BOSTON TECH HUB FACULTY WORKING GROUP
REPORT SERIES

Funding Part 1:

Tech Hub Competition and Federal R&D Funding

HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs
TECHNOLOGY AND PUBLIC PURPOSE PROJECT

Harvard John A. Paulson
School of Engineering
and Applied Sciences

June 2022

AUTHORS

Sarith Felber (Harvard Kennedy School)

Chuck Meire (Harvard Kennedy School)

Gopal Nadadur (Harvard Kennedy School)

Christina A. Nguyen (MIT)

Ariel Higuchi, *Tech Primers Project Lead* (Harvard Kennedy School)

Amritha Jayanti (Harvard Kennedy School)

REVIEWERS

Eric Evans (MIT Lincoln Lab)

Erica Fuchs (Carnegie Mellon)

Venkatesh Narayanamurti (Harvard University)

The authors would also like to thank countless others who provided helpful insight and feedback.

FACULTY PRIMARY INVESTIGATOR

Ash Carter, Faculty Director, Technology and Public Purpose Project

Francis J. Doyle III, Dean, Harvard John A. Paulson School of Engineering and Applied Sciences

The Boston Tech Hub Faculty Working Group Report Series was designed to provide a brief overview of various tech policy topics. These papers are not meant to be exhaustive.

Technology and Public Purpose Project
Belfer Center for Science and International Affairs
Harvard Kennedy School
79 John F. Kennedy Street, Cambridge, MA 02138

www.belfercenter.org/TAPP

Harvard John A. Paulson School of Engineering and Applied Sciences
29 Oxford Street, Cambridge, MA 02138

www.seas.harvard.edu

Contents

Boston Tech Hub Faculty Working Group Report Series

This report is part of a 3-part series of research primers produced by the Technology and Public Purpose (TAPP) Project focused on the strengths, weaknesses, opportunities, and challenges faced by the Boston tech hub.

Report Topics

1. Funding Part 1: Tech Hub Competition and Federal R&D Funding
2. Funding Part 2: Tech Hub Competition and Private Funding of the Innovation Life Cycle
3. International Students and Scholars in STEM in the United States

The report authors would like to thank the Boston Tech Hub Faculty Working Group speakers and attendees for their perspectives on the topics covered in each report.

About the Boston Tech Hub Faculty Working Group

The Boston Tech Hub Faculty Working Group (FWG), founded by former Secretary of Defense and Belfer Center Director Ash Carter and Harvard John A. Paulson School of Engineering and Applied Sciences Dean Frank Doyle, holds monthly discussion-based meetings with senior facultynand Boston-based practitioners/decision makers across the public and private sectors that explore and answer the question: How do we resolve the dilemmas posed to public good and public purpose, created by technology's unstoppable advances?

For the Spring 2022 FWG series, the working group focused on Boston's competitive edge in science, technology, and innovation.

Session Topics

- Tradition of S&T Excellence: Boston's History of R&D during WWII, the Cold War, and beyond.
  Speakers: David Kaiser, Sheila Jasanoff, Robin Wolfe Scheffler, G. Pascal Zachary, and Kate Zernike
- How can Boston acquire increased federal R&D funding?
  Speakers: France Córdova, Eric Evans, Susan Hockfield, and John Holdren
- How can Boston compete with other tech hubs for private funding from companies and investors?
  Speakers: David Cox, Vilas Dhar, David Fialkow, Katie Rae, and Vicki Sato
- How will Boston universities address the challenges of recruiting, training, and retaining international STEM students and scholars?
  Speakers: Nicole Elkin, Rebecca Keiser, David Kris, and Richard Lester

Executive Summary

Funding for Research & Development (R&D) is crucial for sustaining a tech hub. Federal funding for R&D in particular plays a unique and important role; federal R&D funding is often focused on basic research which contributes to the foundation of scientific research which is the catalyst for innovation – the bedrock of tech hubs.

In this report we examine the competitiveness of Boston's tech hub by comparing its performance to other leading hubs. When examining *input* metrics, established tech hubs, like Boston and the Bay Area, receive the lion's share of the federal funding for R&D. However, Boston's growth rate of federal funding lags behind emerging tech hubs, such as Seattle, that show consistent growth in their share of funding. In addition, Boston relies mainly on funding from the Department of Defense, while Seattle enjoys more diverse funding sources. Recent political developments indicate that the federal government is more inclined to increase its stagnating investment in R&D. However, there are also growing demands for geographical diversification of federal investments across the country – a development that might further increase Boston's competition with emerging tech hubs over federal funding.

Boston and Massachusetts maintain their competitiveness, but are still in a close competition, when measuring *output* metrics such as utility patents and the number of individuals employed in tech occupations. In terms of the number of tech firms, Boston trails behind or is in a close competition with other tech hubs, such as the Bay Area, Austin, Seattle, New York, and the DMV area.

To sustain the Boston tech hub, we recommend that local and federal policymakers: (1) diversify their federal funding, mainly through investments in Biotech; (2) attract more government facilities to the area, such as government labs; (3) increase collaboration with emerging tech hubs, mainly in geographically dispersed areas; and (4) emphasize small businesses with innovative ideas. Adopting these recommendations would not only support Boston's economy but also safeguard one of the country's leading scientific and innovative ecosystems, maintaining American scientific leadership.

Framing and Organization of Report

A myriad of essential interdependent factors have won the Boston metro area the status of a leading tech hub: strong academic institutions, skilled workers, burgeoning tech firms, and substantial private and federal research funding. However, growing competition internationally and domestically, the decline in federal funding as a share of national GDP over the last several decades, and the growing migration of talent pose challenges to sustaining Boston's tech hub. In addition, there are also growing concerns that federal investments in research and development (R&D) and scientific research are not distributed equally among all regions in the U.S.[1] Consequently, the Boston metro area, already considered a leading tech hub, faces increasing competition from existing *and* emerging tech hubs across the U.S.

At the same time, changes to the workforce brought on by the COVID-19 pandemic and ongoing discussions regarding U.S. scientific and technological leadership present opportunities for Boston. There is a renewed discussion about the role of the federal government in promoting the U.S' scientific and technological leadership. President Biden has declared his intent to increase federal investments to propel research and development of critical technologies.[2] Federal R&D funding is also being hotly debated in the halls of Congress.[3] After decades of relative decline in Federal R&D funding levels,[4] current debates and initiatives may begin to reverse the trend. This increased momentum provides an opportunity for existing tech hubs, such as Boston, to utilize robust federal R&D funding for increased innovation and social benefit.[5]

Boston can leverage the momentum for increased support for R&D funding while tackling the equity challenge by finding ways to collaborate with geographically dispersed institutions:

On the national level, the Boston metro area already has the infrastructure to assist in promoting the U.S scientific and technological leadership in light of international competition.

On the local level, Boston's status could promote the wider region's economic prosperity. Technological leadership and an innovative economy have the potential to spur economic growth and wages that may spill over beyond Boston and benefit other parts of the state or region.[6] [7] There are also opportunities to increase the cooperation between the Boston metro area and other emerging areas. Federal policies could foster and incentivize cooperation between academic and other federally funded institutions in emerging tech hubs.

Throughout this report, the authors review the importance of federal funding for R&D, compare Boston's share of federal funding to other tech hubs and explore how Boston could leverage its advantages to increase its own share of federal funding.

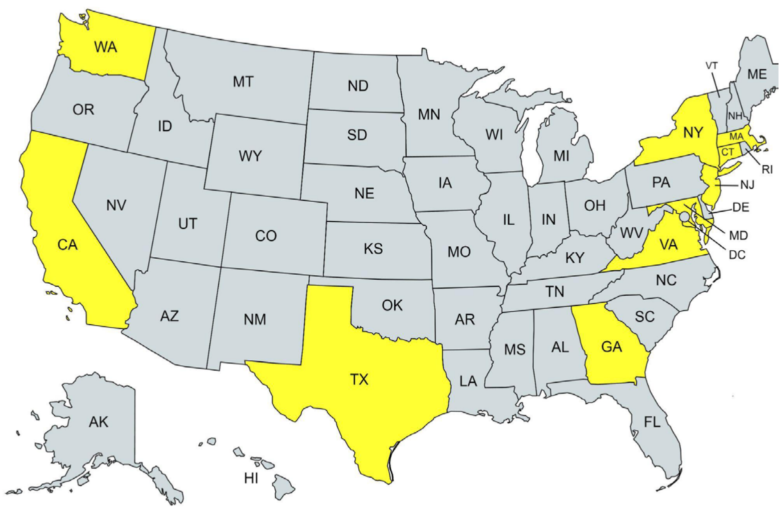
The challenge: Maintain and improve Boston's share in federal funding while ensuring that the benefits from this funding will expand beyond the Boston metro area tech hub.

