02.03.2022

Government Procurement: A Policy Lever to Revitalize Corporate Scientific Research

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EXECUTIVE SUMMARY

- Procurement policy is a major catalyst of corporate R&D. In response to the "Sputnik shock," the government harnessed the private sector to invest heavily in risky R&D that did not have immediate commercial applications. The reward mechanism was guaranteed demand: firms that demonstrated superior technological capabilities in R&D races received lucrative noncompetitive contracts for the resulting products. In this respect, the government effectively de-risked corporate scientific research.
- In its procurement strategy, the federal government pursues the dual objectives of securing technological superiority over rival nations and promoting social and economic development. As the primary objective of government procurement changes, so do the types of problems it is trying to solve, and the mechanisms required to incentivize businesses to solve those problems. In this respect, the large and growing size of federal procurement ensures that the primary objective of the government has a profound effect on how much corporations invest in scientific research.
- After the collapse of the Soviet Union, in response to a decline in geopolitical threats, technological superiority became less important to the government compared to projects that emphasized social and economic development. Procurement contracts increasingly prioritized dual-use technologies (those with both military and civilian applications) and commercial-off-the-shelf (COTS) products and services. These changes redirected corporate R&D toward problems that already had existing private market applications. Naturally, those problems did not require the same level of scientific sophistication that had characterized the pursuit of America's technological superiority.
- Because of several policy reforms that culminated in the Federal Acquisition Streamlining Act of 1994, guaranteed public demand fell out of favor. As an unintended consequence, the change in government procurement policy contributed to the decline of corporate scientific research.
- New geopolitical tensions suggest that the pendulum is swinging again toward prioritizing technological superiority in the government's objectives. With the rise of China, we are potentially facing a new "Sputnik moment."
- The United States should use this moment as an opportunity to revitalize corporate science, which bridges the chasm between "pure" science and useful applications, thus increasing the innovation potential of the economy. This will require deepening our understanding of which companies are likely to partner with the government on recapturing technological leadership, and the optimal conditions required to facilitate that partnership.
- The leading technology firms (who face high opportunity costs in diverting attention away from their large and growing private markets) and startups funded by venture capital (who face pressures to deliver short-term results) are unlikely to respond to guaranteed public demand. It is the established firms (who have excess capacity, yet fewer growth opportunities in private markets), traditional government contractors (who rely on government procurement), and startups funded by ultra-wealthy entrepreneurs (who have access to deep

pockets) that are likely to engage in pushing the frontier of science and technology while helping the government bolster national security and geopolitical influence.

INTRODUCTION

The federal government, through such agencies as the Defense Advanced Research Projects Agency (DARPA) and national labs as the MIT Radiation Laboratory, has always been an early investor in, and an important source of, American innovation. DARPA, for instance, contributed not just to the development of military technologies (e.g., precision weapons, stealth aircraft) but also to civilian innovations (e.g., the internet, automated voice recognition, language translation, and Global Positioning System receivers). However, in the 1980s and 1990s government technology priorities shifted toward supporting innovation that had existing commercial applications. This reorientation stemmed from several factors: (i) military procurement becoming far less important to leading technology firms over time (forcing government agencies to emphasize more strongly dual-use and commercially viable innovations); (ii) the rise of Japan in key technology sectors; and (iii) the end of the Cold War. The widespread use of "full and open competition" in procurement contracting reduced the government's ability to de-risk corporate R&D.

In addition to funding R&D, the government provides incentives to businesses to participate in R&D through a procurement mechanism, whereby the government rewards firms that have superior technological capabilities with guaranteed public demand for the resulting products. Guaranteed demand was particularly popular during the Cold War (1948-1989), when government procurement focused on achieving and sustaining technological superiority for the purpose of national defense and geopolitical influence. Federal agencies acquired products and services that met unique government requirements and specifications and were often unproven in commercial markets. Procurement contracts from the Department of Defense enabled firms to reduce the uncertainty of performing scientific research (the upstream or "R" part of R&D) that did not have commercial applications at the time. Federal agencies, such as the Department of Defense and NASA, set the mission, funded risky R&D through competitive R&D grants and contracts, and rewarded winners of R&D races with noncompetitive procurement contracts for the resulting technologies and products. Today, federal procurement dwarfs federal funding as a driver of business R&D investment. Procurement has been growing while funding to businesses has been shrinking. In fiscal year 2019, the federal government awarded businesses $6.4 billion in grants (down 7% compared to a decade earlier), $47.8 billion in contracts for R&D services (down 20%), $309.1 billion in contracts for other services (up 17%), and $233.2 billion in contracts for products (up 8%).

