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Sharpening America's Innovative Edge

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A Report of the CSIS Trade Commission on Affirming American Leadership

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About the CSIS Trade Commission on Affirming American Leadership

U.S. economic leadership faces pressure at home and abroad. The global institutions built on the back of the post-war U.S. alliance structure, and the rules and norms they support, were constructed for the twentieth century, not the twenty-first century. New challengers to the existing system have emerged. Confidence in the international order is eroding within the United States, as many Americans feel that the benefits of the existing system are not as widely shared as they once were. A mishandled health pandemic has raised questions about U.S. competence. As a result of these and other forces, American leadership on the global stage has been seriously eroded. Allies are beginning to question America's commitment to the institutions and rules that it enlisted them to craft and uphold, and adversaries are seeking to take advantage of these doubts. As history moves toward a pivot point, there is an urgent need for revitalization and affirmation of American leadership.

The CSIS Commission on Affirming American Leadership was created in the summer of 2019 to develop a series of recommendations to cement U.S. global leadership in light of these twenty-first century challenges. In a series of reports, the commission lays out recommendations for the U.S. workforce, U.S. innovation policy, and U.S. engagement in the international trading system.

Members of the commission are listed below. Each commissioner participated in an individual capacity, not on behalf of their organizations. Individual members of the commission do not necessarily endorse all of the recommendations in this paper.

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Elizabeth Economy	**Kevin Nealer**	**David Steel**
Susan Esserman	**John Neuffer**	**John Veroneau**

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Executive Summary

Since World War II, the United States has led the world in developing cutting-edge knowledge and technology. A dynamic private sector, a skilled workforce, leading universities, and federal support for research and development (R&D), reinforced by an open trade and investment environment, kept America at the innovation frontier for decades. Technological superiority has not only driven higher incomes, living standards, and life expectancy but has supported national security and buttressed U.S. global leadership. Going forward, U.S. technological prowess will be indispensable to growth and to solving such crises as public health emergencies and the threats posed by climate change.

But U.S. policymakers have grown complacent, resting on the success of the Cold War model without maintaining or modernizing it. National R&D spending as a percentage of gross domestic product (GDP) has barely grown over the past few decades, with rising private sector expenditures offset by declining government funding.[1] Primary and secondary education outcomes—particularly in science, technology, engineering, and mathematics (STEM)—have stagnated despite rising costs. Other countries, notably China, are rapidly advancing in critical technologies. As a result, U.S. leadership is in a perilous position.

As the United States emerges from the Covid-19 pandemic, policymakers must seize the opportunity to reaffirm U.S. technological leadership. To further the discussion, the Commission on Affiming American Leadership recommends the following seven elements of a national technology strategy, organized in three lines of effort: investing in innovation; protecting critical technologies; and championing data governance. If adopted, these recommendations would sharpen the U.S. innovative edge and position the country for long-term leadership.

1. **Recommit to the innovation base:** Reaffirming U.S. leadership begins with reinvesting in the innovation base: increasing federal funding for R&D, strengthening and diversifying a world-class talent pipeline, encouraging business investment, and building digital infrastructure. Policymakers should restore federal R&D funding to its post-War World II average of 1 percent of GDP over the next 5 to 10 years, an increase of about $100 billion per year. These investments can help address major societal challenges in climate, defense, and health. In addition, policymakers should improve STEM education outcomes and workforce inclusiveness while expanding opportunities for highly skilled individuals to work and remain in the United States.
2. **Support key technology categories:** Broad investments in the innovation base are a necessary but not sufficient element of a national strategy. Targeted federal action can mobilize resources and catalyze efforts to develop breakthrough technologies. Washington should leverage government purchasing power to create markets for and stimulate investment in early-stage, pre-competitive technologies in categories including artificial intelligence, biotechnology, quantum computing, and robotics.
3. **Set global standards:** To compete in today's standards environment, Washington should encourage and support the active participation of domestic companies and experts in the technical process. Policymakers can do so by advocating for process reforms in standards-setting groups and facilitating renewed industry participation in technical discussions.
4. **Promote whole-of-government technology control policy:** The high degree of interconnectedness in the global economy means that there are multiple vectors for sensitive technology and data transfers to adversaries, requiring coordination across policy areas. As a guiding principle, policymakers should reaffirm the benefits of open investment, trade, and research while tailoring control mechanisms to address specific vulnerabilities, using multilateral action where possible. In an interagency process, policymakers should align on top-level objectives and standardize guidance between various control mechanisms (e.g. investment screening, export controls, research collaboration).
5. **Work with allies on multilateral technology controls:** Multilateral cooperation is necessary both to maximize policy effectiveness and minimize negative spillover effects. U.S. allies and partners share many similar concerns about national security risks stemming from technology transfer, especially to China, but are earlier in their reform cycles. Policymakers should continue to deepen cooperation, including by establishing an Allied Technology Controls group that would coordinate various mechanisms for managing technology transfer policy.
6. **Adopt national data privacy regulation:** If the United States does not step up in discussions on the rules, standards, and norms that govern data privacy and digital trade, others will. Beijing and Brussels have each articulated a data privacy framework. U.S. states have started to put in place their own systems, but the federal government has yet to follow suit. Policymakers should accelerate discussions on a national privacy framework, with the goal of reaching an agreement by the end of 2021.
7. **Align data governance principles with allies:** Despite the role of data in driving future economic growth, there have been no successful international efforts to set rules directing its collection, processing, storage, and use. The United States should build on recent momentum to closer align data governance frameworks with partners in the Asia-Pacific region while constructively engaging in plurilateral discussions at the World Trade Organization (WTO).

