DAY ONE PROJECT

The Invention Ecosystem:

A Pathway to Economic Resilience and Inclusive Prosperity

February 2021

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Executive Summary:

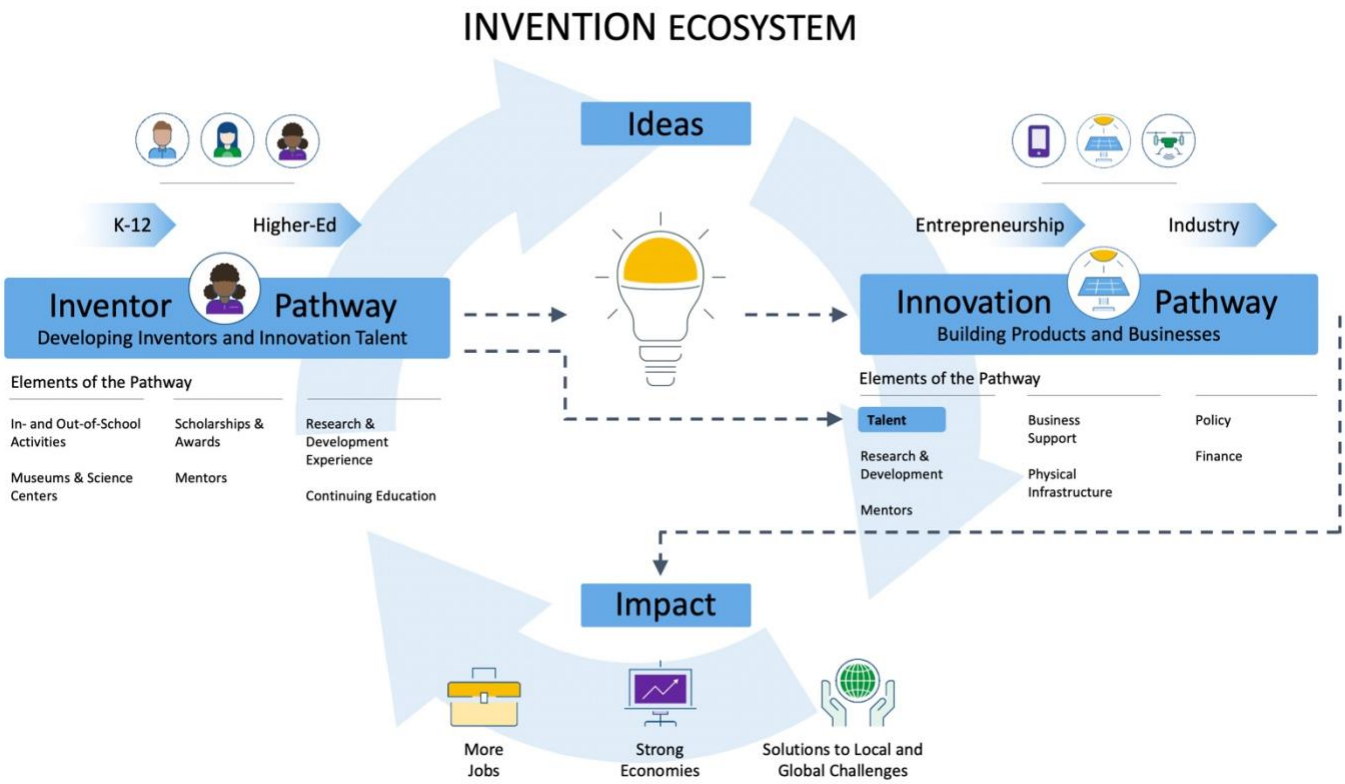
The Invention Ecosystem: A Pathway to Economic Resilience and Inclusive Prosperity

INTRODUCTION

The United States is an invention and innovation powerhouse that has long produced remarkable achievements. Yet American invention is at a crossroads today. After more than a half-century of unrivaled global leadership in basic science, innovation, and manufacturing, the U.S. is losing ground throughout the innovation pipeline across a wide range of sectors. The COVID-19 pandemic has exposed this vulnerability, making brutally clear the need for innovation to address major challenges that arise and highlighting weaknesses such as our dependency on global supply chains.

THE INVENTION ECOSYSTEM

A strong invention ecosystem powers the path to economic growth and resilience. The invention ecosystem consists of two pathways. The inventor pathway inspires and prepares students to address crucial challenges and thrive in the innovation economy. The innovation pathway supports inventors and entrepreneurs so that they can create value from their ideas in the form of products and businesses. Together the pathways yield a pipeline of people and businesses which create jobs, foster resilient economies, and produce solutions to our most pressing challenges. The full potential of these outcomes is achieved when women, individuals from underrepresented ethnicities and geographic regions, and other historically marginalized groups are able to participate in the invention ecosystem and contribute to the innovation economy.



THE INVENTION ECOSYSTEM IS COMPRISED OF FOUR PILLARS:

Pillar I: K-12 Education

K-12 Invention Education (IvE) (inventioneducation.org) is a powerful, transdisciplinary, and experiential approach that teaches the unique ways inventors find and solve problems. IvE cultivates the soft and hard skills most valued by industry leaders.

Pillar II: Higher Education

Higher education enables students to hone vital STEM skills while building innovation and entrepreneurial mindsets. As central hubs for discovery, institutions of higher education are essential to developing the talent needed in the innovation economy and to converting U.S. investment in research and development into economic and societal impact.

Pillar III: Entrepreneurship

Innovation-based companies that do research and development disproportionately drive the creation of jobs and economic impact. New firms are responsible for nearly all net new jobs, and businesses that draw on STEM disciplines play an outsized role in that job creation. However, the unique needs of innovation-based companies—and the systemic obstacles that limit many Americans from pursuing and participating in entrepreneurial ventures—are often overlooked.

Pillar IV: Industry

Industry performs 73% of all research and development in the U.S. and employs nearly all of the country's skilled technical workforce. Yet the innovation potential of industry is far from fully realized. A combination of "short term-ism", barriers to new market entrants, and declining government support has led to diminished funding for industry research.

Conclusion

Existential threats such as climate change and the COVID-19 pandemic underscore the need for innovative solutions to current and future crises. This time of disruption and economic rebuilding presents opportunities to strengthen the four pillars of the invention ecosystem. To reach our full innovation potential, it is critical that opportunities to engage in the invention ecosystem are extended to everyone, regardless of background. The result will be a stronger and more inclusive workforce, a resilient economy that benefits everyone, and progress on our nation's most pressing issues.

Policy Recommendations to Strengthen the Four Pillars of the Invention Ecosystem

Pillar I: K-12 Education Policy Recommendations

- **Create a national strategy to foster invention, innovation, and entrepreneurship skills and mindsets in all students.** Provide universal, equitable, and inclusive access to IvE in all K-12 schools.
- **Create and launch a national initiative to train K-12 teachers in invention, innovation, and entrepreneurial curricula, pedagogy, and assessment.** Invest in universal STEM and IvE professional-development opportunities for teachers and in ways to measure student learning in invention.
- **Develop and design new federal education programs aimed at expanding the diversity of our future inventors, entrepreneurs, and STEM workforce.** Allocate resources to increase the number of opportunities for underrepresented populations in invention, entrepreneurship, and STEM.

Pillar II: Higher Education Policy Recommendations

- **Close critical gaps in the university lab-to-market pipeline.** Assess the existing lab-to-market pipeline and take a series of steps to address critical gaps. The goal should be to ensure that discoveries are converted into promising inventions and innovations, which in turn can be converted into promising businesses.
- **Restore federal R&D budgets to their historic levels as a percentage of GDP.** As part of this restoration, make funding available for universities to invest in programs that support researchers and inventors in converting and commercializing research and innovations into viable products and businesses.
- **Expand successful models and explore promising new opportunities to support the higher-ed innovation pipeline.** Scale existing successful models that foster support for STEM innovators and would-be entrepreneurs in higher education while exploring and experimenting with new programs.
- **Enhance opportunities for diversity and inclusion broadly, and for retaining and supporting immigrant contributions.** Higher-education institutions should leverage their resources and institutional influence to promote increased diversity on campuses. These institutions should intentionally invest in pathways and programs to ensure opportunities for underrepresented populations in innovation, entrepreneurship, STEM, and invention education.

Pillar III: Entrepreneurship Policy Recommendations

- **Promote diversity and inclusion in entrepreneurship.** For instance, increase early exposure to relevant inventor role models and entrepreneurship programs for young people. Shape Small Business Innovation Research (SBIR) programs toward first-time applicants, with an emphasis on women and minorities.[1]
- **Expand entrepreneurship education and diffuse it throughout federally funded programing.** Pursue effective methods for scaling entrepreneurship education across federal education and entrepreneurship investments.[2]
- **Expand and improve core federal investments in commercialization and entrepreneurship.** While SBIR and SBA programs form the foundation of the Federal Government's work to support invention-driven entrepreneurship, greater and more continuous support for the early stage of invention and opportunity development is critically needed.
- **Close gaps in access to early-stage capital.** Encourage greater private-sector participation in angel and seed-stage capitalization of emerging S&T ventures.
- **Tackle licensing and regulation barriers.** Identify and clear barriers that stymie R&D commercialization and the development of key emerging technologies.
- **Restore highly skilled immigration as a key source of entrepreneurial potential.** Immigrant entrepreneurs are one of the most important sources of high-growth entrepreneurship.

