Prepared remarks
of

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Introduction

Madam Chair, Ranking Member Wicker, and Members of the Committee, on behalf of the University of Notre Dame, I am honored to appear before you today to offer testimony regarding the Endless Frontier Act.

Chair Cantwell, as a career scientist, researcher, and higher education administrator, I am grateful for your commitment to scientific discovery and innovation, and your Committee's dedication to strengthening our nation's innovation ecosystem. I am particularly appreciative of your efforts and leadership in creating pathways for women and other underrepresented groups to pursue STEMM (science, technology, engineering, mathematics, and medicine) fields.

I also extend greetings to my own Indiana Senator, Todd Young, who is working with Senator Schumer to author this important legislation. Thank you for your leadership and longstanding support and commitment to university research and learning.

I am particularly pleased to be here in person – something that might not have been possible a month ago, but is today due largely to the tremendous U.S. federal government investments made over many years in basic science and technology research conducted at our nation's universities. Those long-term, strategic investments in science and technology established the knowledge base and foundation that enabled pharmaceutical companies to develop and produce several safe, effective vaccines to combat the COVID-19 pandemic in a timespan previously unimaginable.

Background

I am a professor of applied and computational mathematics and statistics at the University of Notre Dame, where I also serve as the Charles and Jill Fischer provost and direct the Children's Environmental Health Initiative (CEHI), which is a research, education, and outreach organization committed to fostering environments where all people can prosper.

I have spent more than 30 years as a use-driven, or applied, researcher who deploys Bayesian spatial statistics to identify impacts of and solutions to environmental and social threats to children. I have applied science and technology to help understand and address complex, real-world challenges locally, regionally, and nationally.

In my own work and in my role as provost at the University of Notre Dame, I have witnessed firsthand the power of the federal government's substantial investments in basic science and technology to improve lives for individuals, communities, and our society more broadly. That is our mission at the University of Notre Dame – *to be a force for good in the world*.

It is common to conceive of researchers dividing up into curiosity-driven versus use-driven scientists and engineers. In fact, a virtuous cycle exists between the two. Curiosity-driven researchers elucidate critical insights into basic science questions that drive new opportunities for use-driven researchers. In turn, use-driven researchers highlight new challenges for curiosity-driven researchers to take up. And in fact, many scientists and engineers are both use-driven and curiosity-driven.

While I am primarily a use-driven researcher, I rely heavily on basic science or curiosity-driven research. Use-driven researchers and curiosity-driven researchers interact constantly, discussing problems, challenging each other, and sharpening each other's work. When I wrote my dissertation, I had to use a mainframe computer to analyze the 40,000 observations in my dataset, and I could only implement the analysis at the county level. Back then, 40,000 observations was big data!

In contrast, for the past 20 years, I have worked on childhood lead exposure, specifically interested in using spatial analysis to identify houses where children are most likely to be exposed to lead, and then remediate houses to prevent future exposure. Federal investments in basic science research on geographic information systems, as well as computational power and speed, made it possible for me to analyze millions of observations on my desktop computer. In addition, new insights from theoretical statisticians made it possible to implement our models at the individual tax parcel level.

Housing departments use CEHI's detailed models to prioritize housing rehabilitation dollars, working with property owners to make homes lead-safe. Health departments use the same models to drive lead screening programs, resulting in one county, for example, experiencing a 600% increase in its ability to identify children with elevated blood lead levels at no additional cost.

These models have been replicated for communities across the United States. As a result, we have protected thousands of children from potential harmful effects of lead exposure, including learning and behavioral disorders, poor hearing, attention deficits, and other negative neurological effects.

While the scope of the Endless Frontier Act is broad, as requested, I will focus this testimony on opportunities to strengthen the nation's research enterprise and increase diversity of the science, technology, engineering, mathematics, and medical (STEMM) fields.

Federally funded research: the foundation of American innovation and security

It is unfortunate that many Americans neither see nor appreciate the myriad, intricate connections between basic, curiosity-driven research and its end uses, developments, and products. Instead, many view the amazing technologies that surround us – self-driving vehicles, rovers on Mars, mobile phones that do everything from navigate our world to monitor our health – as the unexpected next new products to shape our world.