01

Introduction

Since World War II, the United States has led the world in developing cutting-edge knowledge and technology. A dynamic private sector, a skilled workforce, leading universities, and federal support for R&D, reinforced by an open trade and investment environment, kept America at the innovation frontier for decades. Technological superiority has not only driven higher incomes, living standards, and life expectancy but has also supported national security and buttressed U.S. global leadership. Going forward, U.S. technological prowess will be indispensable to growth and to solving such crises as public health emergencies and the threats posed by climate change.

The United States achieved innovation leadership by leveraging the strengths of government, academia, and business working together in a "triangular alliance." Building on a robust education system, Washington used federal purchasing power and large R&D budgets to create demand for early-stage technologies and accelerate their development. Scientists at national laboratories and universities generated foundational breakthroughs, which the private sector then commercialized and deployed at scale.

But U.S. policymakers have grown complacent, resting on the success of the Cold War model without maintaining or modernizing it. National R&D spending as a percentage of GDP has barely grown over the past few decades, with rising private sector expenditures offset by declining government funding.[2] Primary and secondary education outcomes—particularly in STEM fields—have stagnated despite rising costs. Other countries, notably China, are rapidly advancing in critical technologies. As a result, U.S. leadership is in a perilous position.

Although the United States faces fierce competitors, it has the means to sharpen its innovative edge and inspire a generation of future scientists and technology entrepreneurs. As the United States emerges from the Covid-19 pandemic, policymakers should seize the opportunity to reaffirm U.S. technological leadership. To further the discussion, this report outlines three broad areas of focus for a comprehensive strategy—investing in innovation, protecting critical technologies, and championing data governance—and concludes with recommendations and implementation steps.

Source: "Main Science and Technology Indicators: Gross Domestic Expenditure on R&D," Organisation for Economic Co-operation, https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB.

02

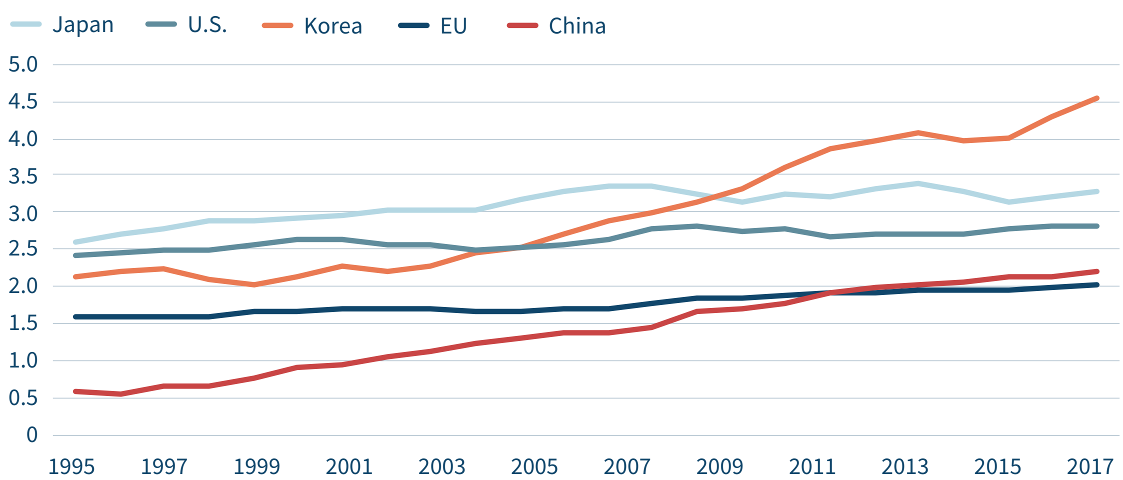
Investing in Innovation

Strengthening the Innovation Base

U.S. technological breakthroughs have relied on a "triangular alliance" among government, academia, and business, each playing to its sectoral strengths. Government provides essential public goods, including education, infrastructure, and funding for basic research. Universities and national laboratories, supported by public investment, incubate and develop early-stage, high-risk ideas and technologies. The private sector then scales up and commercializes promising projects, as well as conducting valuable research itself.

