obtain ownership of Bayh-Dole patents related to quantum information science if contractors did not meet certain domestic manufacturing requirements.[5] However, these situations are rare, and in most cases, organizations that develop patented inventions through federally-funded research retain the associated IP rights.

The Bayh-Dole Act was designed to fix a purported inefficiency in the federal research ecosystem.[6] As the federal Research and Development (R&D) enterprise expanded in the aftermath of WWII, each agency developed its own processes for managing IP.[7] Over the years, leaders started raising concerns that these inconsistent policies hindered efforts to bring government-funded inventions to market.[8] By the 1970s, a growing consensus of lawmakers viewed the existing federal IP regime as a barrier to innovation, one that left thousands of patents collecting dust. In 1976, a Commerce Department official testified that only an estimated 5 percent of the 28,000 patents

assigned to federal agencies had been commercially licensed, while the rest were "doing no good to anybody."[9] These figures proved difficult to corroborate, but even so, proponents of the Bayh-Dole Act argued that private organizations with commercial incentives would do a better job exploiting this IP than federal agencies.[10]

In the years since its passage, the Bayh-Dole Act has earned much praise. *The Economist* hailed the law as "possibly the most inspired piece of legislation to be enacted in America over the past half-century," and numerous experts across industry and academia have echoed the same sentiment.[11] The law is broadly heralded as the foundation of the academic technology transfer process, as universities could now benefit financially from moving technologies from the lab to the private sector.[12] More than 11,000 startup companies spun out of university research between 1995 and 2017, and many experts credit the Bayh-Dole Act with creating this ecosystem.[13] However, some studies suggest these claims are overblown.[14] Annual academic patents had roughly quadrupled in the 15 years prior to the Bayh-Dole Act's passage, and some argue the law was more a response to growing university patenting activity rather than its driver.[15]

Furthermore, the measure has also attracted criticism that centers on the notion that taxpayer-funded inventions should not be leveraged to the exclusive benefit of a private organization. In a 1979 congressional hearing, Admiral Hyman Rickover—the reputed father of the nuclear submarine program—summarized this argument, remarking that "government contractors should not be given title to inventions developed at government expense … these inventions are paid for by the public and therefore should be available for any citizen to use or not as he sees fit."[16]

In recent years, critics have also focused on the federal government's reluctance to use the so-called "march-in" rights provided by the law. Under the Bayh-Dole Act, the government can force patent assignees to license their IP under certain circumstances, including situations in which the current assignee has not made an effort to use the IP or when there are public health concerns the assignee cannot address.[17] To date, federal policymakers have never exercised these rights. Lawmakers including Sens. Elizabeth Warren and Angus King have called on the National Institutes of Health (NIH) to use march-in rights against pharmaceutical companies, which could lower the cost of life-saving drugs invented through publicly funded research.[18] These calls received substantial pushback from some think tanks and industry advocates, who argue such measures would disincentivize innovation and "violate the spirit" of the Bayh-Dole Act.[19]

In light of these debates, it is critical to understand the role the Bayh-Dole Act plays in the U.S. innovation ecosystem. To date, little research has attempted to characterize the publicly-funded, privately-owned IP produced under the law. In this data brief, we aim to shed light on this under-explored corner of the U.S. patent landscape, examining trends in the number of Bayh-Dole patent approvals, the prevalence of Bayh-Dole patents in different categories, top funders of Bayh-Dole patents, and top recipients of Bayh-Dole patents. Future analysis of patent licensing data, technology transfer trends, and the economic effects of march-in rights would help policymakers better assess the law's strengths and weaknesses.

Methodology

Our dataset includes unclassified patents granted by the U.S. Patent & Trademark Office (USPTO) between 1981 and 2020. The grant date for each patent is used to evaluate trends over time. [20] To avoid double-counting patents that result from the same initial invention, we only include the first granted U.S. patent in each patent family. Subsequent patents in the family (such as continuations, continuations-in-part, and divisionals) are not included. [21] We divide patents into two categories:

1. **Bayh-Dole patents**: Patents that were developed at least partially with government funding. [22] Note that while we use "Bayh-Dole patents" as a short-hand for all patents produced via government funding, not all of the patents we analyze fall under the Bayh-Dole Act (e.g., patents already assigned to government agencies). This category includes:

    i. *Government Bayh-Dole patents*, which are assigned at least in part to a federal agency; and,

    ii. *Private Bayh-Dole patents*, which were developed through government-funded research (as disclosed by the patent applicants), but assigned to a non-government entity.

2. **Non-Bayh-Dole patents**: USPTO-granted patents that were not developed via government-funded research.

Most of our analysis compares Bayh-Dole patents to non-Bayh-Dole patents, but in some cases, we discuss trends in government Bayh-Dole and private Bayh-Dole patents separately. Note that our analysis focuses only on unclassified patents granted

by the USPTO, not all patents filed (but not yet granted) in the United States during the period of time under observation.

With these two categories in mind, we examine the following:

1. How has the number of Bayh-Dole patents changed over time, and what is their share of the overall U.S. patent ecosystem?
2. In what technology categories are Bayh-Dole patents most prominent?
3. What federal agencies are the top funders of research that produces Bayh-Dole patents?
4. What types of entities are granted the most Bayh-Dole patents, and does this vary across emerging technology categories?

We use datasets curated by 1790 Analytics, which rely on criteria from Cooperative Patent Classification (CPC) codes, International Patent Classification (IPC codes), and keywords to define patent categories and emerging technologies. For comparisons to all U.S. patents, we use CSET's unified patent dataset, which contains patent data from Dimensions and 1790 Analytics.[23]

It is important to note that patents can have multiple assignees or inventors. They can also be associated with multiple technology categories or topics. For instance, a patent can be AI-related, robotics-related, and "industrial" (i.e., often involving business or manufacturing) in nature. Our analysis deduplicated annual patent counts for all Bayh-Dole and non-Bayh-Dole patents to provide a reference point for the scale of government-funded patents in the U.S. patent ecosystem.