The reorientation of procurement contracts toward technologies with proven private market demand reduced the diversity of the American innovation ecosystem. Rather than complement corporate investments in innovation (by supporting long-term projects with uncertain appropriability), the government increasingly displaced corporate investments (by supporting projects that already had high commercial potential). As corporations largely withdrew from performing scientific research, the United States experienced an increased division of labor between universities and startups (that focused on research) and large corporations (that focused on development). The result has been a slowdown in the translation of science into innovative products and services that drive productivity and employment growth.[1] The rise of China as a technology powerhouse poses a threat to American technological leadership, but also an opportunity to revive corporate investment in scientific research. Once we understand which companies are likely to partner with the government and how best to facilitate that partnership, the government should go back to rewarding some firms that invest in cutting-edge research with guaranteed demand for the resulting products. This would allow firms to invest in scientific research without worrying about how (and whether it is possible) to profit from it in the short term.

THE DUAL OBJECTIVES OF THE GOVERNMENT

When choosing which technology problems to solve by specifying procurement requirements, the government pursues dual objectives: the first is to secure technological superiority over rival nations, and the second is to promote social and economic development. While these objectives are related, they are not the same. Achieving technological leadership is critical for national defense but may not lead to economic benefits and competitiveness in global markets. Similarly, a higher level of economic development may not produce the advanced technologies needed for national defense and geopolitical influence.

How much weight the government places on each objective changes over time in response to shifting geopolitical realities. The 1957 Sputnik shock — the start of the space race between the United States and the Soviet Union, when the Soviets successfully launched the world's first artificial satellite — is an example of a moment in history when the objective of ensuring technological superiority came to the forefront. The government sought solutions to "extreme quality" problems (i.e., projects aimed at pushing the frontier of scientific and technological knowledge, such as putting a man on the Moon by the end of the 1960s), even when those solutions had little practical commercial applications, at least at the time. In other moments, economic considerations loomed larger. This was the case at the end of the Cold War. The so-called "peace dividend" allowed issues of national competitiveness (especially vis-à-vis Japan in such important industrial sectors as semiconductors) to feature prominently in U.S. policymaking. The government sought to reduce cost by prioritizing the development of dual-use technologies, acquiring commercial-off-the-shelf (COTS) products, and using "full and open competition" in procurement.

As the primary objective of government procurement changes, so do the types of problems it is trying to solve and how to incentivize businesses to solve those problems. The large and growing size of federal procurement ensures that the primary objective of the government has a profound effect on corporate R&D.

CUTTING-EDGE INNOVATION REQUIRES COLLABORATION BETWEEN GOVERNMENT AND BUSINESSES

The government cannot solve the technological problems it faces without harnessing the massive resources of the private sector, as the American innovation ecosystem is heavily reliant on private investment. Data collected by the National Science Foundation show that the ratio of federal funding for R&D to business funding for R&D was 2:1 in the 1950s.[2] However, federal support for R&D has steadily declined since then. The ratio was barely 1:4 in fiscal year 2019. Moreover, businesses accounted for 45% of all basic and applied research and 90% of all development performed in the economy that year.

Throughout the 20th century, corporate R&D labs originated many scientific and technological breakthroughs that have since profoundly changed both government operations and our lives. For example, the processors that run today's computers consist of solid integrated circuits, which were pioneered by Jack Kilby at Texas Instruments. In turn, integrated circuits are collections of transistors, which were invented by Bell Labs scientists. The U.S. Air Force and NASA were early customers, using integrated circuits in missile-guidance technologies (part of the arms race) and space-guidance systems (part of the space race), respectively. In 1964 alone, Fairchild Semiconductors shipped 100,000 integrated circuits for the Apollo space program.[3] Other examples include the laser beams that encode Zoom calls and the optical fibers that carry the information around the world, which were researched by Technical Research Group (TRG), Bell Labs, GE, IBM, and Corning. The graphical user interface that frames the Zoom window was based on research conducted at Xerox PARC.

As much as the government depends on businesses, businesses also depend on the government, especially when it comes to capturing private returns to risky scientific research. While small businesses may need the government to fund their R&D activities, large businesses do not. Large businesses can fund their R&D from internal resources or capital markets. As of November 2021, companies in the S&P 500 were estimated to hold a combined $2.77 trillion in cash.[4] And just 15 non-financial firms, including high-tech leaders Apple, Alphabet, and MSFT, were estimated to sit on a combined $1 trillion in cash and investments. What large businesses need is a market to sell the products resulting from their R&D, so they can generate returns on investment. Without demand, there can be no returns on investment, no matter who pays for the R&D. Government procurement can be an important part of the demand for innovative goods and services. Indeed, major technological breakthroughs would not have been possible without the government acting as the buyer of first resort.