Pillar IV: Industry Policy Recommendations

- **Expand and streamline the Federal Research & Experimentation Tax Credit.** This tax credit was recently made permanent—a step to be applauded. Yet the credit is nonetheless both more complicated and less generous than analogous incentives offered by peer OECD countries.
- **Boost industry-relevant federal R&D spending.** Erosion of federal spending for industry-sponsored research has created a major gap in the invention ecosystem. Expansion of federal R&D should include a focus on bridging the late-stage gap through programmatic efforts such as Manufacturing USA, small business voucher programs, Manufacturing

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[1] Ibid.
[2] National Science and Technology Council Committee on STEM Education, 2018.

Extension Partnerships, cluster programs, Small Business Innovation Research (SBIR) grants, and Lab-to-Market activities. Federal funding can also incentivize industry to undertake more transformative R&D. For example, reviving and modernizing the National Institute of Standards and Technology's (NIST) Advanced Technology Program would be a positive step toward filling the gap in incentives for transformative R&D.

- **Leverage federal workforce-development activities to support a greater industry role in a forging a demand-driven talent pipeline.** As anchor institutions, large firms are capable of playing a greater role in engaging with higher education to ensure skills development efforts are driven by demand to address the growing skills gaps in fields critical to the industries of the future.
- **Encourage high-growth firms to recognize and invest in supporting the U.S. inventor ecosystem.** A thriving inventor community underpins national competitiveness and helps grow a talent pool for key skills gaps. Led by the White House, Federal policymakers and agencies should highlight the activities of firms and executives that give back by supporting the inventor ecosystem. The Federal Government should also launch initiatives, such as nationwide prize competitions, that further encourage the private sector to bolster the inventor ecosystem.

The Invention Ecosystem:

A Pathway to Economic Resilience and Inclusive Prosperity

INTRODUCTION

The American invention engine has long been peerless in its ability to innovate and convert scientific breakthroughs into societal gain. In the past 60 years, we have put a man on the moon, transformed military technological capabilities so radically that global geopolitics have been entirely recast, revolutionized the field of biology by leading an effort to map and sequence the human genome, and connected the world through digital technologies.

Today, American invention is at a crossroads. After more than a half-century of unrivaled global leadership in basic science, innovation, and manufacturing, the United States is losing ground through the innovation pipeline. We as a nation are not tapping our full potential to prepare, educate, and enable scientific leaders. Our long-held "edge" in science and technology (S&T) is under threat by rising global competition and increased S&T investment in other countries, while investment in U.S. research and development (R&D) has declined. We have become vulnerable in critical emerging industries as a result, threatening the long-term economic prospects for our country's development and job growth.

The COVID-19 pandemic has underscored the consequences of our eroding S&T capacity. COVID-19 has exposed cracks in our country's innovation pipeline—a pipeline that must be responsive and capable enough to quickly deliver urgently needed solutions like new vaccines and therapeutics, but also strong and forward-thinking enough to steadily drive human progress. For policymakers, grappling with the immediate human, economic, and social costs of COVID-19 are urgent priorities. But policymakers must not neglect our underlying invention ecosystem—the engine of economic growth and driver of new approaches to key societal challenges—in its entirety.

In the wake of COVID-19 lies both an opportunity and a need to make a generational commitment to strengthening all aspects of this American invention ecosystem: its infrastructure, its access pathways, and its resources. As the pandemic has underscored, our invention ecosystem is only as strong as its weakest link. Restoring it will require an all-hands-on-deck approach focused on mobilizing all of our nation's ideas, voices, talent, and resources to surmount these obstacles.

The American response in the post-pandemic era could mirror the American response in the aftermath of the Second World War. The post-war period saw a historic conversion of wartime capacity seed the modern invention ecosystem through investments in research and education paired with new infrastructure to convert invention breakthroughs into world-changing innovations. These investments helped the United States and the U.S. economy emerge from war as the global leader in innovation, and to launch brand-new industrial sectors such as advanced aircraft, drugs and vaccines, microelectronics, satellites, and digital computers.[3] Advances made in the post-war period were the direct result of partnerships across the private sector, Federal Government, and higher education. The resulting innovation ecosystem laid the foundation for a golden era of scientific productivity and economic growth in the United States: an era that remains the world's best example to date of training and harnessing the talents of a skilled scientific workforce for discovery and commercialization of novel technologies.

Yet even as the U.S. economy has come to rely increasingly on S&T—and hence federal investment in research[4] —our societal efforts to sustain and evolve the invention ecosystem have not kept pace. The COVID-19 pandemic is the latest, but far from the only, example of the acute need for a more coordinated, integrated system of invention and innovation, supported by a diverse cadre of trained scientists, researchers, and public health experts. Despite the overwhelming evidence of the critical role invention plays in tackling the wicked challenges[5] of the world, much work remains for policymakers to rebuild an invention ecosystem for the 21st century.

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[3] Jonathan Gruber and Simon Johnson, *Jump Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream* (New York City: PublicAffairs, 2019).

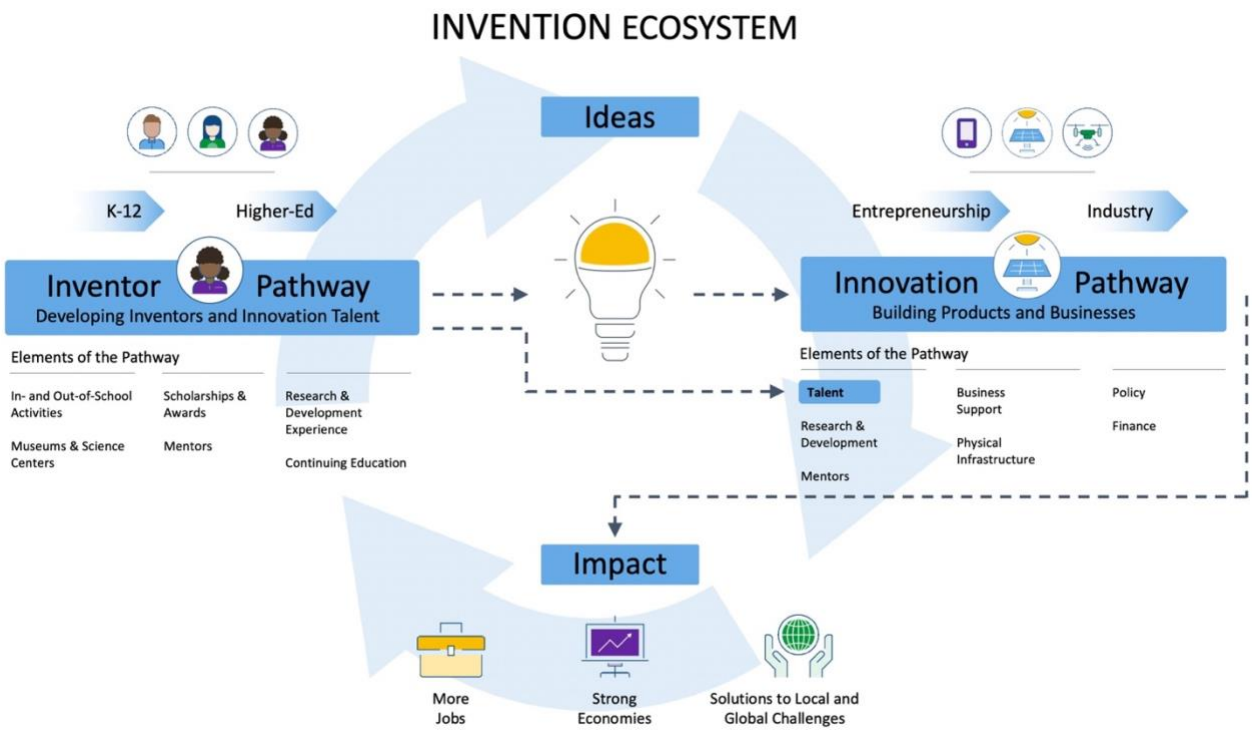
[4] E.g., L. Fleming, H. Greene, G. Li, M. Marx and D. Yao, "Government-funded research increasingly fuels innovation," *Science* 364, 6446 (2019): 1139-1141 found that roughly 30 percent of all U.S. patents issued by the Patent and Trademark Office now rely on federal research funding in some fashion, more than double 1970s levels.

[5] Horst W.J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning", *Policy Sciences* 4 (1973): 155-169.

ONLY AS STRONG AS OUR WEAKEST LINK

Rebuilding a robust U.S. invention ecosystem requires greater emphasis on how education, innovation, and entrepreneurial systems can best (1) cultivate and ignite the imaginations of inventors (the "inventor pathway") and (2) support innovators and entrepreneurs who convert ideas into products and businesses (the "innovation pathway") (Figure 1). These pathways together comprise the "virtuous cycle" needed to build a sustainable invention ecosystem: one in which new ideas and associated high-growth, invention-based companies have the space and resources to emerge and flourish, even as the established firms that are the engine of the American economy continue to innovate and thrive. For Americans, a sustainable invention ecosystem means quality jobs, a stronger and more productive economy, and solutions that tackle local and global challenges.

Figure 1



Creating robust, interconnected innovation pipelines requires a comprehensive view of the invention ecosystem. Specifically, we must recognize the following:

- **Innovation is critical to meeting societal and economic challenges.** Technical innovations are and will be critical to responding to urgent issues, from the COVID-19 pandemic to climate-change mitigation and adaptation. Innovation is an underlying driver of our nation's economic competitive advantage, and is fundamental to the future of our country.
- **Yet at a critical time, the United States' global innovation leadership is eroding.** National Science Foundation (NSF) data shows that competitor nations are closing in on U.S. leadership in spending and patenting activity, and are in some cases outpacing us. For example, the United States' share of all global publications about results from R&D in the physical sciences and engineering dropped from 22.8% in 2003 to only 12.8% by 2016.
- **A long-term cause of eroding U.S. leadership in innovation is our collective failure to invite, engage, and harness the full potential of our nation's human capital.** Many people lack access to training, resources, and meaningful opportunities for participation in the innovation economy.[7] The contributions and ideas of too many communities, demographics, and regions are left behind as a result.