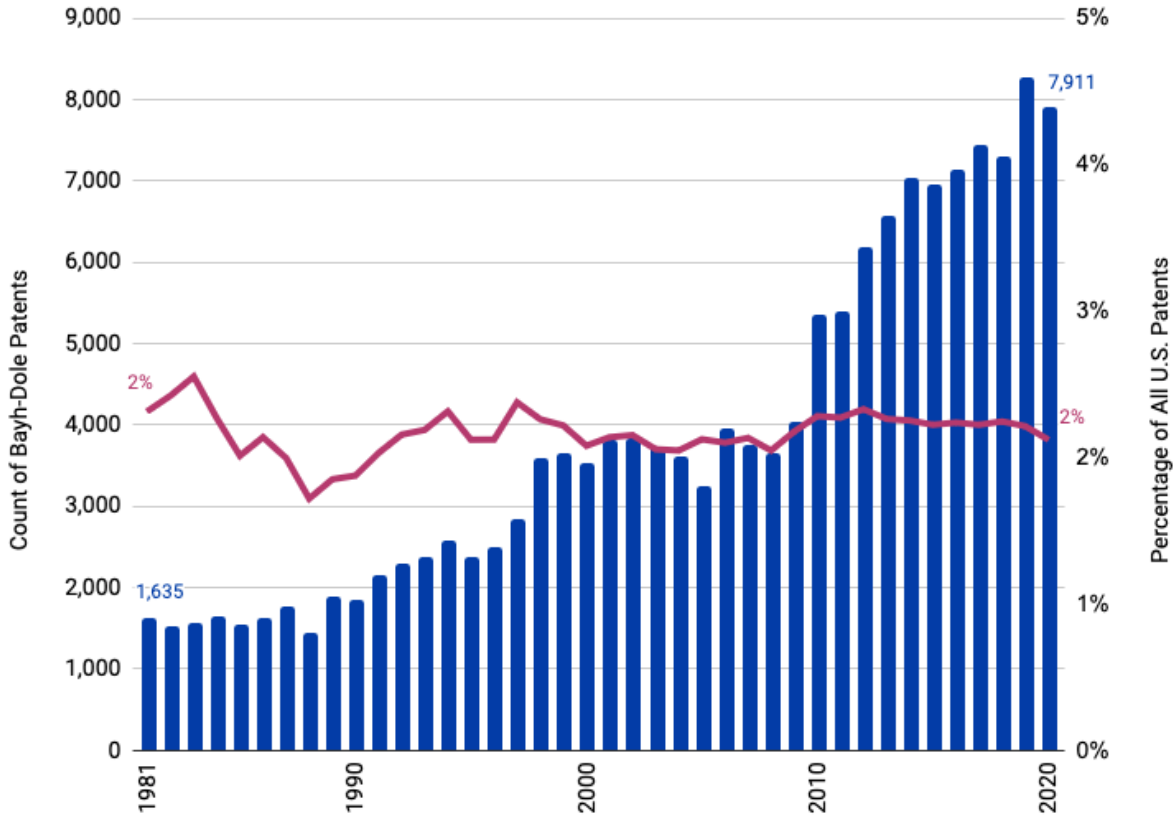
Results

Bayh-Dole Patents Over Time

Our analysis found the annual number of Bayh-Dole patents issued by the USPTO has risen steadily from the law's passage in the early 1980s through the present day. As shown in Figure 1, the number of Bayh-Dole patents granted annually rose substantially over the last four decades, from 1,635 in 1981 to 7,911 in 2020.[24] However, this increase generally tracked the broader growth in U.S. patenting activity during the same period, and overall, Bayh-Dole patents represent a relatively small proportion of U.S. patents. Only about 2 percent of U.S. patents granted between 1981 and 2020 fall under the Bayh-Dole Act, meaning that they were directly developed

through federal funding (Bayh-Dole patents). These include both "government Bayh-Dole patents" assigned to federal agencies *and* privately-assigned Bayh-Dole patents.

Figure 1. Bayh-Dole Patents Issued Annually, 1981-2020



Source: 1790 Analytics and CSET unified patents dataset

Interestingly, the growth in Bayh-Dole patent production since 1981 far outpaced the increase in government R&D funding that ostensibly helped produce those patents. While we find that the number of Bayh-Dole patents granted annually rose nearly 400 percent between 1981 and 2020, federal R&D spending only increased about 72 percent during that same period (when adjusted for inflation).[25] There are a variety of possible reasons for this trend, including changes in joint-funding arrangements, and changes in the relative distribution and size of funding programs. However, this topic falls beyond the scope of this brief.

Bayh-Dole Patents by Technology Category

While Bayh-Dole patents constitute a relatively small share of U.S. patents overall, they are more prevalent in certain technology categories than others. We use CSET patent categories to classify patents.[26] Figure 2 shows the number and share of patents in select categories that resulted from federal funding.[27] In general, Bayh-Dole patents tend to make up a larger proportion of patents in bioscience-related categories, like biotechnology and pharmaceuticals, as well as defense-related categories like weapons manufacturing, compared to the proportion of Bayh-Dole patents across all categories.

Federally funded patents make up a smaller share of the intellectual property in information and communication technology (ICT) categories such as semiconductors, telecommunications, computing equipment, and information storage. One potential explanation for this pattern is the rapid digitization of the global economy in recent decades. Bayh-Dole patents made up a larger proportion of the IP in computing categories through the 1980s, but fell off amid the expansion of the commercial hardware and software industry in the 1990s. As private ICT companies multiplied, they built off the foundational federally-funded innovations and generated more patents, ultimately reducing the government's role in the space.[28] Another possible explanation relates to the nature of the technology itself—other researchers have found that government funding is more important for driving innovation in categories that are more constrained by unproven technologies, like biotechnology, than unproven commercial demand, like ICT.[29]

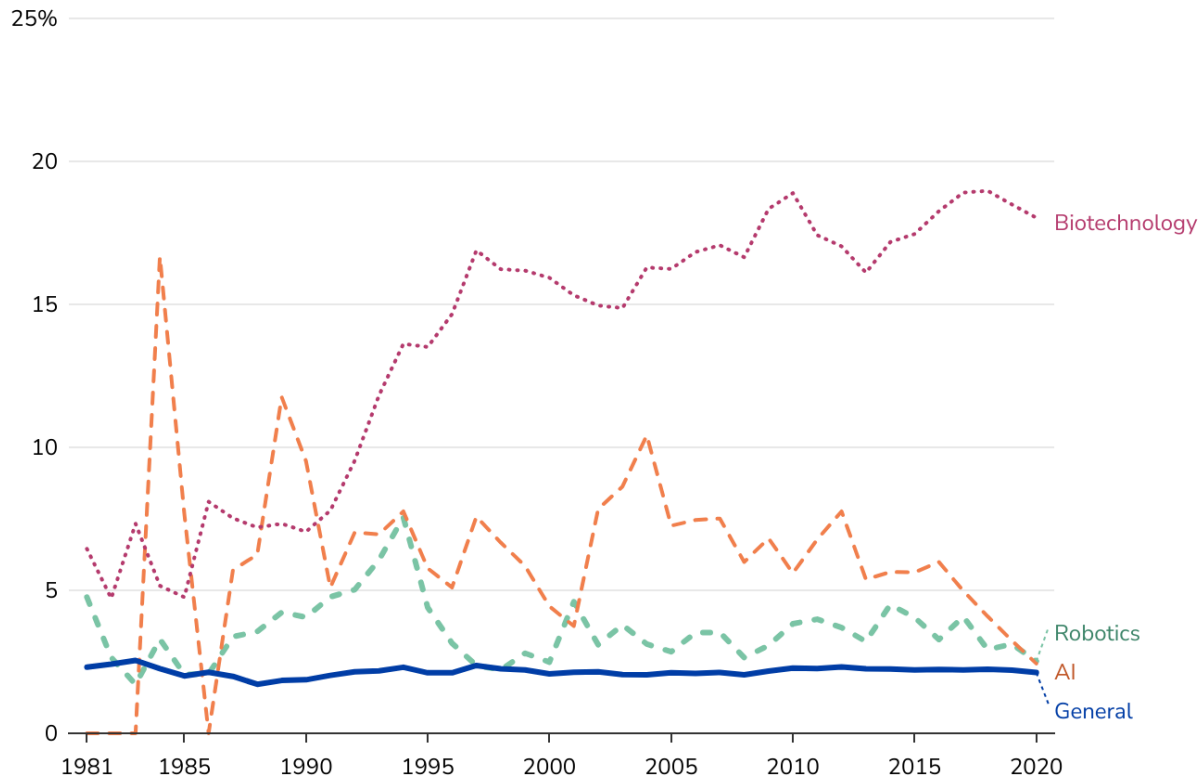
Figure 2. Share of Bayh-Dole Patents by Category