The invention of the laser shows how government demand drove firm engagement in upstream R&D when private market demand for the technology was insufficient. In the 1950s, the Department of Defense funded competing teams in the R&D race to build the first laser. Military contractor Hughes Research Laboratories demonstrated the ruby laser on May 16, 1960, followed by demonstrations at TRG and Bell Labs shortly thereafter. It took many years for private laser markets to develop. Throughout the 1960s, the government acted as the buyer of first resort. Procurement contracts for measurement and optical communication lasers enabled corporate research laboratories to scale and improve the technology. By 1969, the DOD's share of the laser market was 63.4%.[5] In the early 1970s, growth in military laser procurement slowed, universities curtailed their laser purchases, and companies redirected their R&D toward commercial applications that held promise for short-term returns on investment. Applications in communications, measurement, cutting, and welding emerged. In the 1980s, lasers became prominent in the consumer economy as supermarket scanners, printers, and optical discs.[6] There is little doubt that the development of the commercial laser industry was enabled by public demand in the technology's early years.

In their R&D strategies, businesses choose how to allocate resources between upstream scientific research and downstream technology development. The close collaboration between government and businesses that characterizes the U.S. innovation ecosystem ensures that procurement policy has a profound effect not only on the size of corporate investments in R&D, but also on the direction and composition of corporate R&D.

GUARANTEED DEMAND DRIVES BUSINESSES TO INVEST IN RESEARCH

A major concern firms face when deciding whether and how much to invest in R&D is whether there will be sufficient demand for the resulting products. Yet, when ideas are at an embryonic stage, as is often the case with upstream R&D, it may be difficult to estimate the potential returns on investment. Even when accurate estimates can be made, the benefits from scientific research may be hard to capture. This can occur when private markets do not exist or are insufficient. Or it can occur in competitive private markets that suffer from appropriability problems (e.g., knowledge spills over to rivals).[7] Thus, profit-seeking firms may be reluctant to make the investments in upstream R&D that are necessary for long-term, radical innovation, choosing instead to focus on short-term, incremental innovation. In this context, government procurement policy effectively becomes innovation policy, as public demand can substitute for missing or insufficient private demand.

Government procurement can increase the private value of corporate research by providing access to guaranteed public demand. This represents a form of exclusivity, a key mechanism that protects the rewards a firm can reap from investing in risky scientific research. In private markets, exclusivity is typically provided by patents. The innovating firm can either commercialize the resulting technology on its own (under a temporary monopoly) or trade the patent to another firm in exchange for a price that is based on demand conditions. Conversely, in the public market, exclusivity is provided by guaranteed demand. In a typical procurement for an innovative product, the government solicits companies to compete in an R&D race. Usually, respondents are a select set of firms that have the technological capabilities to compete in the race, as well as the complementary assets to manufacture the resulting product. Firms invest their own funds in R&D (above and beyond the government funds that were specified in the R&D contract) to increase their chances of winning the race. The winning firm subsequently receives lucrative, noncompetitive manufacturing contracts for the resulting product.

A key difference between upstream and downstream R&D is that patents are not well suited to protect the fruits of scientific research. This contributes to upstream R&D's relatively low private value. Even when the cost of performing upstream R&D is not a major concern (e.g., for large corporations, which tend to invest a relatively small fraction of their overall R&D budgets into scientific research), winning an exclusive market because of developing a radical innovation can be an attractive driver of firm investments.[8]

Through the guaranteed demand mechanism, the government can steer firms away from incremental innovation that already has commercial applications and toward radical innovation that solves "extreme quality" problems but is not immediately rewarded in private markets. In many cases, solving big problems can lead to future rewards in private markets. Aerospace, semiconductor, computer, and software technologies provide many examples of innovations originally developed to serve government needs, but eventually achieved huge commercial success in private markets. By substituting for missing or insufficient private demand, public demand effectively de-risks upstream research.

The development of stealth aircraft shows how guaranteed demand affects corporate research. In the 1970s, the Defense Advanced Research Projects Agency (DARPA) launched an R&D race to design and build the first stealth aircraft.[9] The leading competitors, Lockheed Corporation and Northrop Corporation, had to solve the technical challenge of minimizing the diffraction of radar waves when they hit the aircraft's surfaces. Both firms used the science of "fringe currents" and the Physical Theory of Diffraction that had been developed by Soviet physicist Pyotr Ufimtsev in the late 1950s. Yet, while Lockheed invested heavily in software engineering (using computer simulations to minimize the radar cross section), Northrop invested in understanding the science behind radar detection, sensors, and the Physical Theory of Diffraction. Lockheed won the race, and subsequently received a noncompetitive contract to produce the F-117 stealth fighter (valued at $122 million each). However, Northrop won the bigger contract to produce the B-2 stealth bomber (valued at $2 billion each) because they were able to build planes with rounded, "big bellies," a capability that evolved from their focus on scientific understanding. The DARPA R&D contracts drove corporate R&D not because they lowered the cost of performing R&D. In fact, Lockheed initially offered to compete for free and self-finance its experimental aircraft. Rather, the DARPA R&D contracts drove corporate R&D because winning the R&D race was the ticket to lucrative, multibillion-dollar production contracts.