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[7] Alex Bell, Rav Chetty, Xavier Jaravel, Neviana Petkova, and Jon Van Reenen, "Who Becomes an Inventor in America? The Importance of Exposure to Innovation," *Opportunity Insights* (Harvard University, 2018), doi:10.3386/w24062.

- **Economists who analyze innovation are increasingly sounding the alarm about impending technical talent shortages.** Talent mismatches persist across the American economy. By some estimates, nearly a million technical jobs go unfilled in key sectors, even as long-term unemployment numbers grow during the pandemic.[8]

The challenges facing our nation's invention ecosystem are considerable and demand a policy response of commensurate ambition. Generational investments are needed across all aspects of the invention ecosystem, including:

- **Expanding public investment in the four pillars of the invention ecosystem: K-12 education, higher education, entrepreneurship, and industry.** Our nation's innovation systems and funding structures have gaps and inefficiencies that cause us to cumulatively punch well below our economic weight. We must expand research investments, while improving and growing the talent pipeline. Policymakers must reverse the years-long trend of declining investment in research as a share of U.S. GDP, while also streamlining pathways for translating ideas and pilot projects into finished, scalable, and world-changing inventions.

- **Ensuring everyone has the invitation, opportunity, and resources to contribute to the innovation economy.** Expanding pathways for meaningful participation for women, individuals from underrepresented ethnicities and geographic regions, and other historically marginalized groups will help meet growing demand for a technical workforce. Engaging a more diverse array of perspectives and approaches will also enable us as a country to reach our full innovation potential.

- **Facilitating regional and local coordination to convert talent and ideas into value, with an emphasis on cultivating and accelerating invention-driven entrepreneurship.** Place-based policies are critical for linking disparate assets and institutions into an effective invention ecosystem, especially in regions where pathways to developing an invention and becoming an entrepreneur are less established.

The Invention Ecosystem

In the natural world, ecosystems are complex, self-regulated, and hyper-connected networks where individual entities and the underlying environment are all interdependent. Through reinforcing feedback loops, each component of an ecosystem both relies on and influences the ecosystem's other components.

The world of invention exhibits these same characteristics (Figure 1). Two pathways lie at the core of the invention ecosystem:

The Inventor Pathway

The inventor pathway is the engine of talent development driven by invention education (IvE). The inventor pathway instills students with the outlook and the knowledge, skills, and processes needed for the problem identification, technical problem-solving, and entrepreneurial thinking that lie at the core of the invention-driven economy. The inventor pathway includes primary and secondary education, higher education, and career trajectories in science, technology, and similar fields built on key knowledge, applied skills, processes, and competencies. The inventor pathway is supported by elements such as extracurricular activities, museums and science centers, scholarships and awards, mentors, R&D experience, and continuing education.

The Innovation Pathway

The innovation pathway offers the supportive context for inventors to build products and businesses. Elements of this pathway include R&D, physical infrastructure, finance and capital, policy, access to mentors and coaching, talent, and business support.

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[8] Yi Xue and Richard C. Larson, "STEM crisis or STEM surplus? Yes and yes," *Monthly Labor Review*, U.S. Bureau of Labor Statistics, May 2015, https://doi.org/10.21916/mlr.2015.14.

An Interdependent Ecosystem

The four pillars of the invention ecosystem—K-12 education, higher education, entrepreneurship, and industry—reinforce one another through feedback loops, working together to function in a virtuous cycle. A vibrant innovation system relies on a technical workforce, and the economic activity that innovation generates helps to stimulate investments and spotlight the importance of education. A robust technical workforce (and the companies that employ it) provides the inspiration, infrastructure, and mentors needed to support emerging scientists, researchers, problem-solvers, and tinkerers. IvE sharpens the skills and capacities of those looking to enter the innovation workforce. Experienced entrepreneurs and industry leaders serve as mentors and/or future angel investors, providing guidance and seed capital for the next generation. Interdependent invention ecosystems with all of these components power the most vibrant innovation economies in the United States, such as those in the San Francisco Bay Area, Boston, and Seattle.

The Roadmap

Invention spans many disciplines and can serve as the tent under which to bring together a broad audience of innovators, entrepreneurs, engineers, educators, and supporting communities. Cooperatively engaging these stakeholders will enable deeper diagnosis of problems and identification of the best ways to support problem-solving across multiple facets of our society. In thinking of invention as an ecosystem, all stakeholders can better understand and shape joint policy priorities, deploy resources as effectively as possible, and focus attention on the areas where decision support is most critical.

A framework structured around the four pillars of K-12 education, higher education, entrepreneurship, and industry can serve as a roadmap to the invention ecosystem. Below, we summarize the components of each pillar and explain how the pillar contributes to the overall invention ecosystem. We also briefly highlight policy actions that could be taken at the state and federal levels to strengthen each pillar.

Pillar I: K-12 Education

OVERVIEW

Economic and productivity growth is fueled by a workforce that is successfully equipped with the technical skills, mindsets, and content knowledge to craft and implement solutions to our country's most urgent and emergent problems and opportunities. We often overlook the foundational role of primary and secondary education in preparing this workforce. Without adequate preparation and experiences in science, technology, engineering, math (STEM), and related disciplines in K-12 school, students will never be able to access innovation opportunities in higher education and beyond. K-12 education is indispensable in giving students the fundamental tools, exposure, and inspiration needed to pursue science and technology-based careers.

CHALLENGES

Cultivating the inventors and innovators of tomorrow requires us to address systemic challenges within our national K-12 education system. Specifically, we must recognize that:

- Primary and secondary education are fundamentally out of step with the workforce needs of America's modern economy.
- There is increasing evidence that exposing K-12 students to invention, innovation, and entrepreneurship early on motivates deeper learning and engagement with STEM education and adjacent disciplines.
- Too few K-12 students, especially those from underrepresented and under-resourced groups, are exposed to STEM and have the opportunity to experience invention, innovation, and STEM at school.

Preparing students to create successful and scalable companies while also meeting demands of emerging industries requires (1) novel curricula, and (2) pedagogical approaches rooted in STEM innovation, invention, and entrepreneurship.

THE OPPORTUNITY

What is Invention Education, and why does it matter?[9]

Invention education (IvE) has emerged as an approach to foster innovation and invention in young people. Through IvE, students learn to both identify a problem and invent a solution. Unlike typical K-12 instruction that focuses on learning within individual disciplines, IvE emphasizes interdisciplinary thinking, encouraging students to uncover passion areas through problem-finding and to create and invent novel solutions. IvE allows students to explore the real-world applications of design thinking, project-based learning, STEM, and entrepreneurship—as well as creative processes and practices common to arts and humanities—through a problem of their own choice and definition. This approach activates deeper student engagement and learning, particularly in STEM and adjacent fields.

Every child deserves the opportunity to experience IvE. IvE provides a structure for young people to grow and cultivate vital formative skills and mindsets that lead to success in life and work. Going from problem identification to the creation of a viable solution builds "soft" skills like creativity, empathy, curiosity, and resourcefulness, "hard" skills such as computer coding, data analysis, and design, and other critical core capacities. Participation in IvE activities and curricula builds student confidence by fostering a new sense of identity, abilities, and the confidence. These competencies, combined with the other practices, mindsets, dispositions, attributes, and traits that IvE fosters, have been identified in the leading innovators, managers, and scientists across all industries today.[10]

Introducing IvE early on can inspire young people to become future inventors, entrepreneurs, problem solvers, and members of the workforce for emerging industries where these skills are in demand. Capabilities generated through IvE are frequently cited as the critical skills that employers seek—and often find lacking—in today's workforce. In 2019, an annual survey of nearly 40,000 global leaders identified talent shortages in information technology, engineering, and other skilled trades. IvE can foster the problem-solving abilities and other technical skills needed to close gaps within the existing talent pipeline.[11]

By cultivating future problem solvers ready to address complex and emerging problems, IvE can serve as a source of economic competitiveness, emerging technology, and growing industries in the United States. The current mismatch of workforce supply and demand, coupled with the changing forces of work globally due to automation and other emerging technologies, exacerbate the need for talent with STEM capabilities and related IvE competencies.

Cultivating the Innovation Workforce

Lemelson-MIT InvenTeams are teams made up of high school students, educators, and mentors who receive grants of up to $10,000 to invent technological solutions to real-world problems that the students identify. InvenTeams research intellectual property, exchange ideas, design parts, build models, and make modifications as they develop their invention prototypes. They learn to move forward through challenges and innovate, all while cultivating technical skills. It's a program that can stoke even the faintest interest in STEM, as it did for a young woman named Katelyn Sweeney. Katelyn wasn't drawn to any of the STEM fields until she was put in a technology class during her freshman year at Natick High School in Massachusetts. Her teacher emphasized learning through inventing: a new way of thinking for Katelyn and one that sparked a passion for solving problems.

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[9] InventEd, *A Framework for Invention Education* (The Lemelson Foundation, 2020), https://inventioneducation.org/framework-for-invention-education/.

[10] Audra Skukauskaite, Stephanie Couch, and Leslie Flynn, *Researching Invention Education: A White Paper,* InventEd, November 19, 2019, https://inventioneducation.org/researching-invention-education/.

[11] Manpower Group, *Closing the Skills Gap: What Workers Want, Talent Shortage 2020* (Manpower Group, 2020), go.manpowergroup.com/talent-shortage.