The opportunity: Boston, with other existing and emerging tech hubs, could leverage current discussions regarding U.S scientific leadership to advocate for an increase in federal funding for R&D.

Overview of Tech Hub Competition

<u>Bottom Line</u> - Boston and Massachusetts are competitive in terms of utility patents and individuals in science and technology occupations, but are trailing competitors in the number of firms in key technology areas.

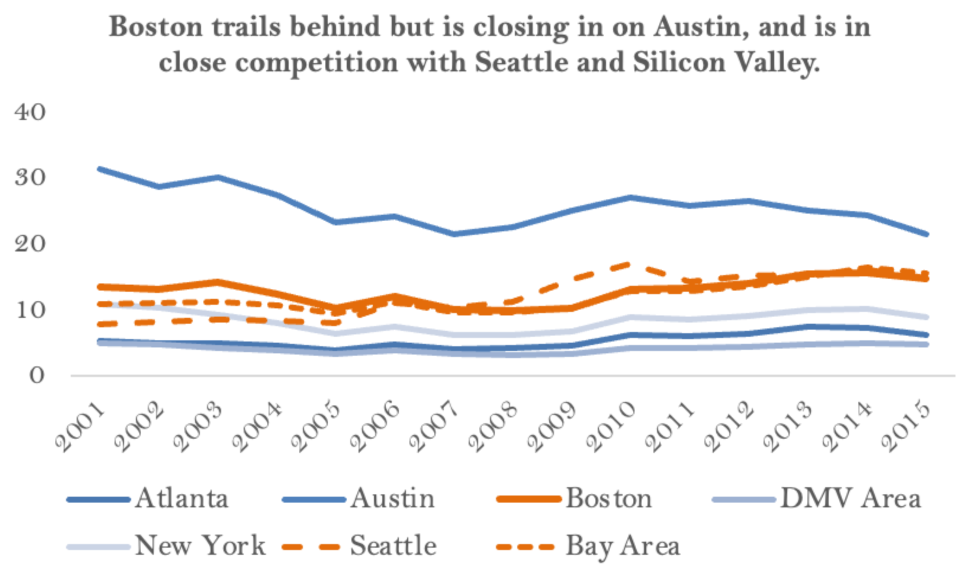
This report looks at the top 7 tech hubs that have emerged over the last two decades in the United States. These include the Metropolitan Statistical Areas (MSA)[8] of Boston, MA; San Francisco Bay Area, CA; the DMV area (Washington, D.C. and counties in Maryland and Virginia); Atlanta, GA; New York City, NY; Austin, TX; and Seattle, Washington. For the Bay Area, we combined the San Francisco and San Jose MSAs to capture both Silicon Valley and San Francisco.



Three Metrics for Comparison - Utility Patents per $1B metro area GDP; Number of Individuals in Science and Tech Occupations per $1B <u>state</u> GDP; and Firms per $1B metro area GDP. These metrics were chosen because: A) they are important output metrics to gauge a region's science and technological status and B) data are easily available for the metro area level (the "number of individuals in S&T occupations" metric is used at the *state* level given the need for further analysis to disaggregate data at the metro area level). In addition, **Annex 1 (page 33)** provides a comparison of Boston, the Bay Area, and Seattle in terms of relative presence; however, these data are only available for 2020.

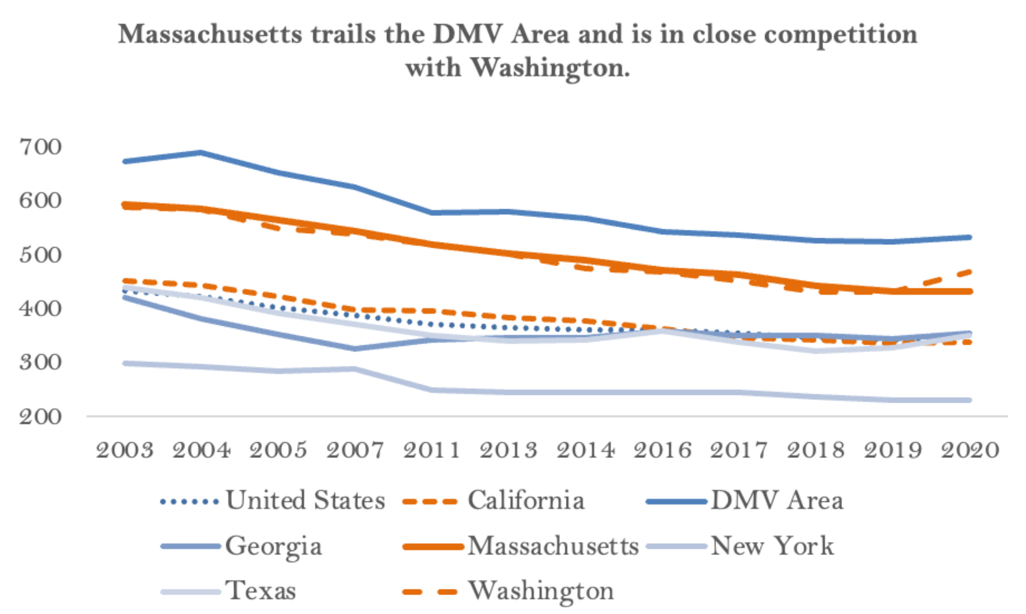
Takeaways from utility patents per $1B metro area GDP comparison. Per Figure 1, Boston (~15 patents per $1 billion GDP) is closing in on Austin (~20 patents), and is in close competition with Seattle and the Bay Area.

Figure 1: Number of **patents** per $1 billion metro area GDP.[9]



Takeaways from the number of individuals in S&T occupations per $1B <u>state</u> GDP. Per Figure 2, Massachusetts (~430 individuals per $1B state GDP) trails the DMV area (~530 individuals) and is in close competition with Washington (~470 individuals).

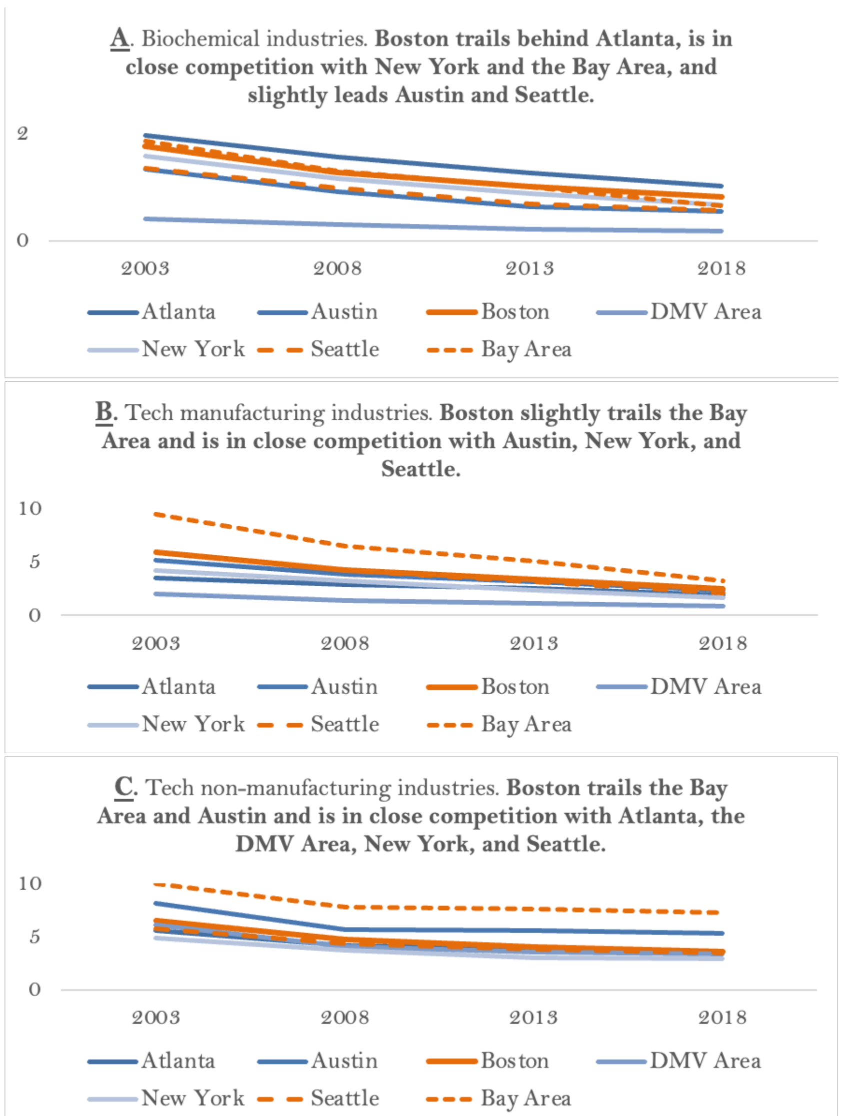
Figure 2: Number of **individuals in science / tech occupations** per $1 billion <u>state</u> GDP.[10]