Beyond anecdotal examples, our study of 4,520 publicly traded U.S. firms from 1980 through 2015 documents that increases in procurement contracts lead firms to invest more in upstream R&D (measured by corporate scientific publications), but there is no effect on downstream R&D (measured by corporate patents).[10] Our results are consistent with procurement policy having an effect not only on the size of corporate investment in R&D (we find that R&D contracts "crowd in" firm R&D expenditures, especially when they are awarded by mission-driven agencies), but also on the composition of corporate R&D (i.e., the allocation of resources toward upstream research or downstream development activities). They are also consistent with the guaranteed demand mechanism, for three primary reasons. First, the effect on corporate publications is stronger when private market incentives to invest in risky upstream R&D are weak. Specifically, government R&D contracts encourage corporate publications that (i) are not used in the firm's internal inventions, (ii) spill over to rivals' inventions, and (iii) are not protected by patents. Second, the effect on corporate publications is stronger for large firms that are well positioned to capitalize on the large public market for the resulting products and services. Third, we find that winning R&D contracts is positively associated with the value of future procurement contracts.

In summary, the mechanism that drives corporate investment in innovative solutions to government problems is the promise of exclusive demand for the products of businesses that demonstrate superior technological capabilities. This mechanism is important for technologies that have no private markets (applications lie in the future) or when returns to risky R&D are hard to capture in competitive private markets (patents are ineffective in providing exclusivity). Therefore, guaranteed public demand is very important for "extreme quality" projects that support the government's objective of achieving technological superiority.

PROCUREMENT REFORMS HAVE PRIORITIZED COST OVER TECHNOLOGICAL EXCELLENCE

As noted in the Introduction, securing technological superiority over rival nations was the government's primary objective during the Cold War. After the fall of the Soviet Union, however, the perception of an existential threat to the United States dissolved. As a result, the government focused on promoting social and economic development. A significant reallocation of procurement contract dollars followed. Between 1988 and 1992, Department of Defense procurement obligations dropped 36%, from $226.7 billion to $145.3 billion (using constant 2012 dollars). Over the same period, Department of Health and Human Services procurement obligations more than tripled, from $1.1 billion to $3.4 billion.

The end of the Cold War was not the only driver of procurement changes. Increased global trade, pressures to reduce cost and increase efficiency and transparency, as well as the need to attract nontraditional, innovative suppliers from the much larger commercial markets — especially those in the growing IT sector — also played a role. The U.S. government implemented sweeping acquisition reforms throughout the 1980s and 1990s. For example, the Competition in Contracting Act of 1984 mandated that all procurement contracts be awarded based on "full and open competition" unless regulatory/statutory exclusions applied. In 1986, the Goldwater-Nichols Department of Defense Reorganization Act reworked the military command structure and implemented shared procurement across the military branches. The Defense Acquisition Workforce Improvement Act of 1990 established education and training standards for government acquisition professionals. These policy changes culminated in the Federal Acquisition Streamlining Act of 1994 (FASA), which sought to streamline federal procurement by reducing unique purchasing requirements, simplifying acquisition procedures, obtaining products and services faster, and lowering purchasing costs. FASA established a statutory preference for procuring commercially available items to take advantage of the larger and more up-to-date commercial industrial base.[11] FASA's sister legislation, the Clinger-Cohen Act of 1996, further streamlined IT procurement by eliminating special bid challenges regarding IT acquisitions.