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As Katelyn began learning to identify issues in her community and how to create solutions for them, she discovered an exciting intersection between STEM and creativity. This led Katelyn to participate with her classmates in the Lemelson-MIT InvenTeam program. Katelyn's team created a remotely operated submersible vehicle to assist their community's ice search and rescue dive teams. Their invention took them all the way to the White House to present at the 2014 White House Science Fair, and even earned them a patent. Katelyn went on to graduate from MIT with a degree in mechanical engineering and to design other inventions with social impact. A valuable contributor to the innovation workforce, Katelyn currently works at OneWeb, designing a satellite-based communications network to expand access to high-speed broadband across the world.

IvE can increase the diversity of our skilled workforce, creating more equitable opportunities to catalyze innovation and economic growth.

Exposure to IvE opens new and alternative pathways for individuals from diverse identity groups and across the socioeconomic spectrum to enter and grow into leaders in STEM fields. Critical competencies developed through participation in IvE are linked to successful long-term outcomes. Exposure to innovation, invention, engineering, and STEM in school has been found to benefit students of all ages.[12] By introducing students to the innovation process during childhood, IvE can also be "…a critical factor that determines who becomes an inventor and the types of innovations they pursue."[13] An innovator's background, upbringing, and lived experiences impact the ways in which they see the world, bringing creativity and new lenses to place on top of intractable societal problems. Research suggests the best approach to creating equitable access and generating interest in inventing and STEM pathways for diverse learners is student engagement in IvE learning, beginning at an early age, to encourage matriculation across all years of schooling and into invention and STEM careers.[15]

The stakes are significant. If underrepresented groups—including women, minorities, and children from low-income families—begin inventing at the same rate as White males from high-income (top 20%) families, it is estimated that the total number of inventors in the U.S. economy would quadruple.[16]

Oregon MESA: Creating a Culture of STEM Pride in Schools

The MESA Schools Program provides no-cost Invention Education (IvE) opportunities to students historically underrepresented in STEM fields. The after-school program trains teachers in the MESA curriculum that is aligned with the Next Generation Science Standards (NGSS), and changes the trajectory of students' lives as they gain confidence in their STEM and problem-solving skills.

The Oregon MESA program has transformed the culture at McKay High School in Salem, where 95% of the 2,500-strong student body qualify for free or reduced-price lunch. Leading the charge on this progress is math and engineering teacher Katrina Hull. Katrina first became interested in IvE when she began hosting a weekly after-school Oregon MESA club where students plan and build human-centered design projects to solve challenges in their own communities. In the process, she saw first-hand the transformative power of invention. One of Katrina's high school teams went on to win the collegiate-level Cleantech Challenge at Portland State University

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[12] Audra Skukauskaite, Stephanie Couch, and Leslie Flynn, *Researching Invention Education: A White Paper* (InventEd, 2019), https://inventioneducation.org/researching-invention-education/.
[13] Alex Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova, John Van Reenen, *Who Becomes an Inventor in America? The Importance of Exposure to Innovation,* Opportunity Insights (Harvard University, 2017), www.equality-of-opportunity.org/assets/documents/inventors_paper.pdf.
[15] Ibid.
[16] Ibid.

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and take second place at InventOregon. Another team was accepted into the Lemelson-MIT InvenTeam competition. "Words cannot describe how special she is," says student Chau Nguyen, who emigrated from Vietnam six years ago not speaking any English. Chau found a mentor in Katrina and a passion for engineering and entrepreneurship through the Lemelson-MIT program. When a school has multiple IvE programs and interventions engaging its students, it inspires a school culture based on invention. The demand for invention-based learning at McKay High School has increased so much that there are now waiting lists for STEM classes and programs.

To grow equitable pathways for problem solvers, policymakers must be intentional about investing in inclusive curricula early on. K-12 IvE curricula provide entry points for young people from underrepresented backgrounds to explore invention in the context of problems with personal relevance. IvE can help close the innovation gap, creating opportunities for all students to enter, persist, and thrive in STEM pathways and careers. And with most measures indicating an overwhelming lack of diversity in the invention ecosystem—for example, patent holders and leading technology innovators are 90% male and nearly 95% Asian or White[17]—there is much progress to made.

K-12 POLICY RECOMMENDATIONS

1. **Create a national strategy to foster invention, innovation, and entrepreneurship skills and mindsets in all students.** Provide universal, equitable, and inclusive access to IvE in all K-12 schools.
2. **Create and launch a national initiative to train K-12 teachers in invention, innovation, and entrepreneurial curricula, pedagogy, and assessment.** Invest in universal STEM and IvE professional-development opportunities for teachers and in ways to measure student learning in invention.
3. **Develop and design new federal education programs aimed at expanding the diversity of our future inventors, entrepreneurs, and STEM workforce.** Allocate resources to increase the number of opportunities for underrepresented populations in invention, entrepreneurship, and STEM.

Pillar II: Higher Education

OVERVIEW

Our nation's institutions of higher education have seeded many of the greatest American inventions and companies, as well as valuable human capital. The U.S. system of higher education is foundational as a source of invention. Yet the higher-education system has unmet potential in terms of human-capital development and commercialization of promising innovations. With COVID-19 threatening the already tenuous financial model at the core of higher education, questions of how to best sustain and strengthen the U.S. higher-education system in a rapidly changing world are ever more timely and urgent for policymakers to confront.

CHALLENGES

Institutions of higher education are an important waypoint along the educational journey of future innovators. Equipped with foundational knowledge and experiences from K-12, students in higher education continue to hone vital technical skill sets—including technological and vocational capabilities—while building innovation and entrepreneurial mindsets applicable to problems throughout life and career.

[17] Skukauskaite, Couch, and Flynn, 2019.

Institutions of higher education are central hubs for discovery: the places where solutions for intractable societal challenges are forged. Colleges, universities, technical and trade schools, and community colleges have long served as critical catalysts of innovation across the invention ecosystem. Our nation's global competitiveness is directly linked to our investment in targeted R&D, an area where researchers, post-docs, and faculty at institutions of higher education have played a crucial role since the 1970s.[1]

Institutions of higher education should enable our country to fully realize the value of its human capital in the invention ecosystem by providing all Americans with the specialized training they need to succeed in STEM careers. Yet our existing higher-education systems collectively struggle to convert already stratified and inequitable investments in people and research into equitable economic outcomes. Preexisting challenges are being exacerbated by the COVID-19 pandemic, as state budgets experience shortfalls, tuitions rise, and new models of online and distance learning and alternative credentialing—coupled with decreasing enrollment—are forcing a rethink of the existing higher education models.

Obstacles to fostering inventors and entrepreneurs within our existing higher-education systems include:

- The U.S. R&D pipeline is declining due to underinvestment and gaps in converting inventions and innovations into new ventures.
- Competition and rapid technological disruption are increasing demand for workers trained in science, technology, and higher-level technical skills, yet higher-education systems are not meeting those needs.
- Systemic barriers hinder progression of underrepresented groups through higher education, as well as engagement by these groups in innovation disciplines. This in turn limits our nation's ability to realize its full economic potential.

THE OPPORTUNITY

Why is higher education central to invention?
Ideally, academic institutions provide the culminating educational experience for many aspiring technologists, engineers, inventors, scientists, and others who go on to become core contributors to the innovation economy.

Promoting invention within higher education supports two primary outcomes:

(1) Cultivating our nation's future talent: training, supporting, and equipping inventors, innovation entrepreneurs, and innovation-economy workers.
(2) Transforming intellectual capital into economic and societal value: bringing basic R&D successes to society through reimagined commercialization and tech transfer.

Higher education is critical to the social contract between government and society and serves as a core component of the invention ecosystem.[18] Thanks in large part to government-funded research, universities have historically been crown jewels in America's innovation landscape, anchoring regional economies while catalyzing research breakthroughs and spinning out companies with outsized economic contributions.

Higher education converts U.S. investment in R&D into economic and societal impact.
The university R&D pipeline is suffering due to sustained decline in funding intensity and endemic challenges in converting inventions and innovations into new ventures. Today's federal R&D funding levels are the lowest they've been since the 1950s. In order to fuel that innovation pipeline, the U.S. must increase its investment in university R&D.[19]

Declining investments in R&D is a result of our collective failure to efficiently capitalize on the inventions and innovations that are developed in and emerge from university systems. Bringing innovations from the lab to the marketplace is an uneven and difficult process under the best circumstances, but mismatched incentives and funding gaps along the way

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[18] Charles I. Jones, and John C. Williams, "Measuring the Social Return to R&D," *Quarterly Journal of Economics*, 113, no. 4 (1998): 1119-35.
[19] Robert D. Atkinson and Caleb Foote, "U.S. Funding for University Research Continues to Slide," Information Technology and Innovation Foundation, October 21, 2019, https://itif.org/publications/2019/10/21/us-funding-university-research-continues-slide.

make development and commercialization even harder. Some researchers suggest that identifying promising innovations is getting more and more difficult.[20]

Efforts to overcome these hurdles, such as university-based proof-of-concept centers and unconventional models to merge scientific endeavor, financing, and technical assistance, are promising paths forward. But maximizing our nation's economic potential within higher education requires significantly broader engagement and collaborations. Federal funding agencies should work more directly with public and private partners to close gaps along the innovation pathway and more effectively support emerging entrepreneurs as they develop business models and begin to form companies. This intervention and support model is especially important in science and technology entrepreneurship, as many S&T start-ups have longer development timelines that require earlier and higher levels of support during the period leading up to commercialization.