Takeaways from firms per $1B metro area GDP comparison (Figure 3).

- *Biochemical firms* (Figure 6.A): Boston is slightly behind Atlanta, is in close competition with New York and the Bay Area, and slightly leads Austin and Seattle. All metro areas are below 2 firms per $1 billion GDP.
- *Tech manufacturing firms* (Figure 6.B): Boston (2 firms per $1 billion GDP) slightly trails the Bay Area and is in close competition with Austin, New York, and Seattle.
- *Tech non-manufacturing firms* (Figure 6.C): Boston (4 firms per $1 billion GDP) trails the Bay Area (7 firms) and Austin (5 firms) and is in close competition with Atlanta, the DMV Area, New York, and Seattle.

Figure 3: Number of **firms** per $1 billion metro area GDP.[11]



Why focus on R&D funding?

Funding isn't everything. Other elements of a metropolitan area, like skilled workers and talents, scientific and traditional infrastructure, collaboration potential between universities, research centers, and private firms,[12] regulation, taxation, and other factors influence the attractiveness of the area. Each of these factors, including R&D funding, contribute to the success of a tech hub.[13]

However, R&D funding in particular plays a central role in contributing to a tech hub's success. R&D funding contributes to scientific research which is often the foundation and catalyst for innovation - and innovation is necessary for the sustainability of a tech hub.[14] Federal R&D funding can also have a positive effect on private funding, especially for small businesses such as start-ups.[15] The funding provided by the government can help small businesses develop and commercialize their innovations into a competitive, market-ready product. Lastly, the attraction of R&D funding to local research facilities or firms can positively affect other factors needed to create a tech-hub, such as the attraction of high-skilled workers (both US citizens and foreign workers) and new innovative firms.[16] R&D funding is a fundamental input metric to measure a tech hub. Indeed, recent policy discussions and research regarding the expansion of tech centers across America emphasize the role of federal funding as an essential component of the "creation" of a tech hub.[17]

Defining the Terms: R&D Stages and Funding Types

Outline of R&D Stages. Two key sources of definitions associated with US federal research and development funding are the White House Office of Management and Budget (OMB) and the National Science Foundation (NSF). Both sources have very similar definitions of the three main stages of R&D: Basic Research, Applied Research, and Experimental Development. This report focuses on these three stages of R&D because they are the three main types of R&D activities[18] and because data is more accessible for these three categories. The NSF definitions[19] are listed below:

Research and [Experimental] Development (R&D). Creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture, and society—and its use to devise new applications of available knowledge. This broad category is broken into three separate phases: Basic Research, Applied Research, and Experimental Development.

Basic Research. Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

Example: A laboratory study to attempt a new type of low-light sensing.

Applied Research. Original investigation undertaken to acquire new knowledge —directed primarily, however, toward a specific, practical aim or objective.

Example: Building a prototype of the new low-light sensor.

Experimental Development. Systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

Example: Putting the new low-light sensor on a vehicle for testing in an operational environment.

NOTE: Updated Definition of "Development." Effective FY2018, OMB adopted a change to the definition of development, applying a more narrow treatment it describes as "experimental development." This change was intended to harmonize the reporting of U.S. R&D funding data with the approach used by other nations.

Federal funding for Research and Development (R&D) is significant for states and cities' economies across the U.S. In Massachusetts, and specifically in the Boston area - universities, hospitals, and other private scientific and research establishments benefit from federal R&D funding that contributes to the area's technological leadership.

There are two broad categories of federal R&D funding: direct funding (grants, loans, procurements) and indirect funding (primarily tax incentives). This report focuses on direct financing. However, the use of tax incentives as a form of federal R&D support is also briefly explained.

Direct Funding: Direct funding support is usually spent on R&D performed by either intramural or extramural performers. Intramural refers to federal agencies that perform the activity the funding is intended for (for example, government owned and operated labs). Extramural refers to organizations outside the federal sector that perform R&D with federal funds under contract, grant, or cooperative agreement: Industry, state and local government agencies, universities and colleges, FFRDCs, and some non-profits.[20] Two prominent examples of direct funding are described below:

- *Contracts:* Mostly competitively awarded agreements used by the government to procure goods and services. Varying degrees of flexibility but funding is usually tied to milestones and deliverables on the project. Government typically retains some or all intellectual property. Agreements are typically governed by the Federal Acquisition Regulations (FAR). Reporting is typically every two weeks to one month.
- *Grants:* Competitively awarded but with the greatest flexibility and fewest restrictions. Designed to support a public purpose, funding is not tied to forward progress or positive results on the project. Reporting is typically annual. NIH is the largest grantmaking agency in the government.

Indirect Funding: Support for R&D in the U.S is largely skewed towards direct funding. However, the federal government also supports R&D through indirect funding, namely tax incentives. These incentives aim to encourage relevant entities to invest in R&D by reducing their tax liability. Some states, including Massachusetts,[21] and other countries,[22] offer similar indirect incentives.[23]

Federal level: A prominent policy tool to incentivize investments in R&D is the tax credit for research and development expenses. Companies that invest in qualified research expenses receive a tax credit for these expenses that reduces the company's income tax liability (the company may still deduct these expenses as well to reduce its taxable income).[24] Qualified research expenses can include certain wage costs for performing research activities in-house or sometimes through contracts, certain supplies used in conducting research, etc. The credit applies to research performed in the United States.[25]

Additionally, the federal government also uses tax incentives to encourage collaboration between academic institutions and the private sector. It offers tax credit to companies that collaborate with certain non-profit organizations, such as universities,[26] to perform basic research.[27] According to the Joint Committee on Taxation, the credit for increasing research activities was expected to reduce federal tax revenues by 59.3 billion dollars over the years 2018-2022.[28]

Funding Channels of Interest

What are the existing federal funding streams that foster innovation?

There are many existing federal funding streams, each tailored to specific functions, however several streams have particular influence as innovation vehicles or on-ramps for nontraditional performers or particular versatility. Some of the most important of these streams are listed below.

Federally Funded Research and Development Centers (FFRDCs): Laboratories operated by non-governmental entities, typically non-profit organizations that perform research for federal government sponsors. The 42 active FFRDCs make up approximately 10% of Federal R&D spending. FFRDCs are nationally strategic R&D assets that represent significant hubs of federal funding for their metro Areas.[29] The Boston Metro has two FFRDCs (MIT Lincoln Labs and the National Security Research Center).[30] Other Concentrations of FFRDCs include the Bay Area and DMV.

Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR): Phased, competitive awards designed to give small businesses the opportunity to develop commercializable technology to the government. The program is funded by a small percentage "tax" on all organizations that have an R&D budget over $100M.[31] The majority of SBIR / STTR funding comes from DOD and HHS, but the program is widely used across the government. Performers that complete the first two phases of an SBIR become eligible for a single source follow-on award (Phase III) funded directly by the client agency instead of the SBIR program.[32] Boston receives a large amount of SBIR obligations (~$1.4B between FY17-FY21) relative to other major tech hubs.[33]

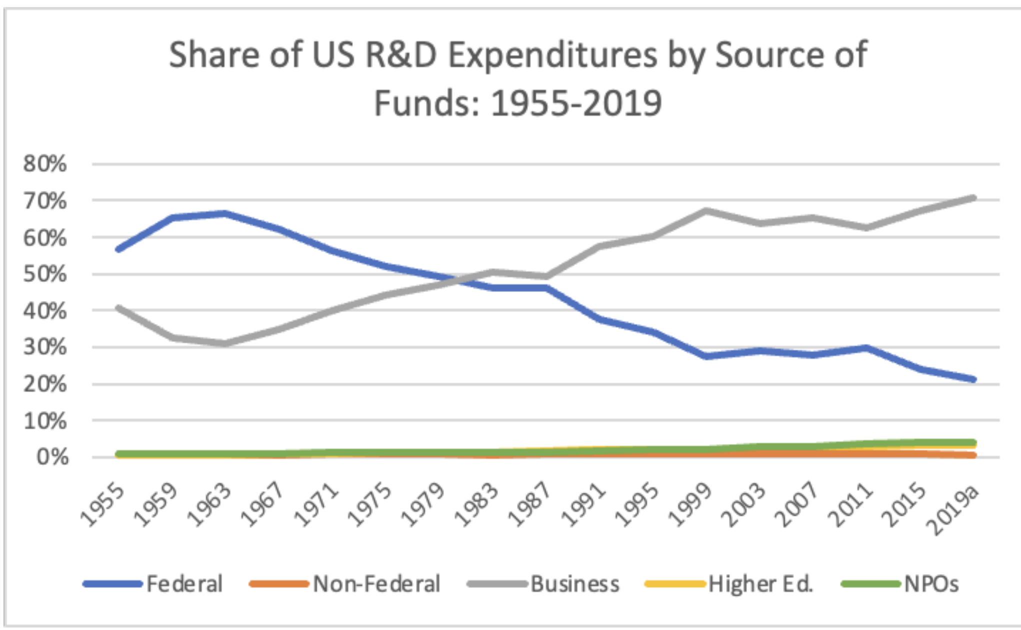
Other Transaction Authority (OTA): A contract type developed by NASA in the 1950s specifically for R&D. Used by DoD, DHS, HHS, DOE, DOT.[34] These allow the government to procure services from private entities without adhering to large portions of the Federal Acquisition Regulation (FAR). **Use of OTAs have increased exponentially in DOD since 2016,** when DOD began to allow the relaxed OTA regulations to apply to the entire life of a contract. Use of OTAs in DoD has increased from less than $2B in FY16 to more than $14B in FY20. Most of this funding is going to development rather than applied or basic research.[35]

National R&D Funding Landscape

National Trends in R&D funding.[36] Over the last half-century, the federal government's share of R&D expenditures has fallen 36% as the business sector's share has risen by 30%. The non-federal, higher education, and non-profit organization (NPOs) share of R&D expenditures has grown slightly from 1% - 4% (Figure 4).

Shift in Federal vs Business Share of Expenditures. While the federal government's share of R&D expenditures peaked in 1964 at 66.8%, the business sector's share of R&D expenditures reached an all time high in FY2019 estimates at 70.7%. This shift in composition did not result from the reduction of federal government R&D expenditures but rather from the tremendous growth of the business sector's investments in R&D.

Figure 4: Overall R&D Expenditures[37]



National Trends by R&D Stages

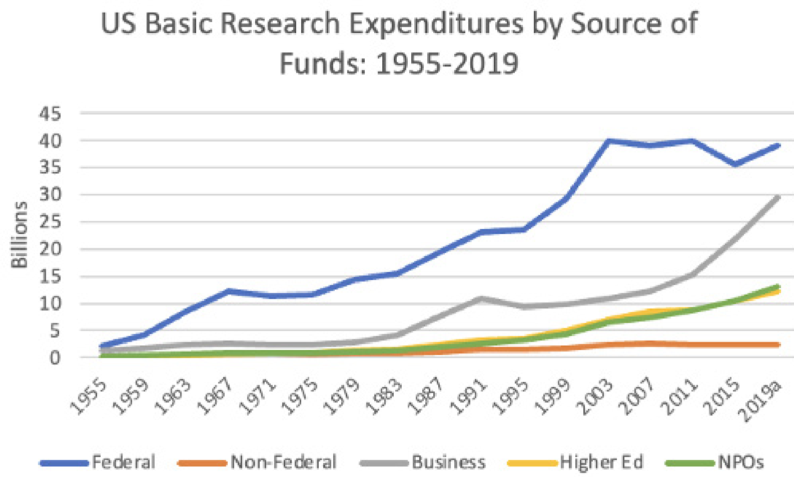
Basic Research: Since 1955, the share of basic research funding as a percent of R&D expenditures has grown from 9%, to a peak in the early 2000s around 19%, back down to 16% in 2019. The federal government has consistently been the largest source of funding for basic research, accounting for 41% of funds in 2019. The federal government plays a unique role in funding basic research, which generates fundamental knowledge. Federal dollars can help researchers overcome a "failure market" of underfunding for research which may be considered high risk but also may advance "public-good research endeavors."[38]

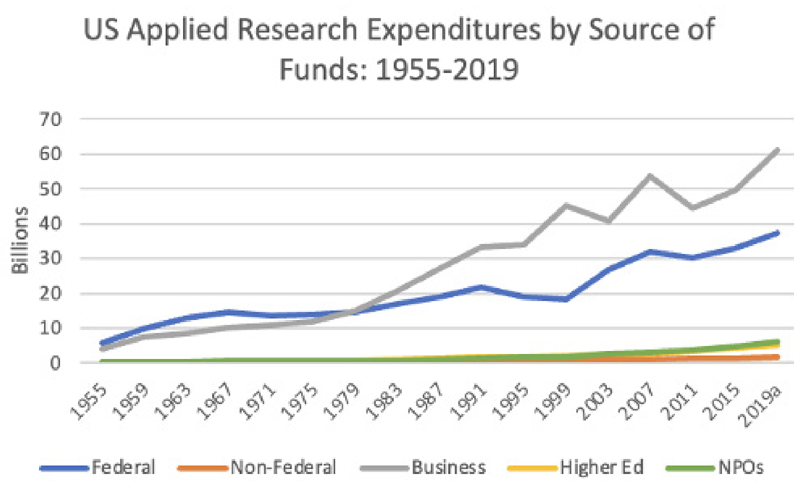
Applied Research: Applied research has consistently accounted for approximately 20-24% of R&D expenditures; the business sector has steadily grown to represent the largest funding source, representing 55% of total expenditures in 2019.

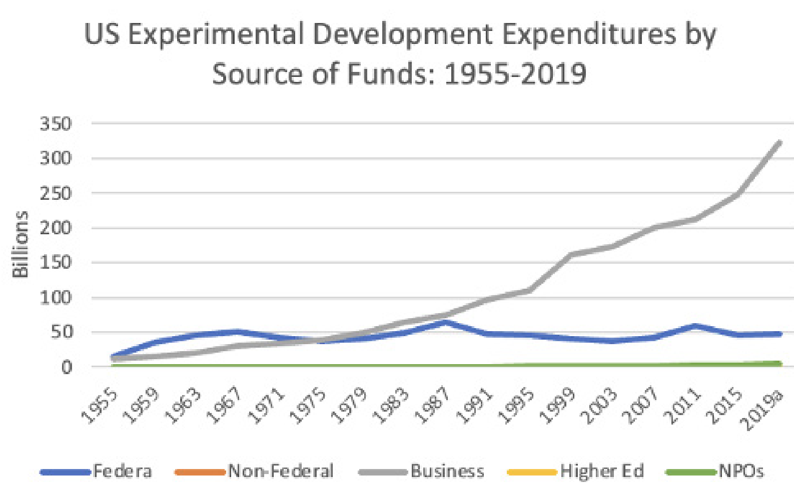
Experimental Development: Lastly, experimental development has consistently accounted for approximately 60-65% of R&D expenditures. Since the mid-1970s, the business sector has accounted for the largest source of funding, representing 86% of funds in 2019.