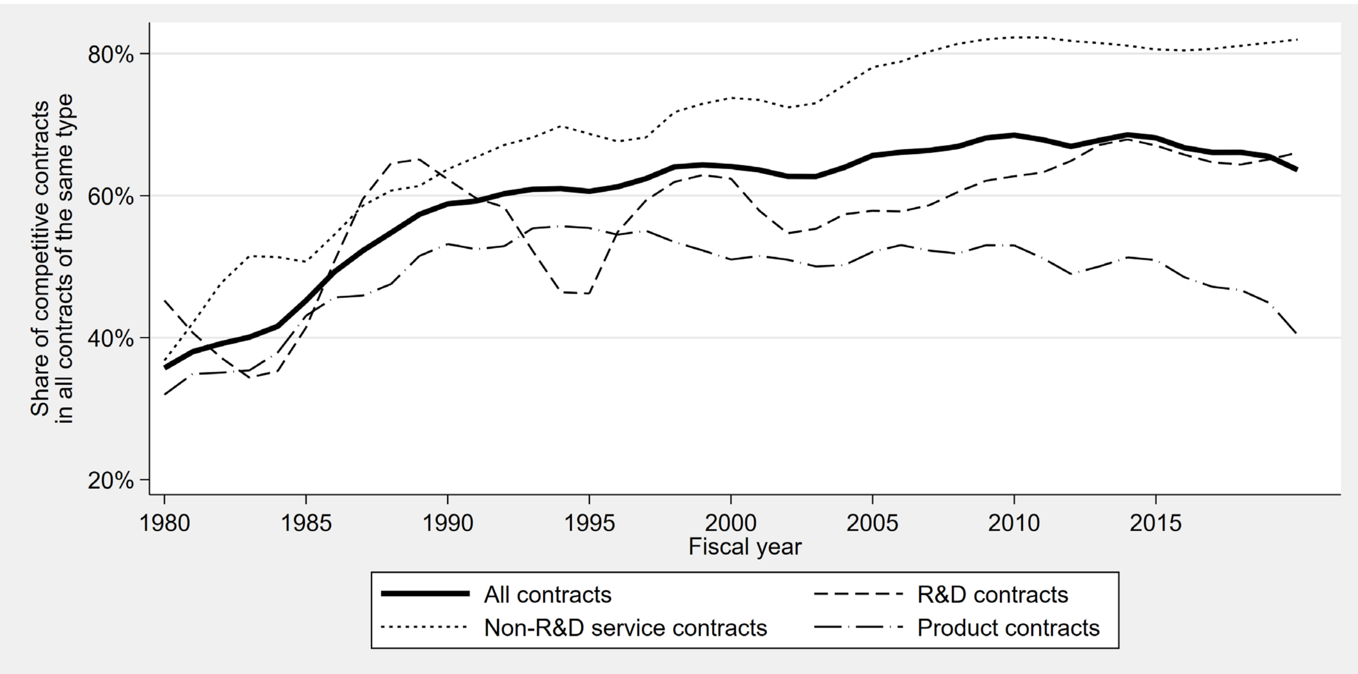
As a result of these and other policy changes, procurement dollars were reallocated away from "extreme quality" technologies that met unique government specifications and toward commercial-off-the-shelf products/services and dual-use technologies} that had both government and commercial potential. By 1995, 25% of the $8.4 billion science and technology budget of the Department of Defense was allocated to dual-use technologies focused on information technology, advanced materials, advanced manufacturing, and advanced simulation and modelling.[12] The government's dual-use focus aimed at ensuring high levels of effort from technology firms (which might otherwise get distracted by the needs of their often-times larger civilian markets) while also leveraging additional resources from private venture capital.[13] Yet, it had the unintended effect of weakening the incentives provided by guaranteed public demand.

Over time, the government substantially decreased the practice of awarding noncompetitive procurement contracts to firms that demonstrate technological superiority in initial R&D races. First, the government de-emphasized R&D races by acquiring COTS products and services rather than funding the development of purpose-made technologies. By dollar value, the share of R&D contracts in all contracts awarded to our sample of 4,520 publicly traded U.S. firms fell from a high of 24% in 1998 to just 10% in 2015. At the same time, the share of commercial contract dollars in all contracts increased from 6% in 1998 to 14% in 2015.[14] The decline in the importance of R&D contracts relative to commercial contracts occurred across a wide range of industries. For example, Electronics saw its share of R&D contract dollars in all contracts drop from 17% in 1998 to just 3% in 2015. Conversely, Drugs had the largest increase in the share of commercial contracts, from 14% in 1998 to 77% in 2015.

Second, the government awarded fewer procurement dollars noncompetitively. In noncompetitive procurement, the government either selects the company to buy from (e.g., based on technological capabilities demonstrates in an R&D race) or restricts the bidding process to certain suppliers. By dollar value, the share of competitive contracts in all contracts increased from 36% in 1980 to 68% in 2015, as shown in Figure 1. Competition among contractors increased even more for service contracts (whether for R&D services or for non-R&D services). At the same time, the share of noncompetitive product contracts dropped from 78% in 1980 to 49% in 2015. The rise in competitive procurement further limited the government's ability to guarantee demand.

Third, the government awarded large procurement contracts to firms with low or no scientific capabilities. The average contract value per $1 million in firm sales remained relatively

FIGURE 1: SHARE OF COMPETITIVE CONTRACTS IN ALL CONTRACTS OVER TIME



Notes: This figure presents the trend in the share of competitive contract dollars in all contracts of the same type obligated by federal agencies to all recipients (not limited to our sample firms). Competitive contracts are awarded using "full and open competition."

stable for firms that perform significant amounts scientific research but increased sharply for firms that do not. Prior research has documented a decline in the stock market value and the mergers and acquisitions value of scientific capabilities.[15] It appears that corporate scientific capabilities have fallen out of favor not only with investors and managers, but also with the federal government.

To summarize, instead of supporting cutting-edge technologies unproven in the market, the government competed with the commercial market for technologies that already had low(er) commercial risk. As a result, corporations had fewer incentives to perform upstream scientific research, but more incentives to invest in downstream development of commercially viable products and services. The unintended consequence of losing the exclusivity provided by guaranteed public demand was that businesses lost incentives to solve "extreme quality" problems.

BUSINESS R&D HAS SHIFTED TOWARD TECHNOLOGIES WITH EXISTING MARKETS

As the nature and composition of public demand changed in the 1980s and 1990s, so did business R&D. Partly due to the decline in public demand for "extreme quality" technologies (i.e., those that ensure technological superiority, regardless of whether they have useful applications in private markets right now), research funded and performed by businesses began to fall. Big American corporations redirected their R&D investments toward developing technologies that already had commercial applications while borrowing scientific knowledge from universities and startups.