Furthermore, early-stage inventors and innovation entrepreneurs often lack training and expertise in areas such as basic financial management, business development, and marketing. Such knowledge gaps make it harder to take products to market. Inventors and entrepreneurs also often lack understanding of critical issues related to intellectual property (IP) and the transition from a research entity to a corporate structure.[21] Only a fraction of the 60,000+ postdocs in the United States have access to support pathways for commercializing research or lab-based innovations.[22]

Misaligned incentives play a significant role in our nation's inability to realize the full potential of higher education in the invention ecosystem. It is problematic that government investment in R&D as a share of GDP has decreased over recent decades. It is equally problematic that the return on dollars that are invested is not being maximized at universities, where the majority of federal R&D resources land.[23] Universities are missing opportunities to commercialize and spin out technologies and companies from the novel inventions and innovations incubated on their campuses.[24] For example, innovation, entrepreneurship, and commercialization resulting from scientific or technological research is often absent from or even a negative factor in tenure-review processes for university faculty. Many forgo opportunities to push novel technologies into the marketplace as a result.

Providing Opportunities for Rural Students to Become Inventors

Invent Oregon (InventOR) is a college-level prototyping competition aimed at mentoring students and inspiring them to develop solutions to today's pressing problems. Participating students receive up to $2,500 in grants to take their inventions from idea to working prototype while learning about the process of commercialization. At the InventOR Collegiate Challenge finals, students present their inventions and compete for $30,000. More than 20 schools across the state participate in the program every year. One such school is Rogue Community College, located in rural Rogue Valley. In 2018, one of its students, an aspiring automotive engineer named Blake Turner, heard about InventOR and decided to enter. Blake created a device that converts traditional car engines to run on hydrogen instead of gasoline. He used his own 1963 Corvair as the first prototype to demonstrate how his device could transform any existing vehicle into a zero carbon-emissions one. Blake won the Cleantech challenge at Portland State University, and then took second place at the People's Choice Award at InventOregon in 2019. He created his own company to bridge the gap between fossil fuels and clean energy and make eco-friendly driving more affordable. This is the power of programs like InventOR: They have the capacity to reach kids from rural communities—whose talent and potential often go untapped—and illuminate for them the pathway to invention.

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[20] Benjamin F. Jones, "Burden of Knowledge and the 'Death of the Renaissance Man': Is Innovation Getting Harder?", *The Review of Economic Studies* 76, no. 1 (Jan 2009): 283-317. https://academic.oup.com/restud/article/76/1/283/1577537?login=true; Robert J. Gordon, "Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds," *NBER Working paper* (August 2012), DOI 10.3386/w18315.

[21] Phil Weilerstein, Shaheen Mamwala, and Heath Naquin, "Closing Critical Gaps from Lab to Market," *Day One Project*, January 23, 2020, https://www.dayoneproject.org/post/closing-critical-gaps.

[22] Ibid.

[23] Matt Hourihan and Dan Correa, "Ambitious, Achievable, and Sustainable: A Blueprint for Reclaiming American Research Leadership" *Day One Project,* January 23, 2020, https://www.dayoneproject.org/post/ambitious-achievable-and-sustainable.

[24] Weilerstein, P. Mamwala, S. and Naquin, H., 2020.

Invention and related skill acquisition are crucial for U.S. economic resilience.
U.S. higher education systems are essential to our nation's ability to respond to and lead a global economic recovery, as well as to maintain and restore our nation's position as a leader across many emerging industries. Pursuit of novel inventions and innovations within a relatively low-risk environment like a university helps drive the talent engine of our economy. Employers are looking for workers skilled in critical thinking, problem solving, working with information (i.e., data analysis), cultural awareness, complex communication, and creativity.[25] These vital skills are honed in laboratories, maker spaces, design facilities, and real-world research. Experimenting, designing, prototyping, and engaging with difficult problems creates a highly trained workforce equipped to lead a resurgence in U.S. science and technology industries.

We can further bolster U.S. economic resilience by making it easier for foreign nationals to pursue advanced degrees at U.S. institutions and to obtain authorization to work upon graduation. Immigrants account for 30% of all inventors in the United States, and sectors with more immigrant inventors produce more patents.[26] Welcoming more immigrants into American academic institutions and facilitating pathways to enable their ongoing contributions to the invention economy represents a significant source of economic advantage.

Higher education can increase diversity in the invention ecosystem.
To tap into the full capacity, ideas, and talents of our population, we must build inclusive and diverse talent pipelines and offer equitable opportunities and training for early-stage innovators, inventors, and all Americans. Higher education plays a significant role in preparing a diverse workforce ready to contribute to the innovation economy.

Higher education in general—and four-year universities specifically—can be more intentional about increasing and retaining diverse student innovators through institutional commitments like hiring and development practices for staff and faculty, and by offering more inclusive innovation, invention, and entrepreneurship programming and physical spaces on campus. Creating or altering institutional policies to support a more inclusive invention ecosystem can also help remove barriers that prevent underrepresented students from participating in entrepreneurship programming and ensure that diverse populations have access to invention opportunities and support.

VentureWell: Supporting Inventors from Underrepresented Communities

VentureWell cultivates student impact inventors, innovators, and entrepreneurs on college campuses, and helps move the strongest ideas rapidly forward to commercialization. Through a network of more than 400 colleges and universities, VentureWell enables the launch and early incubation of student-led, invention-based enterprises that demonstrate the ability to be financially viable, scalable, and attractive to downstream investors. Its core construct, E-Teams, has enabled thousands of emerging innovators to get their start and has inspired widespread adoption in higher education and research of a hands-on approach to innovation and entrepreneurship. E-Teams has also served as an engine for the National Science Foundation (NSF)'s I-Corps program. I-Corps is designed to move NSF-funded research from academic labs to the marketplace, where that research can have wide societal impact.

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[25] Lee Rainie and Janna Anderson, "The Future of Jobs and Jobs Training," Pew Research Center, May 3, 2017, https://www.pewresearch.org/internet/2017/05/03/the-future-of-jobs-and-jobs-training/.
[26] Ufuk Akcigit, John Grigsby, and Tom Nicholas, "Immigration and the Rise of American Ingenuity," Working Paper 17-064, Harvard Business School, January 26, 2017, https://www.hbs.edu/faculty/Publication%20Files/17-064_50573c08-d0ca-4092-9f51-b079ed33c26b.pdf.

Continued

One of the inventors VentureWell has supported is Dr. Maria Artunduaga, a Colombian-born and -raised founder and CEO of Respira Labs. Trained as a surgeon, Maria created a device that continuously monitors changes in lung function using a patented acoustic resonance technology that Maria invented after losing her grandmother to Chronic Obstructive Pulmonary Disease (COPD). Respira Labs participated in many VentureWell programs, including the E-Team grant and ASPIRE programs. In 2019, Respira Labs was awarded a $225,000 Phase I SBIR grant from NSF and subsequently secured a second Phase I STTR grant from the National Institutes of Health (NIH) to continue developing and validating Maria's breakthrough technology inside and outside the hospital. Maria recently closed a pre-seed venture-funding round of $320,000, bringing the total funds received for her invention to $1 million. She was the first solo Latina immigrant in Silicon Valley to reach this milestone.

Inventors from underrepresented communities, like Maria, face additional challenges raising money from venture-capital investors because they do not have equitable access to the innovation pathway. The business skillsets of people from underrepresented communities are constantly questioned simply because those people come from non-traditional backgrounds. Especially for these individuals, the staged support that programs like E-teams and I-Corps offer to nascent entrepreneurs is crucial. Such programs provide a solid foundation upon which collegiate and non-traditional inventors can build successful businesses. These programs make it possible for ideas like Maria's to develop into solutions that save lives.

A college education should be highlighted as a key opportunity to increase the involvement of potential inventors from underrepresented groups. Greater representation will improve the quality of the inventions and solutions generated on campuses while simultaneously expanding the opportunities that higher education supports.

HIGHER EDUCATION POLICY RECOMMENDATIONS

1. **Close critical gaps in the university lab-to-market pipeline.** Assess the existing lab-to-market pipeline and take a series of steps to address critical gaps. The goal should be to ensure that discoveries are converted into promising inventions and innovations, which in turn can be converted into promising businesses.
2. **Restore federal R&D budgets to their historic levels as a percentage of GDP.** As part of this restoration, make funding available for universities to invest in programs that support researchers and inventors in converting and commercializing research and innovations into viable products and businesses.
3. **Expand successful models and explore promising new opportunities to support the higher-ed innovation pipeline.** Scale existing successful models that foster support for STEM innovators and would-be entrepreneurs in higher education while exploring and experimenting with new programs.
4. **Enhance opportunities for diversity and inclusion broadly, and for retaining and supporting immigrant contributions.** Higher-education institutions should leverage their resources and institutional influence to promote increased diversity on campuses. These institutions should intentionally invest in pathways and programs to ensure opportunities for underrepresented populations in innovation, entrepreneurship, STEM, and invention education.

Pillar III: Entrepreneurship

OVERVIEW

Inventors are not only inspired by ideas in the abstract, but also by real-world problems. Innovation and entrepreneurship enable inventors to translate ideas into solutions with real-world benefits.

Innovation-based businesses that emerge from scientific or technological advances generate tremendous economic impact in terms of jobs and in delivering world-changing innovations that enhance our quality of life. New firms are responsible for nearly all net new jobs, and high-tech businesses (i.e., those that draw on STEM disciplines) play an outsized role in that job creation.[27]

CHALLENGES

Entrepreneurship is often hailed as a key element of the spirit of American ingenuity, but data indicate that our country's entrepreneurial output is weakening.[28] Additionally, this framing of entrepreneurship—a framing prevalent in both the popular imagination and among policymakers—often conflates the subset of innovative, invention-driven new businesses with a much larger community of new and existing small businesses. The latter includes everything from retail stores to fitness centers to restaurants. While "Main Street" businesses like these are more prevalent in our society and their role in the economy should not be overlooked, it is typically the former category of innovation-based enterprises that commercialize new technologies. These enterprises bring important new products and services with high growth potential to the marketplace.