The truth, of course, is that nearly all of the technological innovations that enable our modern society emerge from a deliberately built foundation of federally funded research conducted over many years at universities or federally funded research laboratories. While many Americans may not fully appreciate this connection, our peers, competitors, and potential adversaries around the globe certainly do.

The initial large-scale investments in federally funded research were a conscious post World War II decision related to the Cold War. Other nations watched as U.S. government investments in science, sustained in part through National Science Foundation (NSF), created a global superpower and shaped a society and economy that have been the envy of the world for multiple generations. The American system awards funding competitively, balancing a centralized source for funding with the incredible entrepreneurial spirit that characterizes our researchers. This system aligns fully with American democratic values.

Other nations are now making similar investments with similar ambitions at a pace that exceeds the United States, especially expenditures in critically important areas such as artificial intelligence, quantum computing, and other advanced technologies. According to data from an April 2020 Congressional Research Service report, U.S. investments in research and development funding declined from 69 percent of the world's total in 1960 to 28 percent in 2018. Interestingly, the U.S. decline is not the result of cuts in U.S. investments. Rather, the decline in U.S. global leadership in this area is the result of even greater investments by the governments of other countries that recognize the importance of R&D to their innovation and competitiveness.[1]

That targeted funding is having direct results. For example, since the mid-2000s, increased investments by China in science and technology have led to steady growth in the number of scientific journal articles published by Chinese researchers, a key measure of scientific innovation. China is now the largest single global producer of scientific journal articles, surpassing the U.S. in 2016.[2]

Education as a foundation of innovation

Sustainable economic development in general is not easy to achieve, and innovation-based economic development is an even greater challenge. However, as noted in the World Economic Forum's 2019 Global Competitiveness Report, "In most advanced and emerging economies, technology adoption and innovation have become priorities for governments and companies alike as a source of value creation, productivity growth, and improved living standards.

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[1] Congressional Research Service, Global Research and Development Expenditures: Fact Sheet Updated April 29, 2020. https://fas.org/sgp/crs/misc/R44283.pdf, 2020.

[2] National Science Foundation, Science and Engineering Indicators 2018, Outputs of SE Research: Publications, https://nsf.gov/statistics/2018/nsb20181/report/sections/academic-research-and-development/outputs-of-s-e-research-publications, 2018.

Technology can also improve access to basic services, working conditions, health outcomes and economic security."[3] Even prior to the COVID-19 pandemic, the nature of jobs and work has been changing at a rapid pace, enabled by advances in computer science and engineering, advancements in learning sciences, and new conceptions of work and workplaces.

Linked to this rapid pace of change is an unprecedented opportunity to expand access to emerging new industries and occupations, enhance productivity and quality of work life, and increase workforce participation. U.S. regions with successful innovation-based "ecosystems" share in common well-defined links between colleges and universities, a skilled workforce, investments in technology and infrastructure, and an entrepreneurial culture that drives a region to capitalize on its economic strengths.

Moreover, America's need for both basic, curiosity-driven research and applied, use-driven research is greater than ever today because the challenges and competition we face as a society and nation are greater and more complex than ever. Our societal and technical challenges also require greater collaboration between research fields, increased diversity of perspectives and skills, and a much larger and broader talent pool entering STEMM fields. The Endless Frontier Act represents a major effort to address these concerns, and I commend its authors and the Committee Members for their renewed commitment to confront these challenges.

Strengthening our U.S. innovation ecosystem necessarily begins with education and efforts to encourage young Americans to pursue rigorous academic courses, and it continues with efforts to transfer technology and knowledge created in research universities to industry, which brings these innovations to the marketplace. Complementary to these technology transfer initiatives are college and university programs that support regional industry innovation, which creates jobs, boosts regional economies, and addresses regional concerns.