Given the importance of R&D funding in the growth and sustainability of a tech hub, and the predominance of federal and business R&D funding, the following sections explain relevant terms regarding federal R&D funding and analyze Boston's federal funding compared to its peers. The "Funding Part 2: Tech Hub Competition and Private Funding of the Innovation Life Cycle" report in this series will similarly analyze other sources of business R&D funding.

Figure 5: National Trends in Basic Research, Applied Research, and Experimental Development[39]







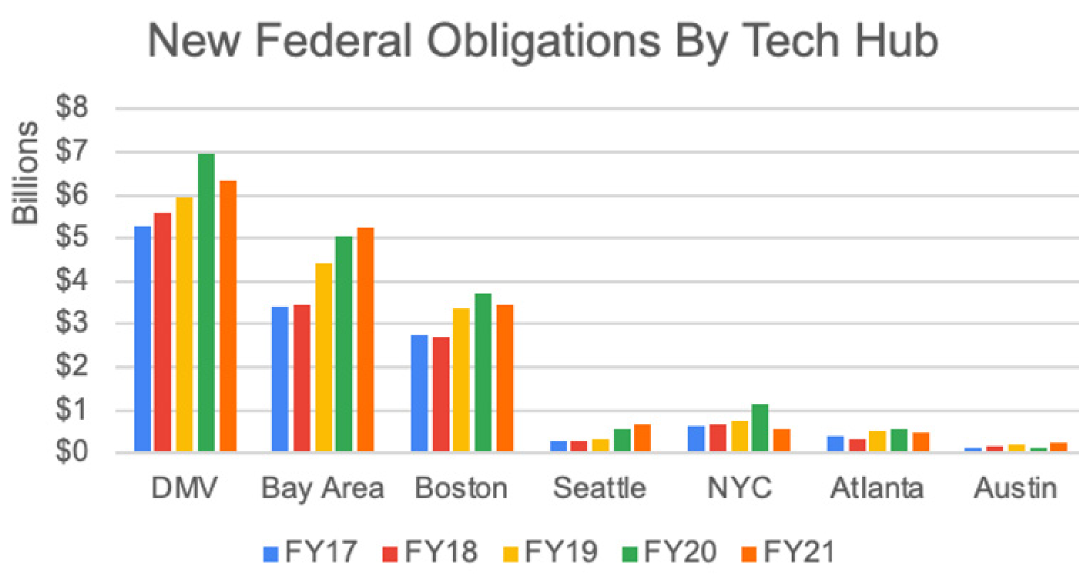
A Comparison of Boston Federal R&D Funding to Other Tech Hubs

Comparison of Federal R&D Obligations. This section compares the federal R&D obligations across the tech hubs that were previously identified in this report. We begin by comparing obligation levels across seven tech hubs over a five year period and proceed by focusing on the federal obligations at specific R&D stages of three hubs.[40] The data in this section was compiled from data available at usaspending.gov. Please see **Annex 1 (page 33)** for more details on the methodology used.

Bottom Line: Established tech hubs like Boston and the Bay Area receive much more federal R&D funding than emerging tech hubs. While Boston receives a high amount of federal funding for R&D it lags behind the DMV and Bay Area in absolute terms and in its growth rate for federal R&D investment.

Analysis of Federal R&D Obligations Across Tech Hubs: Boston, the Bay Area, and DMV have led the other tech hubs in Federal R&D obligations for the previous 5 FYs. However, Seattle showed consistent growth, passing NYC and Atlanta to rise from 6th place to 4th place.

Figure 6: New Federal R&D Obligations by Tech Hub



Federal Funding by R&D stages in three Tech Hubs. Figure 7 and 8 represent the total value of obligations for each step of the R&D pipeline by the federal government for two discrete 5-year periods, FY12-16 and FY17-21.[41] This data includes the total obligation value of R&D contracts active within the tech hub during the given time period. Aggregating the data by time period is useful for illustrating the scale of government R&D investment within each tech hub, but long running contracts may overlap between time periods.

Three Tech Hubs. We have chosen to focus on Boston, the Bay Area, and Seattle. The Bay area was chosen for analysis because it is Boston's closest competitor in terms of Federal R&D obligations. Despite its comparatively small amount of funding, Seattle was chosen for analysis because it is the tech hub that has seen the greatest relative growth in federal R&D obligations over the last five fiscal years.

DMV was not included in this analysis because its role as the national capital region provides a structural advantage that other metro areas cannot easily overcome.

Comparing the two time periods reveals that, while Bay Area funding has remained relatively stable across the R&D pipeline, Seattle and Boston's funding structure has evolved.

Seattle has seen a decline in Federal R&D Obligations in the past 5 FYs compared to the previous 5 FYs. The biggest decline has been in Development obligations, while Applied Research obligations have slightly increased. **Boston** has experienced growth in both Basic and Applied Research Obligations, but a substantial fall in Development obligations.

Changes to the Definition of Development. In FY21, the US Government began tracking R&D using a new Product and Service Code breakdown that switched from seven codes to five. This table includes all development in the experimental development category as well as the now defunct Advanced, Engineering, and Operational Systems Development categories.[42]

Figure 7: Federal R&D Obligations **FY12-16**

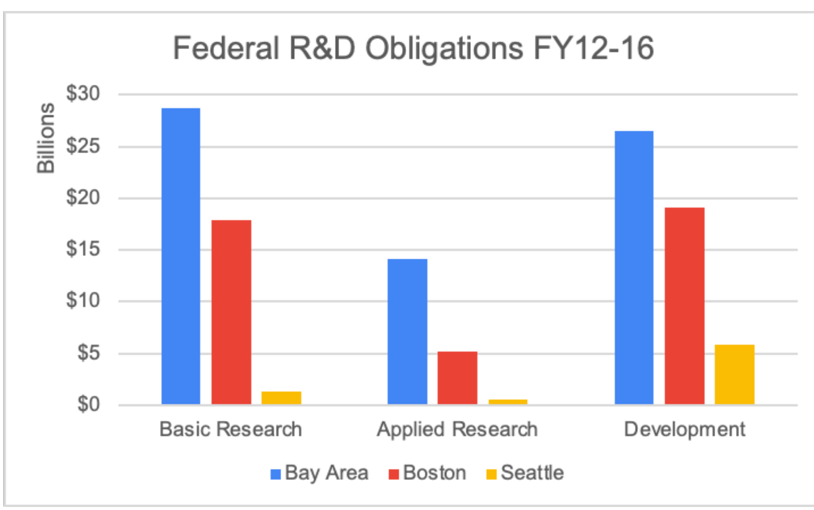
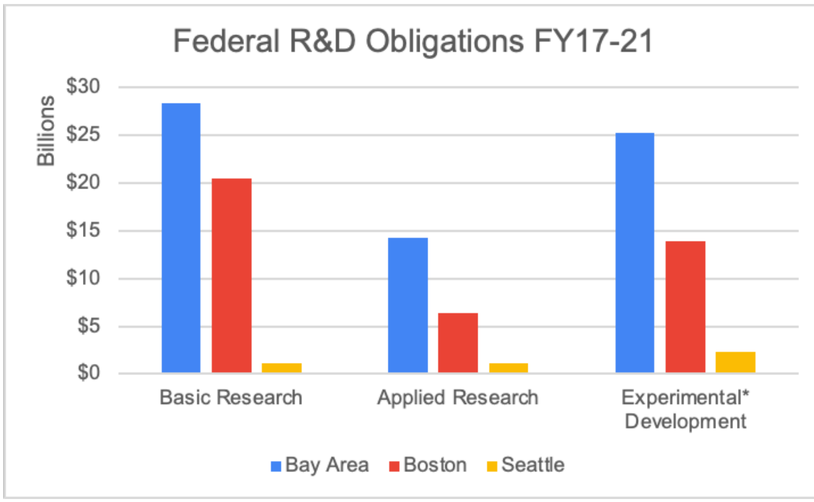


Figure 8: Federal R&D Obligations **FY17-21**



Recommendations

The primary question we aim to address with these recommendations is: **What are some potential ways in which Boston can attract more funding in the relevant federal funding channels?**

Diversify Federal R&D by prioritizing Biotech. Boston is a leader in Biotech, however federal R&D support in Boston is disproportionately funded by DOD. This is despite the fact that HHS/NIH are among the largest funders of government R&D. Boston should continue to emphasize its leadership in this area to attract additional Federal R&D support from diverse agencies. While other tech hubs have similar issues, they do have better diversification with other agencies like NASA and DOE providing major support to parts of the R&D pipeline.