Meeting the Needs of an Entrepreneur Yields Economic Value

Rensselaer Polytechnic Institute (RPI) in upstate New York offers a course called the Inventor's Studio, which gives undergraduate and graduate students from area schools access to mentoring and equipment to invent and innovate. Students are coached in how to turn their ideas into patents, seek initial investment for their companies, and commercialize their products. In 2006, Eben Bayer was a participant in Inventor's Studio. Today he is a successful inventor-entrepreneur delivering world-changing environmental innovation. Along with classmate Gavin McIntyre, Eben developed and patented a method of growing a mushroom-based insulation and packing material that is safe and sustainable. The technology has the potential to reduce petroleum use while also cutting down on landfilled petroleum-based waste.

In 2007, Eben and Gavin founded the company Ecovative. They have since successfully expanded Ecovative to meet the needs of major clients such as Ikea and Dell. But, as with all entrepreneurial ventures, there were challenges along the way, especially early on. RPI's Business Incubator was invaluable to Eben and Gavin as it provided networking and coaching during the formative stages when support is often most critically needed. Most importantly, the RPI incubator gave the inventors free access to office space and a wet lab.

Ecovative is not only providing an innovative environmental solution to packaging, but also jobs and commerce that spur the U.S. economy. Ecovative's impact landed both co-founders on the Forbes 30 Under 30 List. Ecovative recently earned a $9.1 million government contract to develop living building materials that would have the ability to self-repair or even generate furniture. In addition, they created a vegan "leather" and spun off Atlast Food Co., which makes plant-based meat. This is the kind of economic return that can result from investing in invention R&D.

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[27] Jason Wiens and Chris Jackson, "*The Importance of Young Firms for Economic Growth*," *Entrepreneurship Policy Digest* (Kansas City: Ewing Marion Kauffman Foundation, September 24, 2014).

[28] U.S. Bureau of the Census, *Bicentennial Edition Historical Statistics of the United States, Colonial Times to 1970,* Part 2, (U.S. Department of Commerce, 1975), https://www.census.gov/library/publications/1975/compendia/hist_stats_colonial-1970.html.

New innovation-based ventures also have specific challenges and needs that are often overlooked by policymakers. For example, invention-based entrepreneurial ventures can be capital-intensive and frequently operate in regulated domains. Their successes often depend on their ability to recruit and retain specialized technical talent. The resulting complexity of their business models creates different risks and longer timelines for getting to market. These new ventures are often based on intellectual capital, making intellectual property an important issue for invention-based entrepreneurs.

Entrepreneurs from underrepresented communities face particular challenges. Those who identify as women, people of color, and/or from a low-income background, or who are located outside of major urban centers are too often excluded from the support systems that should invite and enable them to participate in invention-driven entrepreneurship. As a society, we are losing value in terms of potential ideas and businesses from the untapped brainpower and perspectives resulting from this exclusion. A study by Citigroup found that the U.S. economy lost $16 trillion because of racism.[29]

We are also losing enormous potential by denying immigrants the chance to be entrepreneurs. In the United States, immigrants are almost twice as likely to become entrepreneurs as native-born U.S. citizens. Immigrants represent 27.5% of the country's entrepreneurs but only around 13% of the population (census.gov). Similarly, about one-fourth of all of the technology and engineering companies that started in the United States between 2006 and 2012 had at least one immigrant cofounder[30].

Entrepreneurship, like invention, is inherently both creative and uncertain. As a result, entrepreneurs must continually design and experiment, and need time to refine and pivot as new challenges arise—often without the deep reserves of capital that larger established businesses can draw upon. The path from laboratory to market is an unpredictable one. Not every promising breakthrough is a marketable innovation. This unpredictability is also one reason that so many patents—approximately 90% in 2013[31]—go uncommercialized. Evidence suggests that interventions to make invention-based entrepreneurship a less risky endeavor could significantly increase commercialization rates.

Recent events have underscored the importance of supporting entrepreneurship-fueled economic and job growth. The COVID-19 pandemic has pushed unemployment to unprecedented levels. April 2020 set a record for job loss in a single month at 14.7%.[33] High unemployment represents a serious threat to one of our nation's core tenets: opportunity. Without jobs, people will be restricted in their opportunities to earn a living, provide for their families, plan for the future, and thrive in the most general sense. Our economy will also suffer at the macro level as a result, compounding the effects of unemployment. New ideas and inventions cannot go far in an economy stripped of opportunity. But invention can also provide a road to job creation and thus economic advancement. The vehicle that will transport us along that road is a robust and well-resourced entrepreneurship ecosystem.

In sum, challenges and gaps in entrepreneurship include:[34]

- **Research breakthroughs face an uncertain pathway to becoming useful innovations.** Improving the commercialization pipeline and supporting innovators to become investment-ready is essential for addressing key societal challenges like access to renewable energy and health interventions for our aging population.
- **Cultivating high-growth businesses requires a focus on invention-driven entrepreneurship.** High-growth, high-tech businesses are the engine of new job creation and manufacturing opportunities. Our ability to address our biggest local, national, and global challenges depends on our ability to translate inventions into products that can inspire investors and grow sustainably.

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[29] Adedayo Akala, "Cost of Racism: U.S. Economy Lost $16 Trillion Because of Disinformation, Bank Says," *NPR,* September 23, 2020, https://www.npr.org/sections/live-updates-protests-for-racial-justice/2020/09/23/916022472/cost-of-racism-u-s-economy-lost-16-trillion-because-of-discrimination-bank-says.

[30] Peter Vandor and Nikolaus Franke, "Why Are Immigrants More Entrepreneurial," *Harvard Business Review*, 2016, hbr.org/2016/10/why-are-immigrants-more-entrepreneurial.

[31] Reddi Kotha, Phillip H. Kim, and Oliver Alexy, "Turn your science into a business," *Harvard Business Review*, November 2014. https://hbr.org/2014/11/turn-your-science-into-a-business.

[33] "Unemployment rate rises to record high 14.7 percent in April 2020," *TED: The Economics Daily*, U.S. Bureau of Labor Statistics, May 13, 2020, bit.ly/3omPMsG.

[34] Alexander N. Pan, "Impact Inventing: Strengthening the Ecosystem for Invention-Based Entrepreneurship in Emerging Markets," (Aspen Network of Development Entrepreneurs, September 2014), www.aspeninstitute.org/publications/impact-inventing/.

- **Many would-be inventor-entrepreneurs lack opportunities in the invention ecosystem.** Lack of coordination and integration across systems of K-12 education, higher education, and industry creates an uneven distribution of opportunity. Much more needs to be done to give meaningful access to people who have been historically underrepresented and marginalized in the entrepreneurship and innovation economy.

THE OPPORTUNITY

Investment in R&D is critical to fostering entrepreneurship.

The United States has untapped innovation capacity, capacity that we cannot afford to waste as industrial R&D declines. Despite the fact that basic research is critical to most inventions—such as new vaccines, clean-energy infrastructure, and solutions to problems not yet foreseen—corporations are playing less of a role in this research than ever before. Entrepreneurial communities must pick up the slack, helping to convert the research of our world-class universities into products and services that benefit society. In doing so, they can bring about a new golden era of innovation as productive and transformative as the era following World War II.

Indeed, much current American science and innovation research policy is based on the R&D boom that followed World War II. During that time period, Congress bolstered the nation's pipeline of science and technology ideas, providing government support for fundamental research at universities to complement the R&D being conducted by industry. Both government and the private sector have decreased funding for early-stage research since then. The private-sector share of investment focused on basic R&D has notably fallen from one third to one fifth since 1987.[35] COVID-19 has placed the results of these diminished investments and gaps on full display. The emergence of a global pandemic demonstrates how essential it is to maintain clear and continuous path of resources and support for innovation in order to address critical societal needs.

The Impact of a Single Inventor

Invention is limitless in its capacity to improve lives. A single inventor can fundamentally change the world. Case in point: Dr. Robert Langer. An Institute Professor at MIT and a co-founder of the drug company Moderna, the creator of a COVID-19 vaccine, Dr. Langer's relentless interest in material engineering has led him to become one of the most prolific and influential inventors in the fields of medicine and biochemistry. His groundbreaking work in tissue engineering and in new polymers for drug-delivery systems have translated into commercial products that have eased the suffering of millions of cancer patients and others who are ill. Dr. Langer holds hundreds of patents and has won many prizes and awards. Many companies that began in his lab have met the 10-year survival threshold. These companies have collectively raised over $2 billion and brought a whole suite of products to market and to scale. A beloved mentor, Dr. Langer has worked with thousands of students in his lab. Many of those students are now professors themselves, carrying Dr. Langer's influence forward by encouraging the next generation of big thinkers to follow their passions, develop solutions, and improve lives. His contributions to engineering and the chemical sciences—and indeed, to human health—have resulted in dozens of successful companies and represent the impact that can come from nurturing one inventor's unbridled curiosity.

Entrepreneurship gives everyone a chance to participate in the innovation economy.