Category	Bayh-Dole Patents	Non-Bayh-Dole Patents	Percentage Bayh-Dole
Biotechnology	15,328	85,185	15%
Nanotechnology	829	6,924	11%
Weapons Manufacturing	3,104	26,479	10%
Pharmaceuticals	11,207	133,236	8%
Measuring and Control Equipment	18,987	320,022	6%
Additive Manufacturing	31	601	5%
Chemicals	13,250	395,228	3%
Other Vehicle Transportation	2,428	90,789	3%
Optics and Photography	5,768	239,109	2%
Information and Communication	4	172	2%
Metals Manufacturing	4,279	189,883	2%
Diagnosis Medical Equipment	6,088	282,559	2%
Electrical Equipment Manufacturing	7,198	352,857	2%
Semiconductors and Electronics	6,812	343,121	2%
Miscellaneous Manufacturing	7,239	437,174	2%
Layered Products Manufacturing	392	24,446	2%
Computing Equipment	6,978	461,056	1%
Telecommunications	9,088	726,641	1%
Information Storage	938	138,015	1%
Road Vehicle Transportation	913	224,096	0%

Source: 1790 Analytics and CSET unified patents dataset
Note: We deduplicated patent counts to ensure there is no overlap between categories

Beyond broad technology categories, we were also able to examine the prevalence of Bayh-Dole patents in three emerging technology categories—AI, robotics, and biotechnology—using custom taxonomies created by 1790 Analytics.[30] Our analysis relies on a similar calculation of the share of patents in each technology category that were produced through federally funded research every year from 1981 to 2020. Figure 3 shows the percentage of annual patent awards in each category that were covered by the Bayh-Dole Act, as well as the annual share of all U.S. patents that were covered by the Act (delineated in blue).

Figure 3. Share of Bayh-Dole Patents by Emerging Technology Category



Source: 1790 Analytics and CSET unified patents dataset
Note: No data exists for Bayh-Dole AI patents in 1986 or before 1984

By 1987, Bayh-Dole patents accounted for a higher share in all three emerging technology categories than in the general pool of U.S. patents. Federally funded research produced a particularly large share of the patents in biotechnology, a category that encompasses basic biological research, bio-AI, and bioinformatics. In 2020, federal research played a role in producing about 18 percent of all U.S.

biotechnology patents and only about 2 percent of U.S. patents overall. The prevalence of federally-funded patents in this technology category is likely driven in part by the government's intensive focus on biomedical research through organizations like the NIH. Experts have noted that federal financial support for biotechnologies, especially in their nascent stages, is critical for facilitating R&D in the private sector by providing publicly accessible groundwork for early-stage technology and science.[31]

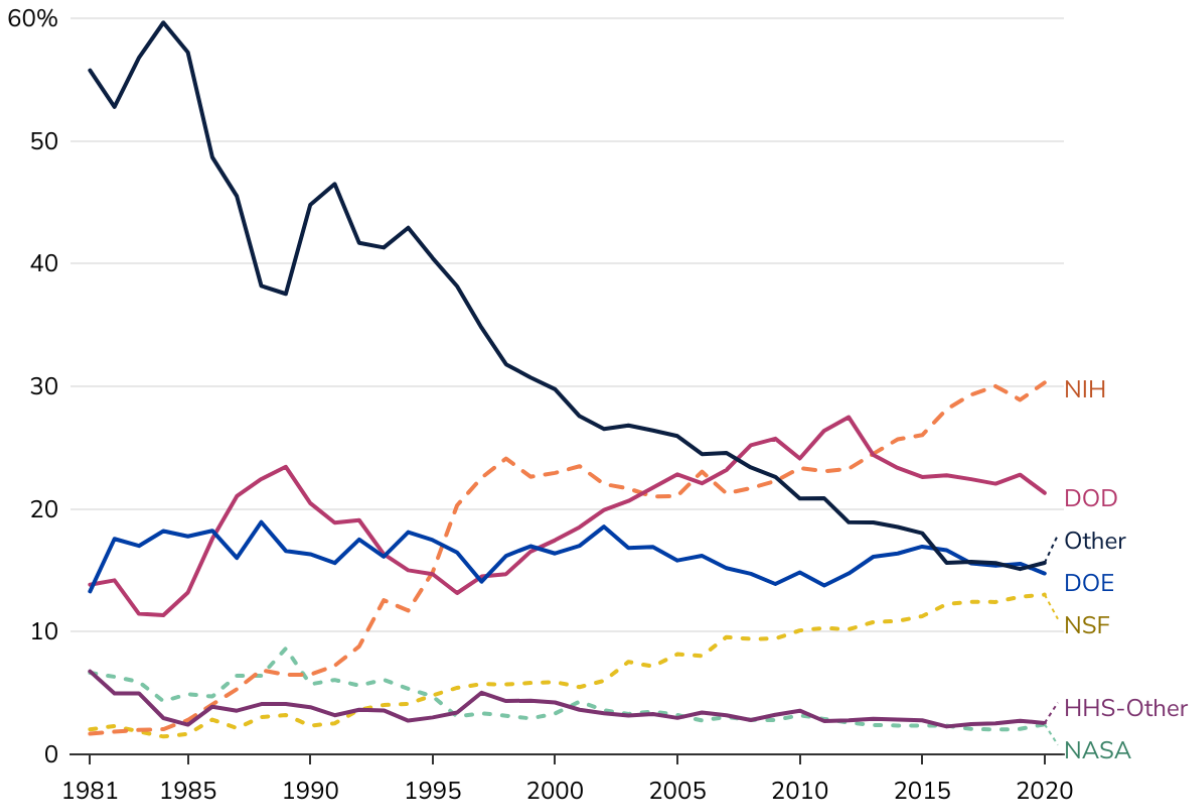
Bayh-Dole patents also make up a larger-than-average share of patents in AI and robotics, though they have declined in recent years.[32] In 1994, Bayh-Dole patents comprised over 7 percent of U.S. robotics patents before dropping to around 2 percent of all U.S. robotics patents by 2020. The share of Bayh-Dole patents in AI was even higher initially—when AI patents appeared in the USPTO corpus in 1989—11 percent of patents in this technology category were developed through government-funded research. This figure ebbed and flowed, but by 2020, less than 3 percent of AI patents granted in the United States were Bayh-Dole. The decrease in shares of AI and robotics Bayh-Dole patents may be due to the fact that part of the value of government funding in research is infusing resources into novel technologies that may not be immediately profitable or require long-term financial and time investments. Perhaps robotics and AI required more government R&D funding when they were less commercially viable, but then as technologies matured and entered mainstream markets, industry was able to more readily build on existing knowledge and develop new innovations.