Thinking outside the pipe

It is popular to refer to the STEMM pipeline as a metaphor for producing a STEMM-enabled workforce. Referring to it as a pipeline, however, implies that there is only one intake point and one outtake point, with potential leaks along the way. In fact, members of the STEMM workforce travel different paths. My own research path moved from mathematics to economics to toxicology to statistics. I encourage people to think about multiple pathways, rather than pipelines.

Some paths are smooth and direct; some are circuitous and must traverse rough terrain. Some lead to STEMM PhDs and some to STEMM bachelor or associate degrees. Some have only one entry point; some have many. We need all these paths to build the STEMM enabled workforce our country needs for national security, for national competitiveness, for national prosperity, and to solve our most challenging societal problems.

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[3] World Economic Forum Global Competiveness Report, http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf, 2019.

While we need PhD-trained researchers to develop new cybersecurity systems, we also need people with associate and bachelor degrees trained to run those systems on a daily basis. While we need PhD-trained researchers to predict and model natural disasters, we need large STEMM-enabled multidisciplinary teams to use that research to react in real time on the ground in disaster zones.

We are also vulnerable when it comes to STEMM talent. The ability of the U.S. to meet the demand for individuals with the knowledge, skills, curiosity, and creativity necessary to enter STEMM-intensive careers is hindered by the lack of women and underrepresented minority populations in STEMM fields.

We must also think broadly about the need to bring our entire talent pool to this issue. For example, women comprise 51.5 percent of our population and 47 percent of the labor force. However, in computer science, only 19 percent of those awarded bachelor's degrees in 2016 were women – down from 27 percent in 1997.[4] Similarly, underrepresented minorities comprise 27 percent of our population and 30 percent of the labor force, but only 9 percent of those with science and engineering doctorate degrees.

Unfortunately, 39 percent of U.S. high schools are unable to offer physics, a foundational course for STEMM fields. The inability to offer physics and other science and mathematics courses relates directly to the lack of qualified teachers, primarily in low resource, smaller schools. So, nearly two in five high school graduates, regardless of their academic ability, interest, or motivation, will start college facing a much tougher path for pursuing STEMM degrees.[5]

At Notre Dame, we established a STEMM scholars program in 2018 to support students who intend to pursue STEMM careers but arrive at our university without the benefit of multiple Advanced Placement courses or other STEMM enrichment opportunities. This program has been very successful in helping these students succeed in their courses and persist in STEMM disciplines, without the emotional burden of feeling less qualified than others.

Modernizing university technology transfer programs

The Endless Frontier Act seeks to strengthen America's economic competitiveness and efficiency by producing innovative technology through research and commercialization grants. Achieving these goals will require commercialization of innovations that emerge from these research investments, much of which will go to universities.

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[4] National Center for Educational Statistics, Women, Minorities, and Persons with Disabilities in Science and Engineering, 2019.

[5] Science Education Policy, Problematizing the STEM Pipeline Metaphor: Is the STEM Pipeline Metaphor Serving Our Students and the STEM Workforce?, 2014.

To achieve the goals of the Endless Frontier Act, universities need to remake their technology transfer and commercialization operations. More specifically, they should shift away from the nearly ubiquitous model of relying on tech managers, who usually have deep technical knowledge and little business experience, to commercialize university discoveries. Twenty years of data have shown this approach does not work.

For example, despite tens of billions of dollars spent on university research each year, 95 percent of all intellectual property discovered in universities goes unlicensed.[6] Of the intellectual property that is licensed, 72 percent takes place at only 37 universities. Furthermore, only 13 percent of tech transfer offices are self-sustaining.[7] Why? Technologies that emerge from universities are very early-stage and full of risk for potential licensees, so potential investors are hesitant to invest. Traditional tech transfer offices lack the skills and processes to de-risk a technology sufficiently enough that the right funders, founders, entrepreneurs, advisors, mentors, or corporate partners will engage.

To address this issue, university commercialization operations should put in place a rigorous and replicable de-risking process. At the University of Notre Dame, we have implemented a stage-gated, milestone driven methodology to de-risk technologies and make them more attractive for commercialization.

