House Committee on the Budget

Hearing on Fueling American Innovation and Recovery: The Federal Role in Research and Development

July 8, 2020

Testimony of Willy Shih

Harvard Business School, Boston, MA 02163

Chairman Yarmuth, Ranking Member Womack, members of the committee, distinguished guests, thank you for the opportunity to address you today.

I am on the faculty of the Harvard Business School, where I have taught for the past 14 years. Prior to that I spent 28 years in industry. I am actually a scientist by training, with two undergraduate degrees in Chemistry and Life Sciences from MIT, and a Ph.D. in Chemistry – Magnetic Resonance from the University of California at Berkeley. I have been a beneficiary of our country's investments in basic scientific research and engineering post-Sputnik, a time where our heroes were the scientists like Jonas Salk or Richard Feynman. I still remember watching the first Telstar trans-Atlantic transmission and the Apollo launches. And I should add a tip of the hat to Dr. Parikh; I went to my first AAAS meeting in 1969, and the AAAS's *Science* magazine is to this day still one of my go to reads when I need an authoritative source.

The post-WWII period was marked by great public faith in science. After all, science had won the war, not only with the atomic bomb, but penicillin and antibiotics, radar, the digital computer, the whole field of operations research. Spurred by Vannevar Bush's *Science: The Endless Frontier* and later the Cold War and Sputnik, investments in basic scientific research led to unquestioned American leadership for decades. And the spillovers into industry, and *from industry* I should add, were spectacular. Bell Labs produced the transistor, photovoltaic cells, the laser, satellite communications, the charge-coupled device; IBM Research produced the magnetic disk drive, the one transistor DRAM, countless innovations in computer architecture, the UPC barcode. And then there were Fairchild Semiconductor, the RCA Sarnoff Labs, the Rockwell Science Center, the Eastman Kodak Research Labs, the DuPont Experimental Station, Xerox PARC; the list goes on. At the beginning of the 1970s, there were many products that were only made in the United States, and this was because of our scientific and technological leadership.

Other countries followed America's lead and invested in basic research, because they too understood the linkage to innovation, technological, and economic progress. The Europeans, the Japanese, the Koreans, the Singaporeans, the Chinese – they have all seen the value and the importance of such investments, and they have invested accordingly. Chinese investments are particularly impressive, but they have been part of a roadmap laid out in the 1980s to develop the capabilities needed to be a modern economy.

Funding for basic research, particularly at Universities, is about building *capabilities*. It's about training future generations of researchers. As these researchers flow into industry, they bring those capabilities with them. I was talking to the Chair of the Electrical Engineering Department at Stanford last week, and he had a great way of describing why so many innovations come out of graduate research: it's because students don't know what can't be done and are willing to try the seemingly impossible. I told him it was the same reason DARPA has been so successful, they're willing to try the audacious, risky projects, and they give their project leaders the autonomy to fail, but occasionally they land the big winners, like GPS, or electronic design automation, or autonomous driving.

Having said that, it is hard to quantify benefits attached to specific lines of research or projects. The more likely value is the ability to recognize future problems and opportunities. In the 1870s, Louis Pasteur thought he was solving problems associated with fermentation and putrefaction in the French wine industry, but along the way he invented the modern science of bacteriology. The General Electric Research Lab was initially focused on improving the filaments in light bulbs, but ended up pioneering high vacuum technology and inventing vacuum tubes along the way, which led to radio and television.

The pandemic has exposed some excellent examples of the value of capabilities in our country. The visionary funding by NIH, NSF and other agencies for the human genome program and fundamental life sciences research from the late 1970s through today have built an unrivaled ecosystem of capabilities in genomics and biotechnology. What has been most gratifying to me is to see how the scientific community led by the U.S. has pivoted to work on vaccines and therapies for COVID-19. We see the Broad Institute turning their automated genomics platform almost overnight into a COVID-19 test facility. We see companies like Moderna, who has the leading mRNA vaccine candidate and others who have world-beating capabilities because of those earlier investments in the basic science, those investments in training the young people to feed those companies, from start-ups to established players. We do this better than any other country in the world, and it's because we made the long term investments in basic sciences in the preceding decades.

But the pandemic has also exposed our nation's reliance on other parts of the world for personal protective equipment, medical devices, and generic pharmaceuticals. With this has also come the realization that we have let our capabilities diffuse away in a range of sectors like semiconductors, electronics, machine tools, and many other areas, although Vice-Chair Moulton knows I published a paper warning about this more than a decade ago.

So what should we do now?

I would like to see more funding for basic research through agencies like NIH, NSF, DOE, DOD, and others. I have talked to people on both sides of the aisle who I think agree with that. But let me tell you another story to give you some context. When I was growing up, my late father was an economist, and I used to watch him come home from work frustrated and not particularly enjoying his job. I told myself, "I'm going to go into science and engineering," which is of course what I did. But you know what I found out? I always ended up working on economic problems, because I found if you didn't get the economics right, it didn't matter how great the science and engineering were. You had to look at the whole picture.

My biggest worry today is that basic research needs *stable* funding that can have the patience for long term results. Since the majority of federal R&D funding is discretionary spending, it is perennially at risk of getting crowded out by mandatory spending on things like debt service and entitlements. This is the old fixed costs versus variable costs problem. When I was in high school and had my sights set on science and engineering, the mandatory portion of the budget was 34 percent. Today it's closer to 70 percent, and as we all know, the economics are not going in the right direction.