Bayh-Dole Patents by Funding Source

By definition, Bayh-Dole patents are at least partially developed through government-funded research. Analyzing the federal agencies that funded Bayh-Dole patents can illuminate broader trends in the federal research ecosystem.

Figure 4 shows the share of Bayh-Dole patents by federal agency funding source each year from 1981 to 2020. We find the NIH supported more patented research than any other agency, funding the development of more than 40,000 patents since 1981. A high number of patents are also developed through funding from the Department of Defense (DOD), which has supported the production of more than 39,000 patents since 1981. Nearly half of all Bayh-Dole patents granted since 1981 were by one of these two agencies.

Figure 4. Distribution of Bayh-Dole Patents by Funding Agency, 1981-2020



Source: 1790 Analytics
Note: "Other" government agencies include the U.S. Department of Agriculture, National Institute of Standards and Technology, and others. "HHS-Other" includes all branches of the Department of Health and Human Services (HHS) except NIH.

The NIH, NSF, and DOD's share of funded patents grew over the period examined. NIH has become the most prominent patent-funding agency in the past decade. In 1981, NIH funded less than 2 percent of patents, but by 2020, it supported over 30 percent—again, this growth coincided with a significant increase in the NIH budget, which rose more than 300 percent between 1981 and 2020 when adjusted for inflation.[33] The proportion of NSF-funded patents also rose substantially, from 2 percent in 1981 to 13 percent in 2020. The share of Bayh-Dole patents developed through DOD funding also rose during the same period, from 14 percent to 21 percent.

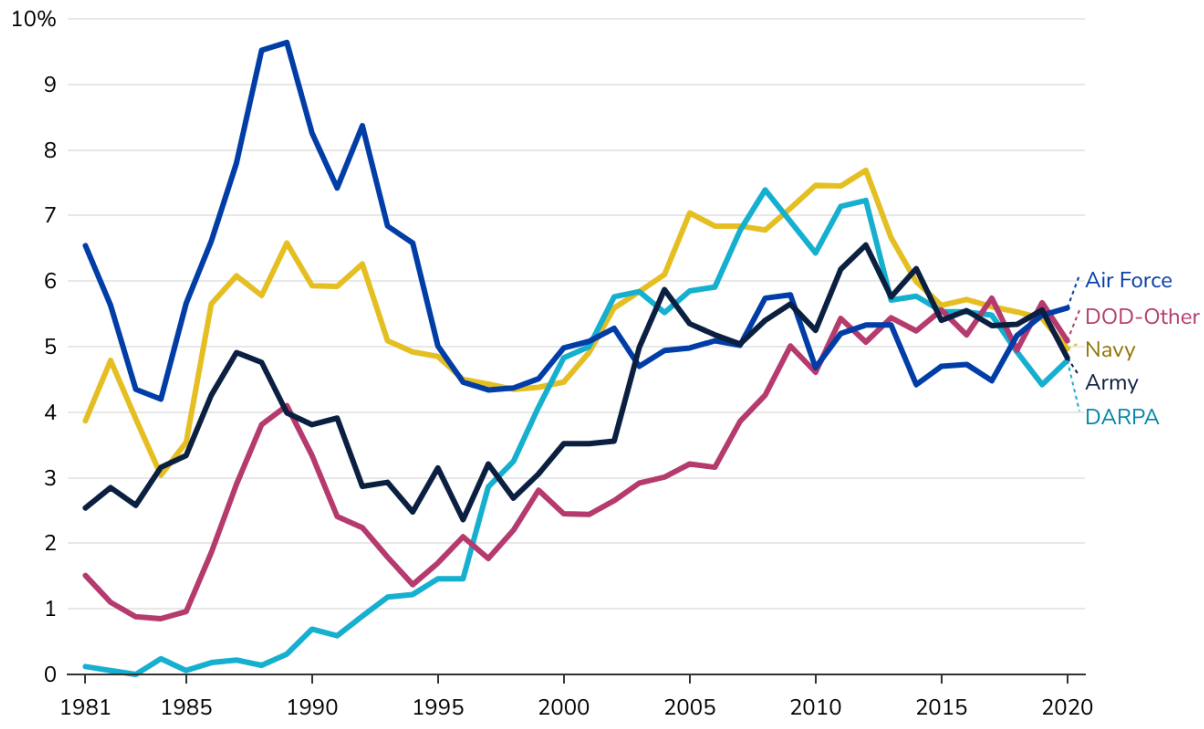
The share of Bayh-Dole patents funded by the Department of Energy (DOE) and NASA remained steady or decreased over time. The DOE has consistently accounted for

about 15 percent of Bayh-Dole patents over the past four decades, while the share funded by NASA fell from roughly 7 percent in 1981 percent to 2 percent in 2020.[34]

Bayh-Dole Patents in the DOD

Additionally, we saw changes in patent funding patterns among the various service branches and agencies within the DOD.[35] Figure 5 shows the proportion of DOD-funded patents that were aligned with different agencies and services.

Figure 5. Share of Bayh-Dole Patents Held by DOD Agencies and Service Branches



Source: 1790 Analytics

In the past decade, the Air Force, Army, Navy, and DARPA have each come to account for about 20 percent of DOD-funded patents, while the remaining 20 percent is attributable to agencies like NSA, DRTA, MDA, and USUHS that together made up the broader "DOD-Other" category. Between 1981 and 2000, the Air Force dominated research that yielded patents (over 40 percent of DOD-funded patents in 1981), followed by the Navy (25 percent) and the Army (nearly 20 percent).