Implementing such a process drives success in a number of ways. First, it allows the commercialization office's staff to specialize in key areas, including IP and technology, business, and startups. Second, it ensures the staff applies the right resources in the right amounts at the right times for the right projects. Finally, it turbocharges the speed with which technologies move from discovery to market.

Over the past five to eight years, a small number of universities have started using a variant of this system and the results are impressive. They have created hundreds of startups, tens of thousands of jobs, and billions of dollars in value. Research funding alone will not achieve the goals of the Endless Frontier Act. New and inventive commercialization processes will be required.

Expanding innovation at the national, state, and regional levels

U.S. business research and development activities are presently concentrated in a relatively small number of states. In 2018, of the $441 billion in R&D performed in the U.S., most went to California (33%), followed by Washington (7%), Massachusetts (6%), Michigan (5%), Texas (5%), New Jersey (5%), New York (4%), Illinois (3%), and Pennsylvania (3%).

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[6] Nature: https://www.nature.com/news/universities-struggle-to-make-patents-pay-1.13811, 2013.

[7] AUTM (formerly the Association of University Technology Managers) Report, https://autm.net/surveys-and-tools/databases/statt, 2019.

While the particular focus of EFA legislation is to address and advance America's national security and global competitiveness, I applaud its efforts to provide targeted investments and development of additional, broadly distributed technology hubs or centers throughout the United States, including in promising "Heartland America" places like Indiana.

Indiana is well positioned to serve as one of these state tech hubs, as we have rich collaborations across the three major research universities; Purdue University, Indiana University, Notre Dame, and with the Crane Naval Surface Warfare Center and the Indiana State government's Indiana Economic Development Corporation (IEDC). We also have a highly active organization coordinating the corporate relationships in the State, the Central Indiana Corporate Partnership (CICP). The CICP has become a major catalyst for growing the industrial competitiveness of the companies in the State in areas such as (see list of EFA foci). In fact, a recent report that we commissioned from the Brookings Institution identified existing strengths and related opportunities in a manner that is generally consistent with the tech hub framework.

As of 2019, Indiana has the nation's third-highest rate of employment in these R&D and STEMM-worker intensive industries. Indiana's advanced industries employ 10.5% of the Hoosier workforce (323,600 individuals), while producing 25% of the state's GDP and 60% of the state's exports. And because of long supply chains and multiplier effects, the state's industries are indirectly responsible for another 700,000 jobs.

Our state's advanced industry mix makes clear that Indiana's economy is largely driven by advanced manufacturing. Among Indiana's advanced industry workers, 76% are employed in advanced manufacturing. These workers produced 79% of the state's advanced industry output—amounting to roughly 20% of the state's contribution to GDP.[8] Furthermore, the life sciences are a particularly significant contributor to the state's advanced manufacturing sector. Specifically, pharmaceutical and medical device production together employ almost 15% of all Hoosier advanced manufacturing workers and are responsible for more than 25% of all Hoosier advanced manufacturing output.

The South Bend–Elkhart (SBE) Region is at the locus of three emergent trends within the global economy: the shift to a digital environment in industry; the growing polarity of innovation and investment; and the renewed emphasis on applied and experiential learning models to better equip the future workforce.

While these developments present potential challenges, they also signal opportunity. The growth of wireless technologies, artificial intelligence and robotics, data analytics, and digital sensor technologies—often referred to as the fourth industrial revolution—have accelerated the pace of innovation and increased the need for highly skilled expertise.

[8] Indiana GPS Project Report, https://indianagpsproject.com/, 2021.

Companies that succeed in this transition will be, first and foremost, enterprises still producing tangible products, but doing so within a data-based, digital environment with connectivity from the shop floor through the supply chain and customer base. Regions at the forefront of digital transformation, in turn, offer some of the most compelling career and economic opportunities for a well-trained workforce, thereby concentrating talent, investment, and innovation.