Diversification of funding sources will increase R&D funding opportunities for a greater array of Boston businesses and play to its strengths. Doubling down on biotech represents a significant growth opportunity that leverages existing funding channels. This includes support for hospitals like Mass. General and Brigham and Women's as well as major educational institutions like Harvard and MIT. NIH funding plays a key role in **mitigating the brain drain** of scientists by providing training and career development grants. Boston firms should place special emphasis on these development opportunities to reduce the severe brain drain in the metropolitan area.

Additionally, the government has shown interest in expanding the Advanced Research Project Agency (ARPA) model to new focus areas. The traditional ARPAs leverage investment in innovative, **early stage** technology to push the bleeding edge of certain capabilities in a domain. Recently, the Biden Administration announced the creation of an ARPA-H under NIH to focus on advancing biomedical and health sciences. With an initial requested budget of $6.5B for three years, this new agency demonstrates increasing government demand for R&D in the domain.[43] This illustrates the opportunity for Boston to capture additional, diversified federal R&D funding by leveraging its existing strength in biomedical and health sciences.

Prioritize Diversity in Funding Distribution. While the relationship between diversity and innovation is complex and far from monolithic[44]; diversity in teams can increase innovative outcomes like R&D efficiency[45] and R&D intensity.[46] Across each Metro Area, small percentages of obligations went to Minority Owned Businesses (.73% in the Bay Area, .31% in Boston, 1.64% in Seattle). Other metrics (Women Owned Small Businesses, Service Disabled Veteran Businesses) show even lower percentages of funding. Boston should work to attract more diverse R&D Firms to increase its innovation talent pool.

Support Existing Government Labs and Attract New Governemnt Research Centers. Boston could lobby for the Federal government to open a new FFRDC that matches its strength in health and biomedical research. However, FFRDCs are major government labs and require significant overhead and planning to establish**.** Their long term nature and high budgets make them difficult to create. Securing a new FFRDC would be a strategic victory for Boston **but has a low probability** of occurring and it's not a short term "game changer." There is not currently significant momentum in favor of adding new FFRDCs, so a better strategy in the near and medium term could be to attract more funding to existing FFRDCs.

Boston's FFRDCs (Lincoln Laboratory, administered by MIT and the National Security Engineering Center, administered by MITRE) are significant sources of funding for the metro area. However, both are sponsored by the DOD, which contributes to the lack of diversification of federal funding in the metro area.

Boston may attract additional federal funding through similar federal programs with somewhat lower establishment criteria and smaller annual budgets like DoD ***University Affiliated Research Centers (UARCs)*** and DHS/GSA/Treasury ***Centers of Excellence.***

While establishing these centers will not be enough to close the gap in funding for federally sponsored labs, they will help to maintain Boston as a hub of influence on Federal R&D. The expertise that is available and innovations produced by these labs would likely create substantial positive second order effects for Boston's ability to attract additional funding; such as increasing the likelihood of new technology and R&D firms being created by lab alumni and attracting existing firms to draw from the labs talent pool.

Emphasize Small Businesses. Boston received high levels of SBIR obligations between FY17-21 ($1.44B). This is more than double the SBIR obligations in the Bay Area ($671.8M) and orders of magnitude greater than Seattle ($7.56M). This is a key strength that Boston should continue to emphasize. SBIRs also build on Boston's strengths such as talent, knowledge and connectedness.[47] SBIRs provide a guided on-ramp to sustained federal funding which allows small businesses to develop their products for commercialization with government feedback while retaining IP rights.

Develop New Strategic Partnerships with Geographically Dispersed Actors. There is discussion and momentum with the government to more equitably disperse federal R&D support across the country. The COVID pandemic has also catalyzed the development and adoption of remote work technology and infrastructure and created a more dispersed tech workforce.[48] This trend does not appear to be temporary.

While human capital is dispersing, physical capital investments (like labs) remain concentrated within the tech-hubs. Boston institutions have access to state of the art capital resources that smaller institutions lack the resources to build or maintain. These resources are key to ensuring Boston's continued technological relevance and competitiveness for federal R&D funding.

Boston's reaction to the dispersion of the tech workforce should be to *lean into the trend rather than fight it.* Large Boston institutions (MIT, Harvard, Mass. General) should work with smaller organizations to implement strategic R&D partnerships that connect geographically dispersed tech talent to Boston's R&D infrastructure.

This strategy would provide Boston institutions with a larger, more diverse talent pool, thus making the institutions more competitive. While Boston already has a large pool of tech talent, it is generally limited by geography. If Boston's institutions can draw from nationwide partnerships without having to attract people to physically move, the talent pool could grow substantially.

Not only would Boston retain access to tech talent, but these partnerships can develop historically overlooked talent pools that lacked access to the capital resources necessary to perform the most cutting edge research. Boston institutions would be best served by tapping into traditionally under-utilized areas of tech talent, and so should prioritize Minority Serving Institutions to fully diversify the Boston talent pool.

Risks and Mitigation

The primary question/challenge we aim to address with these risks and mitigations is: **What are the risks to Boston's ability to attract more federal R&D funding and how might they be addressed to ensure stable and sustainable growth for the Boston tech hub?**

Risk: Funding levels fall across tech hubs.

Boston and other tech hubs already receive a high level of federal R&D funding when compared to the average American city. The COVID pandemic is leading to a more distributed tech workforce that is less concentrated in the traditional hub cities.[49] [50] This distribution could lead to funding being spread more evenly across the country, leading to less funding dollars in places like NYC, the Bay area, and Boston.

Mitigation: Boston can mitigate the impact of this risk by working to ensure that its research strengths are aligned with the government's medium and long-term needs and by working to slow the loss of STEM talent from the region.

Risk: Exacerbating wealth inequities in society.

Economies that are intensive on science and technology may tend to reward those with higher education / skill levels and higher ability to access capital. In other words, such economies tend to be skill-intensive and capital-intensive. Such economies could further disadvantage people with lower education / skills or lower access to capital. This is already an issue in the United States.

Mitigation: Any strategy to boost Boston's status as a science and technology hub should be complemented by policies to tackle potential inequities. For instance, such policies could aim to increase access to education or re-skilling, greater social protections for people who lose employment in a diminishing sector and need time and resources to access new sources of employment, etc.

Risk: There is no government appetite to build new government labs in Boston.

Labs generally represent major capital investments. Given the declining share of federal R&D funding as a share of GDP, the government may consider the opportunity cost of lab construction to be too high to justify their construction.

Mitigation: Boston and its institutions should consider cost sharing agreements with the government to lower the initial investment of lab construction. Labs' longevity makes them attractive assets in the long term for attracting additional federal R&D funding. Boston's and Massachusetts' economies will also stand to gain from the innovations and new companies that new labs will produce.

Risk: The toughest technical problems require a geographically centralized workforce to solve.

While remote work is a substantial opportunity for Boston to reduce the effects of its technical brain drain, it is possible that the toughest challenges (advanced manufacturing, nano-technology, quantum computing, etc.) are not well fitted to remote work. For example, the constant need for physical experimentation could require a workforce to be much more geographically centralized than would be necessary in other innovation areas. This limits Boston's ability to capitalize on the shift to remote work.

Mitigation: Boston should mitigate this risk by attempting to retain a cohort of scientists and engineers working on these issues in the area. Institutions may consider providing extra support or incentives to attract and retain tough tech workers within the metro area. While every technical area should attempt to incorporate remote work as much as possible, in all likelihood some areas will be less suited to this model. Institutions should retain flexibility to allow each innovation area to work in the way best suited to achieve innovation success.

Risk: Federal Funding cannot overcome impedance mismatch in the later stages of development/commercialization.