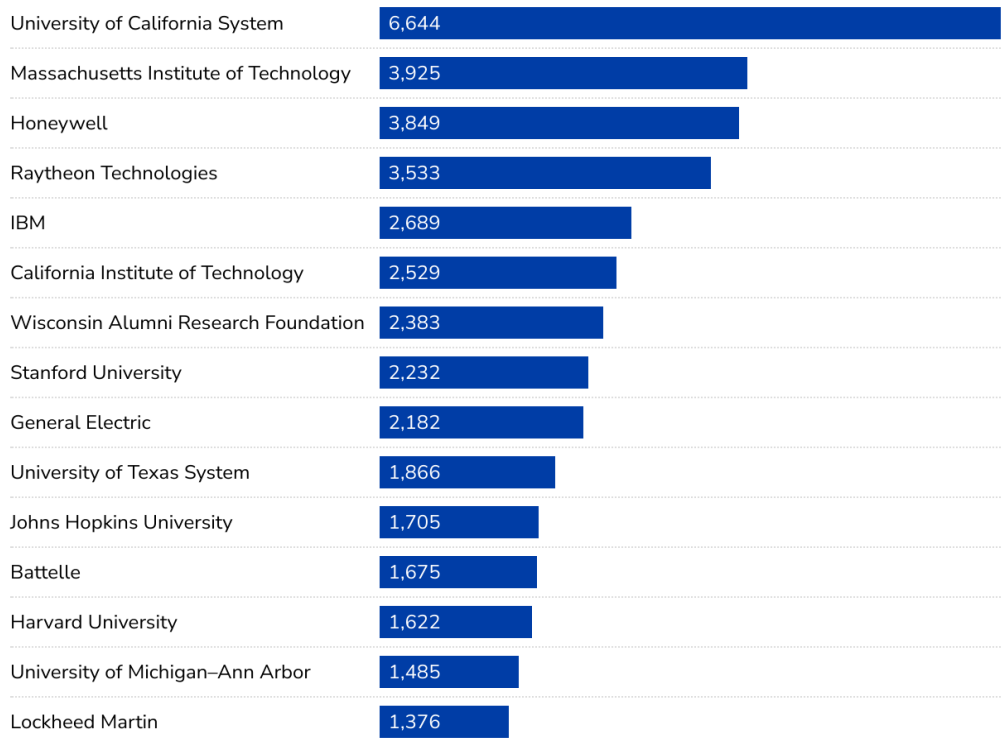
The increase in DARPA-funded patents over the four decades is especially notable; DARPA accounted for 19 percent of DOD-funded patents in 2020, up from less than 1 percent in 1981. The reasons for this growth is unclear—it may result from an increase in research productivity, a shift away from classified R&D, a greater focus on applied research, or other factors. This growth is particularly notable considering the agency's inflation-adjusted budget did not increase dramatically during this time.[36]

Top Patent Assignees

While government research funders sometimes own the patents resulting from the research they financed, other entities or individuals (patent "assignees") may also own Bayh-Dole patents. Here, we examined the top assignees on Bayh-Dole patents, noting that patents can have multiple assignees or that an assignee may be included after they no longer have rights to the patent (e.g., they sold their rights).[37] Below, we display the top non-government entities listed as assignees on Bayh-Dole patents between 1981 and 2020.[38] This list is primarily composed of large research universities and companies that do substantial government contracting work. The University of California system topped the list, followed by MIT, Honeywell, Raytheon, and IBM, respectively.

Looking at the top 15 assignees for patents in emerging technology categories (Table C in Appendix), there is some overlap with those listed in Table 1, including the University of California and Stanford University. Several of the top assignees overlap across robotics and AI, including Honeywell, MIT, and the California Institute of Technology.

Table 1. Most Frequent Bayh-Dole Patent Assignees

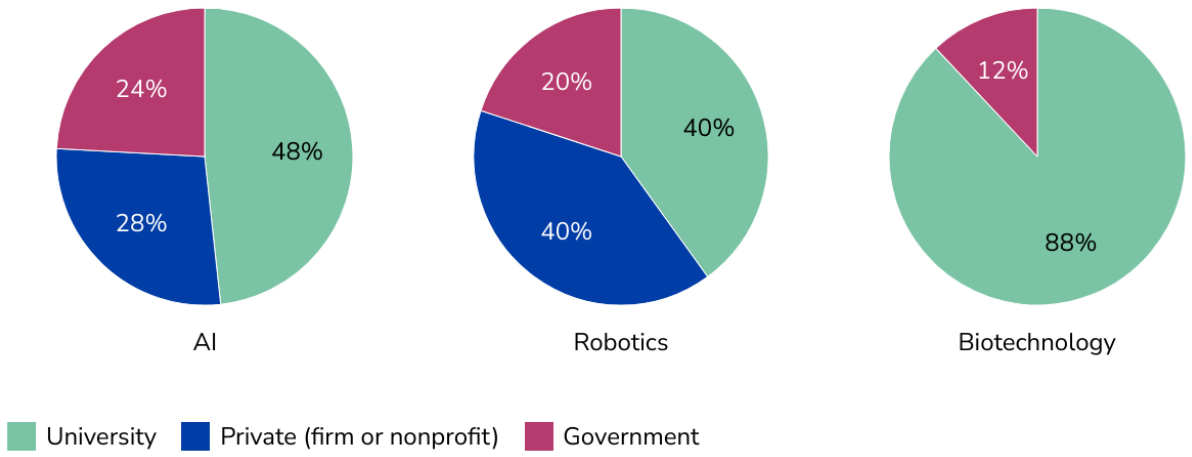


Source: CSET unified patents dataset

As shown in Figure 6, most of the top Bayh-Dole patent holders in the field of biotechnology are academic institutions—22 of the 25 organizations that hold the most Bayh-Dole biotechnology patents were universities. Notably, there are no private companies among the top 25 most prolific biotechnology Bayh-Dole patent holders (see details in Appendix). Academic institutions are not as dominant in other emerging technology fields, though they still represent a large share of top Bayh-Dole patent holders. Fourteen of the top 29 AI Bayh-Dole patent holders were universities, as were 10 of the top 25 robotics Bayh-Dole patent holders.* This finding is consistent with government-funded patents' outsized role in the biotechnology patent ecosystem in general. Because the lead time between R&D and profitability may be long, universities, government, and non-profit-driven entities may have been better equipped to conduct foundational and basic bioscience and biotechnology research.

* We included the 29 top Bayh-Dole patent holders in AI due to ties and null values

Figure 6. Top Bayh-Dole Emerging Technologies Patents Holders (1981-2020)



Source: 1790 Analytics
Note: "Government" entities include agencies like the U.S. Department of the Army, the U.S. Department of the HHS, and the U.S. Department of Energy.

Conclusion

Over the last half century, few policies have done more to transform the U.S. patenting landscape than the Bayh-Dole Act. The law—which allowed private entities to retain ownership of patents developed through federally funded research—is broadly heralded as the foundation for academic technology transfer and laid the groundwork for numerous commercial innovations. At the same time, the law has drawn criticism for privatizing the rewards of publicly funded research. This brief examined broad trends in Bayh-Dole patents and shed light on the role federal funding plays in the U.S. patent landscape.

Our analysis found the number of Bayh-Dole patents granted annually has more than quadrupled since the law's passage in 1980, though these patents represent a relatively small and stable portion of U.S. intellectual property production overall. Only about 2 percent of the U.S. patents granted between 1981 and 2020 were directly developed with federal funding.

However, Bayh-Dole patents are much more prevalent in certain technology categories, particularly those related to the biosciences (pharmaceuticals, biotechnology) and defense (weapons manufacturing). Our findings suggest federal funding also plays a significant role in generating IP in emerging technology

categories, particularly in their earliest days. Bayh-Dole patents made up a relatively large share of the early IP in AI and robotics, but the proportion fell as the fields commercialized. Bayh-Dole patents still make up a large share of overall patents in biotechnology.