In response to these emerging economic demands and need for a coordinated solution, funded by a $42 million grant from the Lilly Endowment, Notre Dame and the South Bend Elkhart Regional Partnership launched the LIFT Network and iNDustry Labs to more effectively and proactively serve the businesses in the South-Bend Elkhart region with a regional innovation hub. The LIFT Network and iNDustry Labs link the faculty expertise, student talent, and R&D capabilities at the University and throughout the region with the regional companies embarking on the digital transformation journey to become more productive, resilient, and skilled organizations in the digital economy.

Recommendations

I offer the Committee seven recommendations to create greater access to STEMM pathways, to promote increased collaboration between and among curiosity- and use-driven researchers, and to ensure the full potential of the Endless Frontier Act is achieved.

1. Create funding mechanisms that encourage research institutions to collaborate with middle schools and high schools <u>at scale</u>, including supporting the professional development of middle and high school science teachers, developing innovative STEMM curricula, and inviting students for meaningful STEMM on-campus experiences. Separately fund a full-scale analysis of the effectiveness of different approaches.

2. Seed fund the development of wrap-around services for first-generation students and those from low resource backgrounds to ensure they can prosper in STEMM fields. Separately fund a full-scale analysis to assess effectiveness of different interventions, preferably as randomized controlled trials.

3. Fund the development and maintenance of networks designed to provide mentorship, research rotations, internships, shadowing programs, support systems, and career advancement in STEMM fields at all levels, especially as they are relevant to gender, racial, ethnic, income, and geographic diversity.

4. Dramatically expand funding for NSF Graduate Research Fellowships (GRFs) and Research Experiences for Undergraduates (REUs), programs that are incredibly effective at attracting and retaining young scholars in STEMM. Craft and fund similar programs for high school students and masters-level students.

5. Create funding mechanisms that promote collaboration between researchers in different fields and between use-driven and curiosity-driven scholars. These mechanisms should also include grants designed specifically to develop the databases that will accelerate use-driven research.

6. Provide funding that extends the length of current grants to address the impacts of COVID-19 on research. Such funding is critical for keeping women and minority scholars in STEMM.

7. Implement funding incentives to help universities transform their tech transfer offices into business-oriented, de-risking operations that better promote commercialization of federally funded research.

8. To maximize the return on federal investments in regional technology hubs, consider regional readiness, including vibrancy of partnerships, existing structures for university-industry partnerships, and local/regional support in workforce development programs.

Conclusion

Keeping our nation secure, prosperous, and economically competitive in a dynamically changing world depends upon a tremendous investment in science and technology research. That investment is a necessary one, and it is one our peers, competitors, and adversaries are making. That investment will also allow us to address our most pressing societal challenges and continue to fulfill the great promise of the American experiment. Our generation must make this commitment, as previous generations did for us, to secure a prosperous future for our children and grandchildren.

As a university provost, with a landscape view of research at Notre Dame and across higher education, I have come to believe that the three most powerful drivers of innovation are curiosity, purpose, and profit. The Endless Frontier Act has the potential to tap deeply into all three of these drivers.

While I am proud that my research group's work has helped protect children across the country from lead exposure, it would be vanity for me to take credit for those impacts. The National Science Foundation funded my graduate education, and federal funding fuels my research. So the credit really goes to all of you, senators, and to your colleagues in the House of Representatives, for your longstanding commitment to science and scientists.

I will close with a personal story of the powerful synergy between curiosity-driven and use-driven research, the role of commercialization, and a single, but important, good outcome.

In the 1950s, curiosity-driven botanists and cultural anthropologists were fascinated by the Madagascar rosy periwinkle. Eventually, an extract of the plant was used by Eli Lilly to develop vincristine, a chemotherapeutic that increased the survival rate from childhood leukemia from 10 to 90%. From the same plant, they also developed vinblastine, one of the four chemotherapeutics that was used to save my daughter Viviana's life when she was diagnosed with Hodgkin's Lymphoma three years ago. She is now a healthy and happy college sophomore, studying chemistry.

Again, I commend this Committee for their dedication to this effort and thank you for the opportunity to testify today.