Despite substantial funding and basic research, some technologies are not easily commercializable. These technologies will likely fail to reach later stages of development or to be successfully adopted by a broader market. This can be caused by issues of scaling (manufacturing technology cannot support mass production, or cost per unit is too great for the market to bear), supply (no reliable supply chain for certain components), or a myriad of other causes. This is an inherent risk with all R&D, especially basic research, where the chances of failure are substantially higher.

Mitigation: Fostering early commercialization efforts for new technologies will help to identify risks of later development and scaling that could harm the technology at later stages. While the development of the technology will inhibit completely accurate commercialization planning in many cases, supporting transition, deployment, and commercialization planning will minimize the risk of the government pursuing technology that cannot be scaled to the required level.

Annex 1: Methodology

Figure 1: Number of patents per $1 billion metro area GDP.

- Download utility patents data for focus MSAs from the USPTO portal
- Download GDP data for relevant MSAs from the BEA portal
- For each year and each MSA, calculate the number of utility patents per $1 billion GDP

Figure 2: Number of individuals in science / tech occupations per $1 billion state GDP.

- Download data on number of individuals in science / tech occupations for focus States from the NCSES portal
- Download GDP data for relevant MSAs from the BEA portal
- For each year and each State, calculate the number of individuals per $1 billion GDP

Figure 3: Number of firms per $1 billion metro area GDP.

- Download raw data of the SUSB annual datasets
- Focus on firms with ENTRSIZE = 1
- For each MSA, group firms by tech category (biochem industries = 325: chemical manufacturing, 326: plastics and rubber products manufacturing; tech manufacturing industries = 334: computer and electronic product manufacturing, 335: electrical equipment, appliance, and component manufacturing, 336: transportation equipment manufacturing (importance of IVs), 339: mechanical equipment and supplies manufacturing; tech non-manufacturing industries = 511: software publishers, 517: telecommunications, 518: data processing, hosting, and related services, 519: other information services. Note: 517, 518, and 519 not available for 1998)
- Download GDP data for relevant MSAs from the BEA portal
- For each year and each MSA, calculate the number of firms in each industry and MSA per $1 billion GDP.

Figure 4: Overall R&D Expenditures

- Drawn from existing data available at National Center for Science and Engineering Statistics (NCSES). 2021. National Patterns of R&D Resources: 2018–19 Data Update. NSF 21-325. Alexandria, VA: National Science Foundation. https://ncses.nsf.gov/pubs/nsf21325.

Figure 5: National Trends in Basic Research, Applied Research, and Experimental Development

- Drawn from existing data. Available at National Center for Science and Engineering Statistics (NCSES). 2021. National Patterns of R&D Resources: 2018–19 Data Update. NSF 21-325. Alexandria, VA: National Science Foundation. https://ncses.nsf.gov/pubs/nsf21325.

Figure 6: New Federal R&D Obligations by Tech Hub

- This data was compiled from the usaspending.gov database using the advanced award search feature.
- Each search was filtered by:
    - 1) fiscal year (FYs 2017-2021)
    - 2) location to include only the counties and cities listed in the OMB definition for each MSA
    - 3) Product or Services Code (PSC) to include only R&D affiliated PSCs
- Click on the "Time" tab and download the data by year for each MSA.
- Compile all data into a single bar chart in excel.

Figure 7: Federal R&D Obligations FY12-16

- This data was compiled from the usaspending.gov database using the advanced award search feature.
- Each search was filtered by:
    - 1) fiscal year (FYs 2012-2016)
    - 2) location to include only the counties and cities listed in the OMB definition for each MSA
    - 3) Product or Services Code (PSC) to include only R&D affiliated PSCs
- Tableau was used to analyze the data further.
- The data downloaded from usaspending.gov comes in four files. One for prime-award contracts, one for sub-award contracts, one for prime-award assistance, and one for sub-award assistance. For each of the three tech hubs analyzed, both assistance datasets contained no award information. Leaving only the prime-award and sub-award contract datasets available.
- We chose to analyze the prime-award contract file because of time constraints and because the prime-contracts represent those where the performer works directly for the government. A future analysis of the sub-award contracts could likely yield valuable insights.
- To determine the funding stages along the R&D pipeline (Basic Research, Applied Research, and Development) the *total obligated amount* element was placed into the rows area on a

Tableau sheet and filtered using the *Product Or Service Code Description* element (which delineates along each stage of the pipeline).

Figure 8: Federal R&D Obligations FY17-21

- This data was compiled from the usaspending.gov database using the advanced award search feature.
- Each search was filtered by:
    - 1) fiscal year (FYs 2017-2021)
    - 2) location to include only the counties and cities listed in the OMB definition for each MSA
    - 3) Product or Services Code (PSC) to include only R&D affiliated PSCs
- Tableau was used to analyze the data further.
    - The data downloaded from usaspending.gov comes in four files. One for prime-award contracts, one for sub-award contracts, one for prime-award assistance, and one for sub-award assistance. For each of the three tech hubs analyzed, both assistance datasets contained no award information. Leaving only the prime-award and sub-award contract datasets available.
    - We chose to analyze the prime-award contract file because of time constraints and because the prime-contracts represent those where the performer works directly for the government. A future analysis of the sub-award contracts could likely yield valuable insights.
    - To determine the funding stages along the R&D pipeline (Basic Research, Applied Research, and Development) the *total obligated amount* element was placed into the rows area on a Tableau sheet and filtered using the *Product Or Service Code Description* element (which delineates along each stage of the pipeline).

Endnotes

1 Atkinson, R., Muro, M., & Whiton, J. (2019). The Case for Growth Centers. Brookings Institution: Washington, DC, USA (available at: https://www.brookings.edu/research/growth-centers-how-to-spread-tech-innovation-across-america/).

2 The White House "A Letter to Dr. Eric S. Lander, the President's Science Advisor and nominee as Director of the Office of Science and Technology Policy" January 202. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/20/a-letter-to-dr-eric-s-lander-the-presidents-science-advisor-and-nominee-as-director-of-the-office-of-science-and-technology-policy/

3 There are currently 175 bills in Congress focused on advancing science and tech R&D: Research and development. GovTrack.us. (n.d.). Retrieved February 21, 2022, from https://www.govtrack.us/congress/bills/subjects/research_and_development/6311

4 Mandt, Rebecca, Kushal Seetharam, and Chung Hon Michael Cheng. "Federal R&D funding: the bedrock of national innovation." MIT Science Policy Review 1 (2020): 44-54.

5 Fleming, L., Greene, H., Li, G., Marx, M., & Yao, D. (2019). Government-funded research increasingly fuels innovation. Science, 364(6446), 1139-1141.

6 Atkinson, R. D., Muro, M., & Whiton, J. (2019, December 9). The case for growth centers: How to spread tech innovation across america. Brookings. Retrieved February 21, 2022, from https://www.brookings.edu/research/growth-centers-how-to-spread-tech-innovation-across-america/

7 Ezzel, S. & Andes, S. (2016) Localizing the economic impact of research and development Fifty policy proposals for the Trump administration and Congress. Brookings Institution: Washington, DC, USA (available at: https://www.brookings.edu/research/localizing-the-economic-impact-of-research-and-development/

8 The United States Office of Management and Budget (OMB) delineates metropolitan statistical areas according to published standards that are applied to Census Bureau data. The general concept of a metropolitan statistical area is that of a core area containing a substantial population nucleus, together with adjacent communities having a high degree of economic and social integration with that core. For more details, see https://www.census.gov/programs-surveys/metro-micro/about.html

9 Utility patent count from: US Patent and Trademark Office (USPTO). GDP data from: Bureau of Economic Analysis (BEA), US Department of Commerce. The timeline displayed in this chart is based on available data.

10 Utility patent count from: US National Center for Science and Engineering Statistics (NCSES). GDP data from: Bureau of Economic Analysis (BEA), US Department of Commerce. The timeline displayed in this chart is based on available data.

11 Number of firms in the 3 industries from: US Census Bureau, Statistics of US Businesses (SUSB). GDP data from: Bureau of Economic Analysis (BEA), US Department of Commerce. The timeline displayed in this chart is based on available data.