Our analysis also found the top funders of Bayh-Dole patents have shifted over time. While the DOD and DOE have historically funded a significant share of patent-generating research, since the passage of the Act, other agencies—namely NIH and NSF—have emerged as major funders as well. Additionally, our analysis found the top recipients of Bayh-Dole patents tend to be universities and large companies that do a significant amount of government contracting.

While our analysis sheds some light on major trends in the Bayh-Dole patent landscape, more research is required to understand the law's role in the broader U.S. innovation ecosystem. Future analysis of patent licensing data, technology transfer trends, and the economic effects of march-in rights (see Introduction and Appendix) would help policymakers better understand the law's strengths and weaknesses, and identify potential reforms that would help maximize the social and economic benefits of publicly funded research.

Authors

Sara Abdulla is a former data research analyst at the Center for Security and Emerging Technology, where Jack Corrigan is a senior research analyst.

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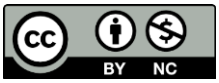

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Appendix

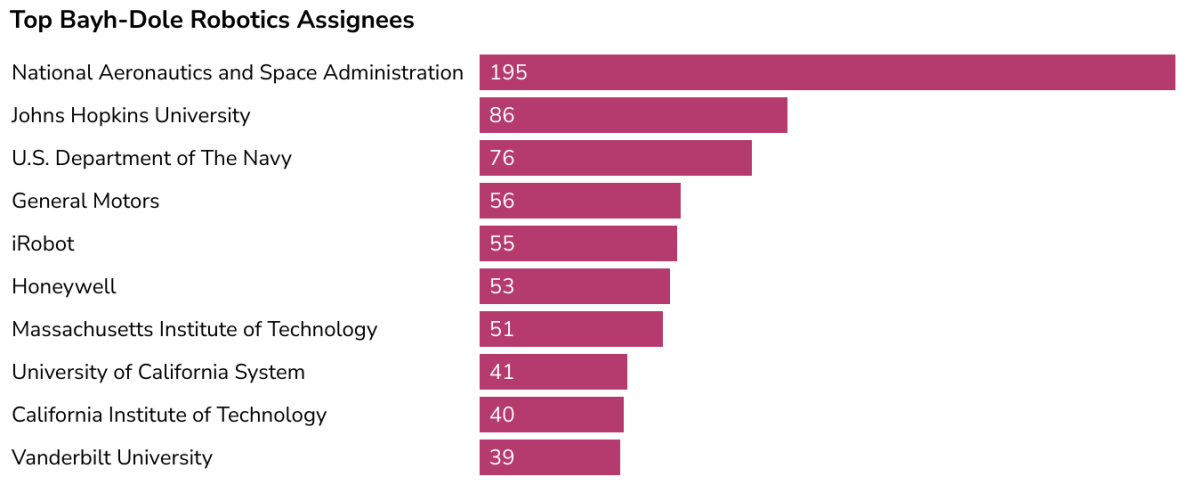
A. *Provisions of Bayh-Dole*

The Department of Commerce issued codified regulations on the Bayh-Dole act in 37 C.F.R. 401. As outlined in a May 1998 GAO report[39], these regulations include:

- Unless the government notes otherwise or "exceptional circumstances" arise, the entity that receives funding (university, government contractor, etc) retains the title to the patents they produce from the government funding.
- The government must receive a "nontransferable, irrevocable, paid-up, nonexclusive license ("confirmatory license") to use the invention."
- "March-in rights:" the government has the right to take over the patent for health or safety concerns. Separately, the government may take over the patent if the entity that receives funding doesn't adequately try to develop the patent invention.
- Small businesses should receive priority for licenses to use the patented inventions.
- The invention should be "manufactured substantially" in the United States.
- The entity that received funding should inform the government of inventions within 2 months.
- The entity that received funding should share royalties with the inventor(s).
- The entity that received funding should inform the government within 2 years of patent filing/disclosure. Once the entity receives patent protection (the 1-year statutory period), the government may shorten the disclosure period to 60 days before the statutory period ends.

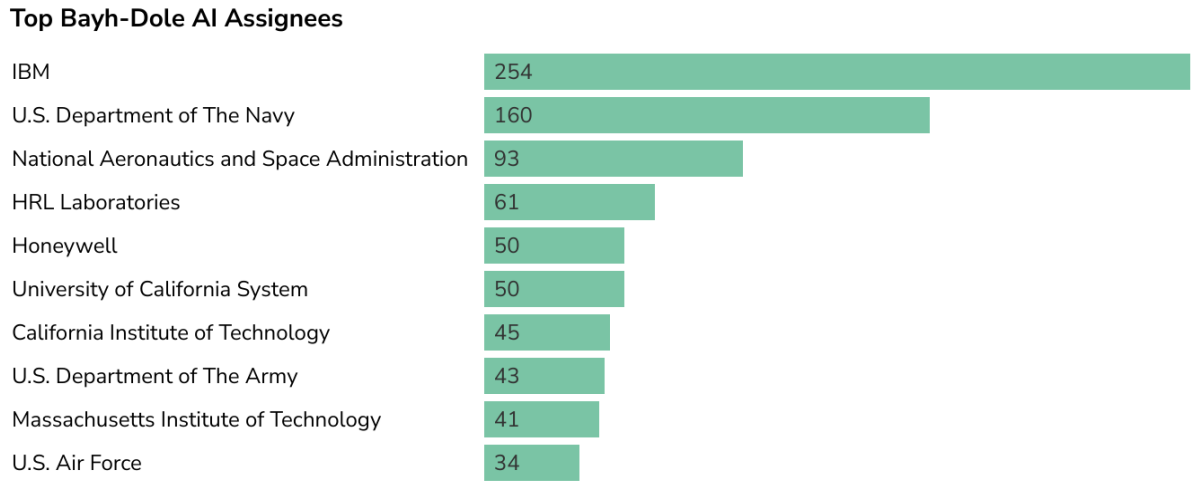
B. Top 10 Bayh-Dole Assignees for Robotics, AI, and Biotechnology Patents