Gradually, famous and once formidable industrial labs shut down under growing shareholder pressure. A good example is provided by DuPont. In the early and mid-20th century, the DuPont Central Research & Development Organization was run on par with top academic chemistry departments. However, in the 1990s, DuPont's attitude toward research changed as the company started emphasizing the business potential of projects over the knowledge gained from basic research. As a result, the number of journal articles authored by DuPont scientists fell from 749 in 1994 to 245 in 2015, while the number of patents the company filed with the USPTO increased from around 1,600 in 1994 to close to 3,500 in 2012. This change reflected a shift to downstream development activities. Following pressure from activist investors, on January 4, 2016, DuPont's Central Research & Development Organization ceased to operate as an independent research unit and was merged with DuPont's engineering division.

The decline of corporate science can be seen in aggregate statistics as well. Over the past three decades, the composition of business R&D changed to include less "R" and more "D." The share of research, both basic and applied, in total business R&D expenditures in the United States fell from about 30% in 1985 to below 20% in 2015. The decline of the corporate lab was striking, especially when considering that the size of America's public corporations increased substantially during this period. For example, net sales at GE grew from around $25 billion in 1980 to around $100 billion in 1998. However, employment of doctorate holders at GE's corporate research laboratory dropped from 1,649 in 1979 to only 475 in 1998.[16] Similarly, IBM's net sales grew from $26 billion in 1980 to $82 billion in 1998. Yet, the number of doctorate holders working for IBM dropped from 1,300 in 1979 to 1,200 in 1998. While we are not arguing that the demise of corporate science was due to changes in government procurement, the aforementioned policy changes have not helped to slow down this process, and perhaps even contributed to its acceleration.

The result has been an increased division of labor between universities and startups (that focus on research) and large corporations (that focus on development). Because the primary alternatives to corporate research — university and government research — are imperfect substitutes, the United States has experienced a slowdown in the translation of leading-edge science into innovative products and services that drive productivity and employment growth.

THE RISE OF CHINA POSES A THREAT, BUT ALSO AN OPPORTUNITY TO REVITALIZE CORPORATE RESEARCH

Today, the United States is facing another Sputnik moment. The country has lost ground in innovation to China, as measured by key inputs (e.g., R&D expenditures) and outputs (e.g., patents). Between 1995 and 2019, China almost quadrupled its R&D intensity — domestic expenditure on R&D as a percentage of gross domestic product — from 0.57% to 2.2%.[17] By 2019, China's total R&D expenditure reached 84% of the United States' (in purchasing power terms), making it the world's second-largest R&D spender. That same year, China overtook the United States in Patent Cooperation Treaty (PCT) patent applications, which seek exclusivity for technologies that have broad potential application around the globe.[18]

China is bound to have a numerical advantage in conventional warfare, which means that U.S. military dominance and its geopolitical influence relies on cutting-edge technology. Yet, U.S. military technological superiority is under threat, as exemplified by China's development of hypersonic weapons capabilities. On July 27, 2021, China reportedly launched a nuclear-capable Long March rocket carrying a hypersonic glide vehicle that could travel at more than five times the speed of sound yet could maneuver like the space shuttle. This was the first instance when a hypersonic glider circled the globe. Subsequent media reports suggested that the speed of Chinese development surprised U.S. national security officials.

This new geopolitical reality will likely change the U.S. government's priority objective once again. To sustain technological superiority in the 21st century, the U.S. government needs to harness the massive resources of the private sector. However, the United States cannot do what China is doing: use a heavy-handed approach to directing the national innovation ecosystem. The U.S. government directing R&D is unfeasible both from a political economy standpoint (the U.S. is a constitutional republic with a predominantly capitalist economy) and because U.S. private investment in R&D is four times larger than the federal investment in R&D, as noted in section 3.

Nor can the U.S. government simply pick-and-choose winners and losers in procurement contract awards. The fallout from (the appearance of) doing so can be significant, as exemplified in the Department of Defense' Joint Enterprise Defense Infrastructure (JEDI) Project. JEDI was supposed to be a single-award commercial off-the-shelf (COTS) acquisition of existing cloud computing technology that would lower the government's cost through economies of scale. It had the potential to be worth $10 billion over 10 years (if all the options were exercised). Yet, the project was mired in controversy since the very beginning. In August 2018, Oracle submitted a pre-award protest alleging that structuring the procurement as a single-award contract violated federal procurement standards and was biased in favor of Amazon. In August 2019, President Donald Trump placed the contract on hold while allegations of favoritism toward Amazon were investigated. In October 2019, an initial $1 million procurement contract was awarded to Microsoft. Amazon challenged the award in court, alleging undue political influence. In 2020, bidding for the contract was reopened and Amazon filed additional protests related to contract modifications. In September 2020, the Department of Defense reaffirmed Microsoft as the winner of the JEDI contract. However, in July 2021, the Department of Defense cancelled the JEDI contract after determining that "due to evolving requirements, increased cloud conversancy, and industry advances," the contract no longer met its needs.[19] It concurrently introduced a new program, called Joint Warfighter Cloud Capability (JWCC), that would involve services from multiple vendors. In November 2021, the JWCC contract was awarded to all four of the original JEDI companies: Amazon, Google, Microsoft, and Oracle. This example can serve as a cautionary tale for awarding contracts in a way that threatens the validity of the procurement process.