12 See for example the discussion about the interaction between these factors in the interview with the authors of "Jump-Starting America", Jonathan Gruber and Simon Johnson, where they also discuss Kendall square: https://mitsloan.mit.edu/ideas-made-to-matter/to-jump-start-america-invest-a-lot-science

13 Moreover, the relationship between these factors and resulting outputs is not linear. For example, historical analyses have shown that research efforts are rising substantially while research productivity is declining sharply. For more details see https://www.nber.org/papers/w23782

14 Localizing the economic impact, the connection between federal funding and patents is explored in further details in Fleming, L., Greene, H., Li, G., Marx, M. and Yao, D. Government-funded research increasingly fuels innovation. Science, 364 (2019), pp.1139-1141.

15 Clayton P, Feldman M, & Montmartin B "Funding Emerging Ecosystems" WP. No. 2019-25

16 Ibid.

17 See research such as "Jump-Starting America" (Gruber and Johnson, 2019), discussions regarding the Endless Frontier Act and the United States Innovation and Competition Act, and Localizing the Economic Impact of research and development (Ezell and Andes 2016)

18 "National Patterns of R&D Resources: 2018–19 Data Update | NSF - National Science Foundation," accessed April 29, 2022, https://ncses.nsf.gov/pubs/nsf21325#technical-notes&data-tables.

19 "The State of U.S. Science and Engineering 2022 | NSF - National Science Foundation," accessed April 29, 2022, https://ncses.nsf.gov/pubs/nsb20221/glossary.

20 In the FY 2019 Federal R&D obligations were attributed mainly to industry, federal government agencies, universities and colleges, federally funded research centers and non profits (Congressional Research Services Federally Funded Research and Development Centers (FFRDCs): Background and Issues for Congress (2020))

21 Massachusetts uses tax incentives as a policy tool to support and encourage investments in innovation. Domestic and foreign companies can receive credit against their corporate excise tax against qualified research expenses or basic research expenses.# In addition to that, MA also has research tax credit designated to life sciences industries. See 830 CMR 63.38M.1: Massachusetts Research Credit for more information.

22 International comparison: The effective tax relief in the U.S. - 7 percentage points for a profit-making SME or a large enterprise - is lower than the OECD's median (20 or 17 pp), the total government support to business R&D in the U.S. is above the OECD average, as a percentage of GDP

23 Massachusetts uses tax incentives as a policy tool to support and encourage investments in innovation. Domestic and foreign companies can receive credit against their corporate excise tax against qualified research expenses or basic research expenses.# In addition to that, MA also has research tax credit designated to life sciences industries. See 830 CMR 63.38M.1: Massachusetts Research Credit for more information.

24 26 U.S. Code § 41 Credit for increasing research activities. This tax credit was extended without limitation in 2015 through The Protecting Americans from Tax Hikes Act (the PATH Act).

25 For more details see: Holtzman, Yair. "US research and development tax credit: a first look at the effect of the PATH act." The CPA Journal 87, no. 10 (2017): 34-37.

26 Gary Guenther, "Research Tax Credit: Current Law and Policy Issues for the 114th Congress," Congressional Research Service, June 18, 2016, https://www.everycrsreport.com/files/20160618_RL31181_ac919b4772ff5f454f8cedd2dd7aa8b290950a41.pdf.

27 Basic research is defined as "any original investigation for the advancement of scientific knowledge not having a specific commercial objective." (IRC Section 41(e)

28 Joint Committee on Taxation, "Estimates of Federal Tax Expenditures for Fiscal Years 2018-2022," Oct. 4, 2018, https://www.jct.gov/publications.html?id=5148&func=startdown. This sum does not include the loss of revenues due to expensing of R&D costs (a favorable policy that ended in 2021).

29 Matt Hourihan, "A Primer on Federal R&D Budget Trends" (American Association for the Advancement of Science, February 2021).

30 "Master Government List of Federally Funded R&D Centers | NCSES | NSF," accessed May 3, 2022, https://www.nsf.gov/statistics/ffrdclist/.

31 "About | SBIR.Gov," accessed May 3, 2022, https://www.sbir.gov/about.

32 "FY19 SBIR STTR Annual Report" (Small Business Administration, 2020), https://www.sbir.gov/sites/default/files/SBA_Final_FY19_SBIR_STTR_Annual_Report.pdf.

33 According to analysis of data from usaspending.gov, for more information on the methodology, see Annex 1.

34 Stan Soloway, Jason Knudson, and Vincent Wroble, "Other Transactions: After 60 Years, Hitting Their Stride or Hitting The Wall?" (The IBM Center for the Business of Government, 2021).

35 Rhys McCormick, "Department of Defense Other Transaction Authority Trends: A New R&D Funding Paradigm?," December 8, 2020, https://www.csis.org/analysis/department-defense-other-transaction-authority-trends-new-rd-funding-paradigm.

36 Figures 4 and 5 are an analysis of data from National Science Foundation, National Patterns of R&D Resources: 2018– 19 Data Update, NSF 21-325, Table 6, Table 7, Table, 8, and Table 9, April 9, 2021, https://ncses.nsf.gov/pubs/nsf21325. 2019 data are preliminary and may be revised.

37 Figure 4 is based on data available via: National Center for Science and Engineering Statistics (NCSES). 2021. National Patterns of R&D Resources: 2018–19 Data Update. NSF 21-325. Alexandria, VA: National Science Foundation. https://ncses.nsf.gov/pubs/nsf21325.

38 For more details, see Mandt, R., Seetharam, K., & Cheng, C. H. M. (2020). Federal R&D funding: the bedrock of national innovation. MIT Science Policy Review, 1, 44-54.

39 Figure 5 is based on data available via: National Center for Science and Engineering Statistics (NCSES). 2021. National Patterns of R&D Resources: 2018–19 Data Update. NSF 21-325. Alexandria, VA: National Science Foundation. https://ncses.nsf.gov/pubs/nsf21325.

40 The data in this section was compiled from usaspending.gov data for R&D Spending identified using Product and Services Codes (PSCs) for FY17-FY21. For more information see Annex 1.

41 The data in this was compiled from usaspending.gov data and focuses on the total value of obligations for R&D in a Metro Area over a five year period. Product and Service Codes (PSCs) were used to determine where funding was being allocated along the R&D Pipeline.

42 See the 2019 Product and Services Code (PSC) Manual. These stages are outdated and no longer used by the PSC Manual as of 2020.

43 The White House. "Advanced Research Projects Agency for Health (ARPA-H)." Accessed June 17, 2022. https://www.whitehouse.gov/ostp/advanced-research-projects-agency-for-health-arpa-h/.

44 Garcia Martinez, Marian, Ferdaous Zouaghi, and Teresa Garcia Marco. 2017. "Diversity Is Strategy: The Effect of R&D Team Diversity on Innovative Performance: Diversity Is Strategy." R and D Management 47 (2): 311–29. https://doi.org/10.1111/radm.12244.

45 Xie, Luqun, Jieyu Zhou, Qingqing Zong, and Qian Lu. 2020. "Gender Diversity in R&D Teams and Innovation Efficiency: Role of the Innovation Context." Research Policy 49 (1): 103885. https://doi.org/10.1016/j.respol.2019.103885.

46 Schneider, Julia, and Verena Eckl Essen. 2016. "THE DIFFERENCE MAKES A DIFFERENCE: Team Diversity and Innovative Capacity." Oecd.Org. 2016. https://www.oecd.org/sti/015%20-%20SKY_Schneider_Eckl_201607025.pdf.

47 "The State of the Startup Ecosystem" https://static1.squarespace.com/static/571681753c44d835a440c8b5/t/60819983b7f-8be1a2a99972d/1619106194054/The+State+of+the+Startup+Ecosystem.pdf

48 Danielle Kaye, "Capitalizing on Remote Work, U.S. Cities Draw in Tech Workers," Reuters, July 14, 2021, sec. The Great Reboot, https://www.reuters.com/world/the-great-reboot/capitalizing-remote-work-us-cities-draw-tech-workers-2021-07-14/.

49 Ibid.

50 Nellie Bowles, "They Can't Leave the Bay Area Fast Enough," The New York Times, January 14, 2021, sec. Technology, https://www.nytimes.com/2021/01/14/technology/san-francisco-covid-work-moving.html.