Figure B1: Top 10 Bayh-Dole Assignees for Robotics, 1981-2020



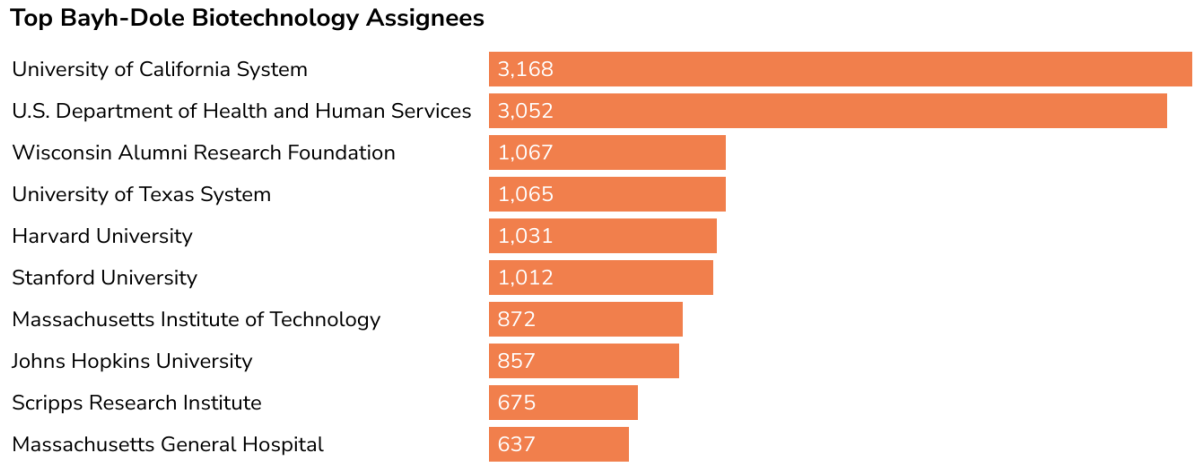
Source: 1790 Analytics

Figure B2: Top 10 Bayh-Dole Assignees for AI, 1981-2020



Source: 1790 Analytics

Figure B3: Top 10 Bayh-Dole Assignees for Biotechnology, 1981-2020



Source: 1790 Analytic

Endnotes

[1] Patent and Trademark Law Amendments Act, Pub. L. No. 96-517, 94 Stat. 3015 (1980).

[2] While private entities may retain ownership of IP developed through federally funded research, they are themselves responsible for paying for the patent application process. Additionally, the Bayh-Dole Act defines relevant funding agreements as any "contract, grant, or cooperative agreement entered into between any Federal agency, other than the Tennessee Valley Authority, and any contractor for the performance of experimental, developmental, or research work funded in whole or in part by the Federal Government."

[3] Initially, the law only applied to a "person, small business, or nonprofit organization," but subsequent executive orders allowed large businesses to benefit from the measure as well. For more, see: Ronald D. Lee and Amanda J. Sherwood, "Amendments to Bayh-Dole Act Regulations Tweak Rights to Inventions Made Using Federal Assistance," *Arnold & Porter*, May 25, 2018, https://www.arnoldporter.com/en/perspectives/advisories/2018/05/amendments-to-bayh-dole-act-regulations-tweak.

[4] Universities, companies and other organizations that develop patents through federally funded research must notify the government that they wish to retain ownership of that IP within two years in order to be assigned the patent. For more information, see: Government Accountability Office, *Technology Transfer: Administration of the Bayh-Dole Act by Research Universities*, (Washington, DC; 1998), p. 3, https://www.gao.gov/assets/rced-98-126.pdf.

[5] Office of Science, "Determination of Exceptional Circumstances Under the Bayh-Dole Act for Quantum Information Science Technologies," Department of Energy, August 28, 2020, https://www.energy.gov/sites/default/files/2021-07/DEC%20Quantom%20Info%20Science%20%28QIS%29%20Signed%20%209-16-2020.pdf.

[6] Government Accountability Office, *Technology Transfer: Administration of the Bayh-Dole Act by Research Universities*.

[7] Ibid.

[8] The Kennedy administration attempted to streamline federal patent policies and promote commercialization through a 1963 executive order. The order permitted the government to offer stronger IP rights to contractors "in exceptional circumstances" when doing so would be necessary to commercialize the invention. For more, see: F.R. Doc. 63-10888 (1963).

[9] This figure is based on the 1976 congressional testimony of Howard I. Forman, the then-deputy assistant secretary of commerce for product standards: Howard I. Forman, "Government Patent Policy," Testimony to Subcommittee on Domestic and International Scientific Planning and Analysis, 94th

Congress, June 3, 1975, https://books.google.com/books?id=yxrSAAAAMAAJ&pg=PP5&lpg=PP5&dq=house+committee+on+science+and+technology+september+1976+hearings+howard+forman&source=bl&ots=P6aW4G5IZv&sig=ACfU3U1HlRXRLTAdjYQd8_dJeQijJM7s0w&hl=en&sa=X&ved=2ahUKEwijz9e1zrj9AhWhmmoFHQzUCNA4HhDoAXoECAIQAw#v=onepage&q=house%20committee%20on%20science%20and%20technology%20september%201976%20hearings%20howard%20forman&f=false.

[10] Alexander Zaitchik, "The Great American Science Heist," *The Intercept*, August 29, 2021, https://theintercept.com/2021/08/29/bayh-dole-act-public-science-patents/.

[11] "Innovation's Golden Goose," *The Economist*, December 14, 2022, https://www.economist.com/technology-quarterly/2002/12/14/innovations-golden-goose; Stephen Ezell, "The Bayh-Dole Act's Vital Importance to the U.S. Life-Sciences Innovation Ecosystem," *Information Technology & Information Foundation*, March 4, 2019, https://itif.org/publications/2019/03/04/bayh-dole-acts-vital-importance-us-life-sciences-innovation-system/.

[12] "Landmark Law Helped Universities Lead the Way," *AUTM*, accessed January 2023, https://autm.net/about-tech-transfer/advocacy/legislation/bayh-dole-act.

[13] "Driving the Innovation Economy:academic technology transfer in numbers," *AUTM*, accessed January 2023, https://autm.net/AUTM/media/SurveyReportsPDF/Survey%20Reports%20Images/AUTM_2017_Infographic_1.pdf; Walter Copan, "Reflections on the Impacts of the Bayh-Dole Act for U.S. Innovation, on the Occasion of the 40th Anniversary of this Landmark Legislation," *IPWatchdog.com,* November 2, 2020, https://ipwatchdog.com/2020/11/02/reflections-on-the-impacts-of-the-bayh-dole-act-for-u-s-innovation-on-the-occasion-of-the-40th-anniversary-of-this-landmark-legislation/id=126980/.

[14] Richard R. Nelson, Arvids A. Ziedonis, Bhaven N. Sampat, and David C. Mowery, *Ivory tower and industrial innovation: University-industry technology transfer before and after the Bayh-Dole Act* (Stanford University Press, 2015).

[15] Elizabeth Popp Berman, *Creating the Market University: How Academic Science Became an Economic Engine* (Princeton University Press, 2012), 101.

[16] Zaitchik, "The Great American Science Heist."

[17] Patent and Trademark Law Amendments Act, Pub. L. No. 96-517, 94 Stat. 3015 (1980).

[18] Warren and King specifically called for the forcible licensing of the patent for Xtandi (enzalutamide), a drug used to treat prostate cancer. The average price of Xtandi is reportedly six-times higher in the United States than in other countries. Warren and King argue that by charging this high price, companies have violated the Bayh-Dole Act's requirement to make the invention "available to the public on reasonable terms." For more, see: Elizabeth Warren, Lloyd Doggett, Angus King, Letter to Xavier

Becerra, February 17, 2022, https://www.warren.senate.gov/imo/media/doc/2022.02.17%20Letter%20to%20Sec.%20Becerra%20on%20Xtandi%20March-in%20Petition%20(2).pdf.