Instead, the United States can implement smart modifications to its procurement policy to provide precision-targeted incentives for corporate scientific research. In deciding whether to award noncompetitive procurement contracts, the government should consider not only costs, but also the nature of the problem and whether the potential technology has any private market applications. When no private market applications exist, government procurement contracts should offer the exclusivity that can incentivize firms to continue investing their own funds in leading-edge scientific research.

The government has long tried to attract the most innovative firms into the public market. As already noted, the Federal Acquisition Streamlining Act of 1994 aimed to attract nontraditional suppliers from the growing commercial IT sector by lowering procurement barriers. Yet, some of the most innovative firms are not currently engaged in federal procurement for emerging technologies. As the number of corporations that perform scientific research in-house has been shrinking for decades, the government's future access to scientific and technological breakthroughs depends on its ability to attract the remaining performers of science to the public market.

Convincing for-profit firms to solve problems that do not directly address their private-sector customers' needs is not an easy task. However, the chasm between the government and the private sector may be smaller for some firms than for others. It might be difficult to convince the leading tech firms to partner with the government on national security projects because they face very high opportunity costs in diverting attention away from serving the needs of their large and growing private customer base. For example, Amazon's annual revenues grew from $34 billion in 2010 to a staggering $386 billion in 2020. Virtually all that growth came from private markets. For instance, in 2020, Amazon was awarded only $33.4 million in procurement contracts, through its Amazon Web Services (AWS) segment. That year, the firm invested $42.7 billion of its own funds in R&D expenditures but received no R&D contracts from the federal government.[20] Amazon is not an isolated example. Other tech leaders derive a similarly small (and decreasing) fraction of their revenues from government contracts, potentially increasing the opportunity cost of diverting attention to a market of secondary importance.[21] In addition, leading tech firms don't need government funding for R&D, as their profitability and fast growth ensure relatively easy access to R&D funding from internal resources or capital markets, even when the required funding is in the tens of billions of dollars.

Moreover, consumer-facing high-tech firms (in the B2C sector) may face pressure from various stakeholders against partnering with the government on military projects. For example, in 2017, Google agreed to develop artificial intelligence (AI) technologies for the Department of Defense's Project Maven. Amid employee uproar, the company withdrew from the project a year later, vowing not to develop AI for weapons. Given the low importance of government sales to leading tech firms and mounting public opinion pressures, trying to attract them to the government market might be an uphill battle.

Yet, some leading tech firms are still willing to work with the U.S. government. Like Google's experience with Project Maven, Microsoft faced employee pushback in 2019 for letting the Department of Defense test its HoloLens augmented-reality headset. Unlike Google, Microsoft signed a contract worth up to $21.9 billion in 2021 to supply the HoloLens to the U.S. Army. The announcement signaled that Microsoft could "generate meaningful revenue from a futuristic product resulting from years of research, beyond core areas such as operating systems and productivity software."[22] Because there are clear benefits to firm scale and scope when it comes to scientific research, we need to understand why some leading tech firms cave to public opinion, while others don't.[23] In addition to tweaking procurement policy to incentivize innovative high-tech firms to solve "extreme quality" problems, the U.S. government must consider the potential side-effects of antitrust policy (aimed at limiting firm scale and scope) on corporate participation in scientific research.

Established firms do not face the same opportunity costs as the leading tech firms. Established firms are those that were once America's dominant technology companies, but have since witnessed a decline (e.g., GE and AT&T). Despite holding a falling share of private markets, these firms still command substantial technological and manufacturing resources. Because they (i) are relatively unconstrained by the needs of their private market customers, (ii) tend to be highly diversified, and (iii) have fewer growth opportunities in private markets, established firms are well positioned to partner with the government on solving "extreme quality" problems.[24]

Another group of firms that would likely embrace the government's renewed emphasis on technological superiority are the traditional government contractors. Firms like Lockheed Martin, Raytheon Technologies, General Dynamics, Boeing, and Northrop Grumman have consistently ranked among the top five government contractors (by dollar value of prime unclassified contracts) over the past decade.[25] In fiscal year 2020, these firms received a combined $167.2 billion in government obligations, representing 25% of all government procurement contracts awarded that year. Solving "extreme quality" problems for the government enabled these firms to grow big during the Cold War. The government's acquisition reform policies pushed many defense contractors to consolidate operations through mergers and acquisitions in the 1990s. Their strong reliance on government sales means that they are likely to compete aggressively on future projects.