The story of entrepreneurship is fundamentally one of human capital. One recent study has confirmed that as more inventors migrate to a region, a greater number of high-growth entrepreneurial firms result.[36] Yet the opportunity to contribute is not equitably available. Women, people of color, and those from low-income areas are vastly underrepresented in the innovation economy. In 2017, only 16% of venture-capital investment went to companies with

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[35] Gruber, J. & Johnson, S., *Jump Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream*, (New York City: PublicAffairs, 2019).
[36] Benjamin Balsmeier, Lee Fleming, Matt Marx, and Seungryul Ryan Shin, "Skilled Human Capital and High-Growth Entrepreneurship: Evidence from Inventor Inflows," Working Paper No. w27605 (National Bureau of Economic Research, July 2020), https://www.nber.org/papers/w27605

at least one female founder. The data for other underrepresented groups are even more abysmal.[37] White males from affluent backgrounds predominate not only in venture capital-backed entrepreneurship, but also in the leadership of organizations across the entrepreneurial ecosystem: from venture capital to mentoring programs and accelerators. Evidence suggests that this is a self-perpetuating cycle. The disproportionate dominance of white males in the innovation economy can negatively impact opportunities available to those from diverse backgrounds.[38]

Less widely known are the tangible impacts of this lack of inclusion. And our current rate of change is far too slow. If the current rate of increase in gender diversity continues, it will take 118 years for women to make up an equal share of U.S. inventions. [39] More must be done.

ENTREPRENEURSHIP POLICY RECOMMENDATIONS

1. **Promote diversity and inclusion in entrepreneurship.** For instance, increase early exposure to relevant inventor role models and entrepreneurship programs for young people. Shape Small Business Innovation Research (SBIR) programs toward first-time applicants, with an emphasis on women and minorities.[41]
2. **Expand entrepreneurship education and diffuse it throughout federally funded programing.** Pursue effective methods for scaling entrepreneurship education across federal education and entrepreneurship investments.[42]
3. **Expand and improve core federal investments in commercialization and entrepreneurship.** While SBIR and certain SBA programs form the foundation of the Federal Government's work to support invention-driven entrepreneurship,[43] greater and more continuous support for the early stage of invention and opportunity development is critically needed.
4. **Close gaps in access to early-stage capital.** Encourage greater private-sector participation in angel and seed-stage capitalization of emerging S&T ventures.
5. **Tackle licensing and regulation barriers.** Identify and clear barriers that stymie R&D commercialization and the development of key emerging technologies.
6. **Restore highly skilled immigration as a key source of entrepreneurial potential.** Immigrant entrepreneurs are one of the most important sources of high-growth entrepreneurship.

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[37] Ian Hathaway, "The Ascent of Women-Founded Venture-Backed Startups in the United States," Center for American Entrepreneurship, February 2019, https://startupsusa.org/women-founded-venture-backed-startups/Report_Final.pdf.

[38] Kamal Hassan, Monisha Varadan, and Claudi Zeisberger, "How the VC Pitch Process is Failing Female Entrepreneurs," *Harvard Business Review*, January 13, 2020, https://hbr.org/2020/01/how-the-vc-pitch-process-is-failing-female-entrepreneurs.

[39] Bell et al, 2018.

[41] Ibid.

[42] National Science and Technology Council Committee on STEM Education, "Charting a course for success: America's strategy for STEM education," Executive Office of the President, December 2018, https://files.eric.ed.gov/fulltext/ED590474.pdf.

[43] SSTI Innovation Advocacy Council.

Pillar IV: Industry

OVERVIEW

From the steam engine to the smartphone, the private sector has cultivated, scaled, and brought to market world-changing ideas. Industry is a central piece of the invention ecosystem, yet its innovation potential is far from fully realized. The combination of corporate "short term-ism," barriers to new market entrants, and declining government support for R&D has especially diminished funding for early- to mid-stage industry research. Restrictive immigration policies and the concentration of people and assets in a few regional hubs means that a critical mass of American talent is untapped and unappreciated. Reinvigorating industry as an engine of innovation requires fresh policy approaches.

CHALLENGES

Industry currently performs 73% of overall U.S. R&D[44] and employs nearly all of the country's skilled technical workforce.[45] Though privately funded R&D is distributed among both new and established firms, the lion's share of private-sector R&D[46] activity originates in large businesses. Small firms account for 49% of U.S. employment but just 16% of business spending on R&D.[47] No proposal to enhance the invention ecosystem can fail to account for the central importance of established firms.

The picture is complicated, however, by the outsized contributions of innovative small firms. While small firms are less R&D-intensive on the whole, the subset of innovative small firms accounts for more IP per employee than innovative large firms, and the patents of small firms are cited at higher rates.[48] It is clear that large and small firms alike play significant, albeit different, roles in the invention ecosystem.

Yet multiple obstacles prevent the private-sector innovation engine from reaching its full potential. First, government support for industry R&D has dropped by an order of magnitude over the past half-century,[49] significantly undermining spending on early- and medium-term research.[50] Corporate investment, which tends to favor later-stage R&D, has not filled the gap. Instead, capital markets increasingly push firms to chase short-term wins rather than investing in innovation that may pay dividends over the long term.[51] So-called "short term-ism" has become fundamental to industry structure, with deleterious effect on spending on invention and R&D.[52] While the later-stage research collaborations that remain are important, these corporate partnerships with universities or acquisitions of promising science-based startups are focused on refining existing knowledge for commercialization instead of on generating new knowledge.[53] Established firms thus have increasingly outsourced the transformational invention process to external actors. Start-ups, for example, now play a critical role in commercializing and de-risking breakthroughs, making them compelling targets for eventual acquisition.

At the same time, vast regional disparities persist in private-sector R&D. Thriving innovation hubs reap the benefits of agglomerations of technical expertise, supply chains, infrastructure, capital, and other assets. Corporate investment continues to flow disproportionately to these regions, causing geographic inequity to persist.

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[44] National Science Board, "Research and Development: U.S. Trends and International Comparisons," *Science & Engineering Indicators 2020* NSB-2020-3, January 15, 2020. https://ncses.nsf.gov/pubs/nsb20203/assets/nsb20203.pdf.

[45] National Science Board, *"Science and Engineering Labor Force," Science & Engineering Indicators 2020,* NSB-2019-8, September 26, 2019.

[46] Raymond M. Wolfe, "InfoBrief" *National Science Foundation,* 2019, https://www.nsf.gov/statistics/2019/nsf19326/overview.htm.

[47] Raymond M. Wolfe, "Detailed Statistical Tables" in *Business R&D and Innovation: 2012,* NSF-16-301(National Science Foundation, October 2015), Table 5, https://nsf.gov/statistics/2016/nsf16301/#chp2.

[48] Anthongy Breitzman, "Patent Trends among Small and Large Innovative Firms during the 2007-2009 Recession," Small Business Administration Office of Advocacy, May 2013, https://advocacy.sba.gov/2013/05/01/patent-trends-among-small-and-large-innovative-firms-during-the-2007-2009-recession/.

[49] Caleb Foote and Rob Atkinson, "Federal Support for R&D Continues Its Ignominious Slide," Information Technology and Innovation Foundation, August 12, 2019, https://itif.org/publications/2019/08/12/federal-support-rd-continues-its-ignominious-slide.

[50] Rachelle C. Sampson and Yuan Shi, "Are US Firms Becoming More Short-Term Oriented? Evidence of Shifting Firm Time Horizons from Implied Discount Rates, 1980-2013," *Strategic Management Journal,* October 1, 2019, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2837524.

[51] Scott Lathamand Michael Braun, "Does Short-termism Influence Firm Innovation? An Examination of S&P 500 Firms, 1990-2003" *Journal of Managerial Issues* 22, No. 3 (Fall 2010): 368-382, https://www.jstor.org/stable/20798917?seq=1.

[52] Anne Marie Knott, "The Real Reasons Companies Are So Focused on the Short Term," *Harvard Business Review,* December 13, 2017, https://hbr.org/2017/12/the-real-reasons-companies-are-so-focused-on-the-short-term.

[53] Ashsish Arora, Sharon Belenzon and Andrea Patacconi, "The decline of science in corporate R&D," *Strategic Management Journal* 39, No. 1 (2018): 3-32, https://doi.org/10.1002/smj.2693.

In some, the challenges preventing industry from reaching its full invention potential include:

- **Given industry trends toward late-stage R&D, there is a gap in funding for early-to-mid stage corporate R&D, a source of key fundamental inventions.** Federal support for industry R&D has declined, and the private sector has failed to make up the difference. The private sector places outsize focus on R&D activities that translate established breakthroughs to market rather than on activities that generate new knowledge.
- **Corporate "short term-ism" reduces effective spending on invention.** Capital markets increasingly push firms to chase short-term wins instead of investing in innovation that may pay dividends over the long term. The result is less capital allocated to invention activity.
- **Innovation activities are concentrated in regional hubs, creating geographic disparities and limiting opportunities to capitalize on innovation potential.** The private sector's investments in invention-economy assets vary dramatically across regions. The result is that too many regions lack the critical mass of invention activity needed to meaningfully participate in the 21st-century economy.
- **Barriers to entry and barriers to knowledge dissemination wielded by established firms make it harder for new entrants to capitalize on new breakthroughs.** From muscular non-compete agreements to the growing use of trade secrets to protect intellectual property, established firms have found ways to limit the positive externalities that attend invention activity.
- **Minorities, underserved populations, highly skilled immigrants, and recent foreign graduates often find it difficult to contribute to the private-sector invention economy.** For generations, immigrants have fueled the engine of American innovation. No single barrier has done more damage to American invention than restraints on skilled immigration, on which industry's technical workforce relies.[54] Likewise, the lack of diversity across industry leadership roles is a significant innovation handicap, given that companies with more diversity tend to derive more revenue from innovation.[55]

THE OPPORTUNITY

Industry's centrality to the invention ecosystem presents both direct and indirect opportunities for greater impact. This foundation is rooted in industry's role as the key driver of invention activity: the private sector accounts for 73% of R&D in the United States, far more than higher education, the Federal Government, or any other sector.[56]

Industry is uniquely positioned to cultivate and scale world-changing ideas and bring them to the marketplace.
Established firms play an enormous role in translating innovations into new products and services. As Rob Atkinson of the Information Technology and Innovation Foundation has observed, "Big companies do more R&D...even controlling for size, big companies get more innovation out of the R&D. On virtually every meaningful indicator, including wages, productivity, environmental protection, exporting, innovation, employment diversity and tax compliance, large firms as a group significantly outperform small firms."[57]

In a direct sense, industry is the engine of invention. From Bell Labs to Xerox PARC, the history of American innovation has been shaped by corporate research labs responsible for developing new breakthroughs and helping to bring them to market. But with today's companies increasingly favoring development activities over basic and applied research—for the reasons described above as well as enhanced competitive pressure[58]—the era of the corporate research lab has been in a long decline. Nonetheless, R&D expenditures by U.S. industry have stayed relatively constant. U.S. firms still interact deeply with the other pillars of the invention ecosystem, not only absorbing trained technical experts to engage in late-stage R&D, but also reaching into research institutions to engage in collaborative research with an eye to future market opportunities.