So for sure more funding for basic research. At the same time I would love to see incentives to encourage firms to conduct more research, especially applied and translational research that can move scientific advances into products. I see great opportunities in manufacturing process innovations as well – things like continuous flow reactors, process intensification, biomanufacturing, things that will enable American firms leapfrog competitors.

In many fields today—especially those at the frontiers of science and technology—investment needs to bring pioneering discoveries to market are beyond the reach of even the best-funded firms. We could encourage, and even fund pre-competitive R&D, collaborations where partners work together on a common technology platform with which they intend to independently develop differentiated downstream products. The obvious benefit is increased research efficiency, increasing scale and scope while reducing duplication through the pooling of resources and capabilities. Participants share knowledge and mitigate risk, leveraging a larger scale and scope of information, resources, and capabilities across firm boundaries. For firms where the incentive to do research may not necessarily be high, being able to tap into a broader knowledge base widens exploratory activities and the development of new ideas.

Two circumstances, in particular, favor such collaborations: when the scale and complexity of R&D needed to remain competitive outpace individual firms' in-house capabilities, and when the target area for partnering is some distance from downstream product markets, focusing on enabling technologies rather than specific market segments or niches.

One example of such a collaboration was SEMATECH, established in 1987 as a way for U.S.-based semiconductor manufacturers to respond to Japanese competitors. The 14 participants felt that no firm acting on its own could compete effectively, so pooling resources and sharing technology had the potential to increase the effective scale of American industry and to recover market share. The founders agreed initially to contribute in proportion to their revenues for an initial period of five years, and the federal government matched the sum, leading to an overall budget of close to $1 billion. While SEMATECH has evolved considerably since its founding, the pre-competitive R&D phase cemented U.S. leadership at a crucial time.

NASA's Aircraft Energy Efficiency program of the late 1970s offers an outstanding example of the impact of government participation in such collaborations. It came out of a hearing before the Senate Aeronautical and Space Sciences Committee in the wake of the 1973 Arab Oil Embargo, which painted a dire picture of "immediate crisis condition," "long-range trouble," and "serious danger." The program's objective was to establish enabling technology that aircraft manufacturers could commercialize at their own expense. NASA contracted with Pratt & Whitney and GE to do early-stage research on advanced propulsion systems for subsonic aircraft, with involvement from Boeing, Lockheed, and McDonnell-Douglas. This learning platform proved to be immensely valuable to the companies and U.S. global leadership more broadly. The Experimental Clean Combustor program sponsored early development of the Dual Annular Combustor at GE, which went into the CFM-56 engine, the most commercially successful turbofan engine in history. The Advanced Subsonic Technology (AST) and Ultra Efficient Engine Technology (UEET) Programs helped to advance the basic science and secure long-term global leadership for the U.S. in the large turbofan category. The program was pre-competitive research at its best.

We could encourage the formation of more pre-competitive research consortia as a way of helping to commercialize innovations in critical areas to cement global leadership, perhaps by providing seed money or sponsorship. I would be especially keen to see it in the development of new process technologies, something that could help us leapfrog foreign competitors. Federal funding for pre-competitive collaborations in important new areas could foster or accelerate the development of important manufacturing capabilities in industries that will be important in the future.

Finally, since I told you I now understand the importance of economics, I want to bring up an idea I have been thinking a lot about recently. Most prescriptions for rebuilding American competitiveness focus on the *supply side*, incenting firms to move production to (or back to) the U.S. and then potentially erecting trade barriers to protect resulting higher-cost positions. A more sustainable approach would be to focus on the *demand side*, growing domestic demand in early markets for new technologies as a way of incenting the growth of local supply.

If we look historically at industries in which the U.S. has led—automobiles in the 1920s, computers, telecommunications, integrated circuits (ICs), the Internet, products using the global positioning system (GPS)—large early markets drove consumption and gave American firms incentives to innovate. These markets were driven by audacious goals and basic research coupled with commercialization. Often, as was the case for ICs and GPS, it was the U.S. military or the space program. In the 1960s, DOD and NASA bought 60% of all the ICs made. A more recent example is NASA and the Air Force securing long-term contracts with SpaceX to deliver payloads to orbit—including Crew Dragon in May—and providing cash flow for the company to develop innovations like reusable vehicles that changed the game in space launch.

Demand provides economic motivation to manufacturers, and proximity to production is valuable for early-stage products for which dominant designs haven't emerged. Close interactions between product developers, manufacturers, and consumers facilitate rapid iterations and product refinements. Having a large home market in which to "practice" is also a significant advantage. As long as consumers will buy interim products as the manufacturer improves its production processes, demand can generate the cash a firm needs to grow, learn, and improve. So strengthening our basic science investments, and then as we look to restarting our economy after the pandemic, using stimulus spending to drive demand for specific technology investments would be a double win in my opinion. This is important as well for people – when there is demand, students will go there for careers.

Basic science research is at the core of America's global leadership. It's why the best and the brightest want to come study here, and work here. Let's ensure our continued leadership. Thank you for giving me the opportunity to speak with you today. I'm happy to take any questions.