Fast-growing startups may also vary in their willingness to partner with the government. Convincing startups funded by venture capital to develop technologies where the only customer is the government may be a difficult task, as noted by In-Q-Tel president Mike Griffin in 2003: "We don't want them building in anything that's just intended for the government. That tends to leave an orphan product and that doesn't contribute to a company's success." Moreover, private venture capital is less likely than internal capital to hold a patient, long-term orientation. Conversely, startups funded by ultra-wealthy entrepreneurs, such as Jeff Bezos and Elon Musk, should not be as reluctant to work with the government on cutting-edge technologies, even when these technologies are unlikely to be rewarded by private markets in the short term. Such startups have access to very deep pockets and pursue objectives that go beyond enriching their already wealthy founders. The desire to solve big problems, even at the expense of short-term profits, has been already demonstrated by such startups as SpaceX and Blue Origin in their repeated collaboration with NASA.

A recent example of an "extreme quality" problem that is solved by established firms is the COVID-19 vaccines. Before the pandemic, the development of a vaccine for an infectious disease took several years. To accelerate COVID-19 vaccine development and address manufacturing challenges, the U.S. government launched Operation Warp Speed on May 15, 2020.[26] This partnership between the Departments of Health and Human Services and Defense awarded approximately $13 billion in procurement contracts and other transaction agreements to six vaccine companies — Moderna, Pfizer/BioNTech, Janssen, AstraZeneca, Sanofi/GSK, and Novavax — to develop or manufacture vaccine doses. By December 14, 2020, the first vaccine shots were administered, demonstrating the potential of large-scale public-private partnerships to address significant societal problems by attracting established firms (e.g., Pfizer and Johnson & Johnson) to the government market. Interestingly, government contracts represented a relatively small share of Pfizer's sales prior to the pandemic. In fiscal year 2019, the firm's $1.2 billion in government obligations represented less than 3% of its annual revenues. In fiscal year 2020, Pfizer received an impressive $14.1 billion in procurement awards. This is an example of how an established firm reacts to a national crisis by working with the government, as well as with other sectors of the innovation ecosystem, to develop new technologies and manufacturing capabilities.

CONCLUSION

The U.S. government needs to regain and sustain its technological superiority. China's model of heavy-handed government intervention in the innovation ecosystem is not feasible in the United States. Instead, the U.S. government must incentivize the participation of the private sector, while still responsibly and efficiently managing taxpayer resources. Yet, we need to develop a deeper understanding of what types of firms are likely to partner with the government on "extreme quality" projects and how these firms should be compensated.

The rise of China as a technology powerhouse presents not only a threat, but also an opportunity. A new "Sputnik shock" can be used to (i) leverage the R&D investments of high-tech leaders for national security, (ii) revitalize the depleted scientific arsenal of America's established firms, and (iii) harness the willingness of its ultra-wealthy entrepreneurs to advance human knowledge. To facilitate collaboration with the government, policy makers should consider returning to the practice of rewarding firms that demonstrate technological superiority (yet don't have sufficient incentives to invest in risky upstream R&D due to missing or insufficient private market demand) with guaranteed public demand in the form of noncompetitive contracts for the resulting products. Doing so would likely be beneficial to U.S. national security and geopolitical influence in the short term, and to society at large in the long term.

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ENDNOTES

[1] Universities and startups cannot fully substitute for corporate labs, whose research tends to integrate multiple disciplines at the large scale typically required to solve significant technical problems.

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[21] For example, Microsoft was awarded $1.4 billion in procurement contracts between 1986 and 2015, representing just 0.14% of total revenues over that period (in constant 2012 dollars). Google was awarded $30 million in procurement contracts between 2004 and 2015, while Facebook received less than $1 million between 2012 and 2015.

[22] Jordan Novet, "Microsoft Wins U.S. Army Contract for Augmented Reality Headsets, Worth up to $21.9 Billion over 10 Years," CNBC, March 31, 2021, https://www.cnbc.com/2021/03/31/microsoft-wins-contract-to-make-modified-hololens-for-us-army.html.

[23] Translating leading-edge scientific research into innovative products often requires substantial investment. Conversely, significant research investment often results in an increase in firm scale and scope, as new product markets are created. There is, therefore, a close relationship between the incentives to invest in scientific research and firm scale and scope.

[24] Science-based projects are more valuable to diversified conglomerates than to specialized firms because the resulting scientific knowledge can potentially be applied to solve a broader range of problems.

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The future can be a better, more vibrant place, but we will need significant technological breakthroughs to get there. To solve climate change, cure diseases, prevent future pandemics, and improve living standards across the globe we need continued scientific advancement and technological improvements. The United States is particularly wellpositioned to drive these advancements because we are on the frontier of knowledge ourselves. Even small changes to the way we govern and incentivize science and technology can have long-run consequences for the US and for the world.

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