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[54] Felix Richter, "How Tech Companies Rely on Foreign Talent," *Statista,* June 23, 2020, statista.com/chart/7863/tech-company-h-1b-applications/.
[55] Rocío Lorenzo, Nicole Voigt, Miki Tsusaka, Matt Krentz, and Katie Abouzahr, "How Diverse Leadership Teams Boost Innovation," *Boston Consulting Group,* January 23, 2018, https://www.bcg.com/publications/2018/how-diverse-leadership-teams-boost-innovation.
[56] National Science Board, 2020.
[57] Robert D. Atkinson and Michael Lind, *Big is beautiful: Debunking the myth of small business,* (Cambridge: The MIT Press, 2018).
[58] Ibid, 105.

A Cycle of Success: Experienced Entrepreneurs Foster New Entrepreneurs

Founded in 1992 in Silicon Valley, TiE Global is a nonprofit organization launched by successful entrepreneurs, corporate executives, and senior professionals devoted to fostering successful entrepreneurs through mentoring, education, networking, funding, and incubation. TiE Global hosts a range of events, from tech conferences to open-mic nights, across 61 chapters in 14 countries. In its local communities, TiE Global has been working to increase diversity among young inventor entrepreneurs. TiE Women, for example, is a new program created to support women entrepreneurs across the globe and help them find funding to grow their enterprises.

Engineer-turned-entrepreneur Nitin Rai helped launch the TiE Young Entrepreneurs Program (TYE), which focuses on inspiring, challenging, and empowering high-school students to become the next generation of entrepreneurs and business leaders. The program's Oregon chapter now runs curriculum development for TYE globally and coaches educators from around the world on how to integrate invention into their programs in low-income schools. In a survey last year, 84% of students who participated in TYE reported understanding how to use design thinking to take an idea from concept to prototype, and 79% said they feel enthusiastic about STEM subjects in school after completing the TYE program. TiE now serves as a platform for entrepreneurs, professionals, industry leaders, and investors to connect and contribute to strengthening the invention ecosystem.

Industry is a catalyst for new contributors to the invention ecosystem and for new breakthroughs.
By generating such a large share of the country's R&D activity—and by employing a commensurately sized technical workforce—established firms catalyze significant contributions that go beyond the direct benefits of scientific progress. These "positive externalities" manifest in several ways.

First, corporate R&D is a key source of technical talent development. Those with experience in corporate R&D labs are primed to engage in invention-driven entrepreneurship and may subsequently launch or join entrepreneurial ventures or mentor those who do. One recent analysis of state R&D tax incentives found that incentives had a significant positive impact on entrepreneurship rates because the presence of corporate R&D is such a strong enabler of an entrepreneurial workforce.[59]

Second, corporate venture capital has grown dramatically over recent decades. It is no longer unusual for leading firms to cultivate and finance new ventures as an opportunity to get a first look at emerging technology or key targets for future acquisition. In fact, corporate venture-capital investments as a share of total investments grew nearly 30% from 2012 to 2017 globally.[60] In 2018, U.S. startups raised roughly $141 billion, half of which came from corporate VC.[61] The phenomenon of industry catalyzing external innovations also extends to new technologies and sharing of core assets. For example, open-sourced algorithmic platforms by Google and Facebook grant even the smallest technology companies access to the world of artificial intelligence. This phenomenon also takes place on an individual basis. The ranks of angel investors are populated with individuals who acquired their wealth through the innovation economy and now seek to invest in promising invention-driven startups.

Finally, industry generates positive externalities in the form of knowledge. All invention activity generates spillovers in the sense that the actors undertaking the research cannot capture all of the benefits. A significant share of the knowledge flows to external collaborators, competitor firms, new startups, and others. To the extent that established firms perform the lion's share of R&D, they are also responsible for a correspondingly large share of these knowledge spillovers. Certain activities enhance these effects. Collaborations—such as those between industry, research institutions, joint ventures,

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[59] Javier.
[60] Michael Brigl, Nico Dehnert, Stefan Gross-Selbeck, Alexander Roos, Florian Schmieg, and Steffen Simon, "How the best corporate venturers keep getting better," Boston Consulting Group, August 22, 2018, https://www.bcg.com/en-us/publications/2018/how-best-corporate-venturers-keep-getting-better.
[61] Alexander Davis, "Facing disaster, corporate venture capital to undergo key stress test," *Pitchbook,* March 24, 2020, https://pitchbook.com/news/articles/facing-disaster-corporate-venture-capital-to-undergo-key-stress-test.

and others—are widely regarded as value-creation processes for this reason, catalyzing invention activity throughout the invention ecosystem.[62]

Industry is clearly fundamental to the invention ecosystem. Yet given challenges such as "short-termism," outsized focus on late-stage R&D, large and persistent geographic disparities, and growing advantages of firm incumbency, policy action will be required to maximize industry contributions to the innovation economy.

Locating Research Centers in Cities Pays Off

Cities are increasingly becoming popular locations for major research centers. In the old days, companies operated in isolation, creating products and monopolizing markets. But today, many if not most companies want to be near helpful resources such as urban universities, clusters of other firms and researchers, and lively neighborhoods that foster creativity and collaboration. Those amenities exist in Atlanta, Georgia, a city that has become home to corporate research centers for major companies such as AT&T, Panasonic, and Coca-Cola, as well as hundreds of technology startups.

Universities play a critical role in catalyzing entrepreneurship. But many do not prioritize commercialization, making them less attractive partners for corporate research centers. Georgia Tech is an exception. With a campus located in Tech Square, a once-derelict part of Atlanta that is now a vibrant urban innovation hub in the heart of downtown, Georgia Tech supports commercialization in a myriad of ways. The university has instituted tenure requirements that reward patents as well as publications, encourages faculty to seek federal grants that support joint research with the private sector, and has started programs to incubate university startups. VentureLab, a university-run business accelerator at Georgia Tech, is ranked second in the world for spinning off startups.

INDUSTRY POLICY RECOMMENDATIONS

1. **Expand and streamline the Federal Research & Experimentation Tax Credit.** This tax credit was recently made permanent—a step to be applauded. Yet the credit is nonetheless both more complicated and less generous than analogous incentives offered by peer OECD countries.
2. **Boost industry-relevant federal R&D spending. Erosion of federal spending for industry-sponsored research has created a major gap in the invention ecosystem.** Expansion of federal R&D should include a focus on bridging the late-stage gap through programmatic efforts such as Manufacturing USA, small business voucher programs, Manufacturing Extension Partnerships, cluster programs, Small Business Innovation Research (SBIR) grants, and Lab-to-Market activities. Federal funding can also incentivize industry to undertake more transformative R&D. For example, reviving and modernizing the National Institute of Standards and Technology's (NIST) Advanced Technology Program would be a positive step toward filling the gap in incentives for transformative R&D.
3. **Leverage federal workforce-development activities to support a greater industry role in a forging a demand-driven talent pipeline.** As anchor institutions, large firms are capable of playing a greater role in engaging with higher education to ensure skills development efforts are driven by demand to address the growing skills gaps in fields critical to the industries of the future.
4. **Encourage high-growth firms to recognize and invest in supporting the U.S. inventor ecosystem.** A thriving inventor community underpins national competitiveness and helps grow a talent pool for key skills gaps. Led by the White House, Federal policymakers and agencies should highlight the activities of firms and executives that give back by supporting the inventor ecosystem. The Federal Government should also launch initiatives, such as nationwide prize competitions, that further encourage the private sector to bolster the inventor ecosystem.

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[62] Omar AL-Tabbaa, Desmond Leach, and John March, "Collaboration Between Nonprofit and Business Sectors: A Framework to Guide Strategy Development for Nonprofit Organizations," *Voluntas: International Journal of Voluntary and Nonprofit Organizations* 25, no. 3 (2014): 657-678.

This report would not have been possible without the participation of the following individuals:

Bilal Zuberi, Lux Capital
Chad Evans, Council on Competitiveness
Danny Briere, STEMIE
David Coronado, Lemelson Foundation
Jason Rittenberg, SSTI
Jonathan Gruber, MIT, and author, *Jumpstarting America*
Juan Barraza, Portland State
Julie Lenzer, Maryland
Leslie Flynn, University of Iowa
Phil Weilerstein, VentureWell
Rob Atkinson, ITIF
Shaheen Mamawala, VentureWell
Stephanie Couch, LMIT

Produced by the Day One Project with support from The Lemelson Foundation