[19] Alexander Kersten and Gabrielle Athanasia, "March-In Rights and U.S. Global Competitiveness," *Center for Strategic & International Studies*, March 24, 2022, https://www.csis.org/analysis/march-rights-and-us-global-competitiveness; Joseph P. Allen et al., Letter to Xavier Becerra, March 17, 2022, https://autm.net/getmedia/6f21972a-6737-4c74-bdfa-921d77e73b57/Bayh-Dole-Coalition-letter-to-HHS-on-Xtandi-march-in-petition,-March-2022.pdf; Joseph P. Allen, "President Biden: Don't misuse march-in rights," *Stat*, September 17, 2021, https://www.statnews.com/2021/09/17/president-biden-dont-misuse-bayh-dole-march-in-rights/; Megan Van Etten, "Patients and innovators lose if the government pursues 'march-in'," *PhRMA*, September 7, 2021, https://catalyst.phrma.org/patients-and-innovators-lose-if-the-government-pursues-march-in.

[20] We use publication year, not first filing date, to group and filter year variables since we only examine granted patents. For more details, see: Sara Abdulla, "China's Robotics Patent Landscape" (Center for Security and Emerging Technology, August 2021). https://doi.org/10.51593/20210002. Our analysis excludes classified patents, which are inventions whose disclosure the USPTO deems potentially "detrimental to national security." There were roughly 5,800 classified patents as of 2017, and excluding these patents, which often relate to defense systems, may affect some of our findings. For more information, see: Pub. L. No. 106-113, 113 Stat. 1501A-566 (1999); Steven Aftergood, "Invention Secrecy Activity (as reported by the Patent & Trademark Office)," *Federation of American Scientists*, accessed March 2023, https://sgp.fas.org/othergov/invention/stats.html.

[21] For more details about CSET's patent datasets, see Dewey Murdick and Patrick Thomas, "Patents and Artificial Intelligence: A Primer" (Center for Security and Emerging Technology, September 2020). https://doi.org/10.51593/20200038 or CSET's CAT: Husanjot Chahal, Jennifer Melot, Sara Abdulla, Zachary Arnold, and Ilya Rahkovsky, "Country Activity Tracker" (Center for Security and Emerging Technology, August 2022).

[22] Note that here, the government does not necessarily fund the patenting process, but funds the research that leads to patented innovations.

[23] Data sourced from Dimensions, an inter-linked research information system provided by Digital Science (http://www.dimensions.ai).

[24] Note that the average time from filing to approval for U.S. patents is 26 months.

[25] National Center for Science and Engineering Statistics, "National Patterns of R&D Resources: 2021" National Science Foundation, Table 2, https://ncses.nsf.gov/data-collections/national-patterns.

[26] CSET patent categories are industry-based category labels for patents and patent families derived from patent classification codes (CPCs and IPCs). The patents and patent families labeled are in CSET's unified patent dataset. Patents are only assigned one category.

[27] Our dataset includes 46 patent categories. Note that not all patents are assigned to a patent category. There are 582 Bayh-Dole patents and 656,257 granted U.S. patents between 1981 and 2020 that are *not* assigned to a patent category. We selected the 20 technology categories included here based on their relevance to critical and emerging technology areas, as well as their share of Bayh-Dole patents.

[28] Rebecca Mandt, Kushal Seetharam, and Chung Hon Michael Cheng, "Federal R&D Funding: the bedrock of national innovation," *MIT Science Policy Review*, August 20, 2020, https://sciencepolicyreview.org/downloads/2020/08/Vol1no7_Mandt.pdf.

[29] Riccardo Fini, Markus Perkmann, Martin Kenney, Kanetaka M. Maki, "Are public subsidies effective for university spinoffs? Evidence from SBIR awards in the University of California system," *Research Policy* 52, No. 1 (January 2023).

[30] These taxonomies are proprietary and broadly based on keywords, as well as CPC and IPC codes.

[31] For example: Ezell, "The Bayh-Dole Act's Vital Importance to the U.S. Life-Sciences Innovation Ecosystem"; M. Anthony Mills, "Why the federal government must put more money toward basic science," *The Hill*, May 6, 2021, https://thehill.com/opinion/finance/551730-why-the-federal-government-must-put-more-money-toward-basic-science/.

[32] This data uses a modern definition for robotics and AI. As technology evolves, so do their definitions, and what might have been considered cutting-edge 20 to 40 years ago may be less so today. Specifically, the CPC and IPC systems are constantly evolving as new technologies emerge. The new classifications (e.g. for AI, machine learning etc.) are then applied retrospectively to older patents from before these classes existed. These temporal elements to taxonomies and definitions of AI are relevant when we ask whether the government is investing in what is cutting edge at the moment. While using our modern, specific definitions of both robotics and AI, we get surprisingly high investments from the federal government through the 1980s, 90s, and 2000s - but it may be even higher historically if we adjusted our definition on a decennial or annual basis.

[33] National Institutes of Health, "Appropriations History by Institute/Center (1938 to Present)," Department of Health and Human Services, accessed June 2023, https://officeofbudget.od.nih.gov/approp_hist.html.

[34] DOE is responsible for several national labs, like Sandia National Laboratories and government contractors that manage them, like UT-Battelle (which administers Oak Ridge National Laboratory). DOE also works with extramural government contractors like the Massachusetts Institute of Technology (MIT) and General Electric.

[35] Our analysis does not include classified patents, which are inventions that the USPTO deems potentially "detrimental to national security" should they be publicly disclosed. This exclusion of these patents, which often relate to defense activities, may skew our results, including those related to DOD funding.

[36] A Congressional Research Service report found that in FY2021 real dollars, DARPA funding decreased between 1996 and 2020. For more details, see: Congressional Research Service, *Defense Advanced Research Projects Agency: Overview and Issues for Congress* (Washington, DC: 2021), https://apps.dtic.mil/sti/citations/AD1158178#:~:text=In%20FY2021%20constant%20dollars%2C%20DARPA,to%203.50%20billion%20in%20FY2021. Once again, there may be a variety of possible reasons for this disparity between patent production and research funding, including changes in joint-funding arrangements, changes in the relative distribution and size of funding programs, or other factors. However, this topic falls beyond the scope of the brief.

[37] The entity or individual that holds the patent, namely the patent assignees, may change over time (e.g., by selling the rights to an invention). Thus, note that the counts for assignees in this section may include assignees that are not the *current* assignee, or entity with licensing rights to a patent, if an inventing assignee transferred ownership of a patent.

[38] We do include national labs that fall under the purview of government agencies here.

[39] Government Accountability Office, *Technology Transfer: Administration of the Bayh-Dole Act by Research Universities*, (Washington, DC; 1998), 3-4, https://www.gao.gov/assets/rced-98-126.pdf.