The United States spends more than any other country on R&D. U.S. gross domestic expenditure on R&D totaled $581 billion in 2018, the highest among advanced economies and an increase from $361 billion in 2000.[3] Other countries, especially China, have ramped up R&D spending to narrow the gap with the United States. China's R&D expenditure growth averaged 17.3 percent annually over 2000–2017, while U.S. growth averaged 4.3 percent during the same period.[4] U.S. R&D expenditure as a percentage of GDP increased from 2.6 percent in 2000 to 2.8 percent in 2018, roughly the same level as the 1960s. Over that time, China's R&D spending increased from 0.9 percent of GDP to 2.2 percent of GDP, more than doubling. As a result, the U.S. share of global R&D funding declined from 37 percent in 2000 to 25 percent in 2017.[5] If current trends remain unchanged, China is on track to be the largest spender on overall R&D, outpacing the United States within the next decade.[6]

FIGURE 1 / **R&D Expenditure as a Percentage of GDP**



Source: "Main Science and Technology Indicators: Gross Domestic Expenditure on R&D," Organisation for Economic Co-operation, https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB.

Types of R&D Activity

R&D activity is typically grouped into three categories: basic research, applied research, and experimental development.[7]

Basic or fundamental research refers to "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view."

Applied research is "original investigation undertaken in order to acquire new knowledge . . . directed primarily towards a specific, practical aim or objective." Applied research often draws on breakthroughs in basic science, such as Albert Einstein's work on the general theory of relatively, to create specific applications, such as the atomic clocks used in Global Positioning System (GPS) satellites.[8]

Experimental development refers to "systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes." Such early-stage development focuses on translating scientific breakthroughs directly into products or processes, which often leads to commercialization.

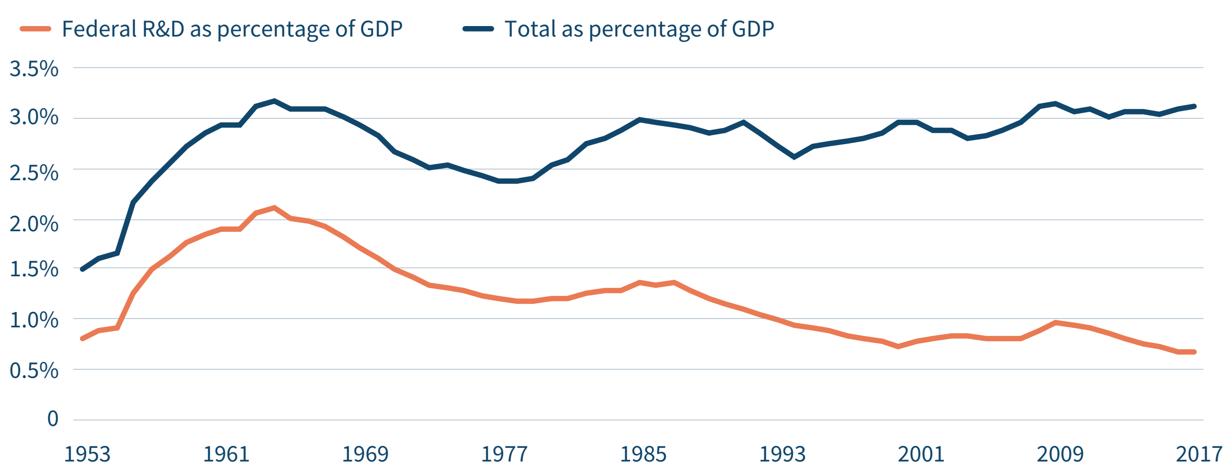
The United States maintains a sizeable lead in spending on basic and applied research, while China leads in development expenditures. U.S. national spending on basic R&D in 2018 amounted to 0.5 percent of GDP, the largest in absolute terms and trailing only Korea, Israel, and the Czech Republic relative to GDP, while China's 2018 basic R&D expenditure totaled 0.1 percent of GDP.[9] Similarly, in 2018 the United States spent almost double the amount of China on applied research, although the gap has narrowed in the last two decades. While the United States leads in research expenditures, China has led in global spending on experimental development since 2014.[10]

Measured by outcomes, the United States remains a leading source of high-quality science and engineering publications, but other countries are catching up. In 2018, the United States held the second-largest share (behind Japan) of "triadic" patent families—those registered in the European Union, Japan, and the United States.[11] While the U.S. share declined from 28 percent in 2000 to 23 percent in 2017, China's share of triadic patent families rose from 0.2 percent in 2000 to 7.6 percent in 2017. Similarly, while the United States still produces the largest number of highly cited science and engineering research articles, China's share has shot up since 2000.[12]

Over time, the primary source of U.S. R&D funding has shifted from the public to the private sector. At the height of the space race with the Soviet Union in the 1960s, federally funded R&D represented over 1.6 percent of GDP, double the amount of business-funded R&D and accounting for two-thirds of U.S. R&D investment.[13] By 2017, government funding for all types of R&D declined to 0.6 percent of GDP, a 60-year low. The decline is notable, since federal spending is a vital source of support for the U.S. research enterprise, especially for fundamental science.[14] By contrast, the private sector funded around 70 percent of U.S. R&D in 2017, focusing primarily on experimental development and, to a lesser degree, applied research. This change was driven by declining defense budgets after the Cold War, the growing role of business in the national innovation system, and austerity measures imposed to limit government spending.

Both public and private R&D investment are essential, but the role of government has been undervalued in recent decades. Since World War II, government financing has made private enterprise more effective by financing basic research and supporting commercialization of resulting invention.[15] Public

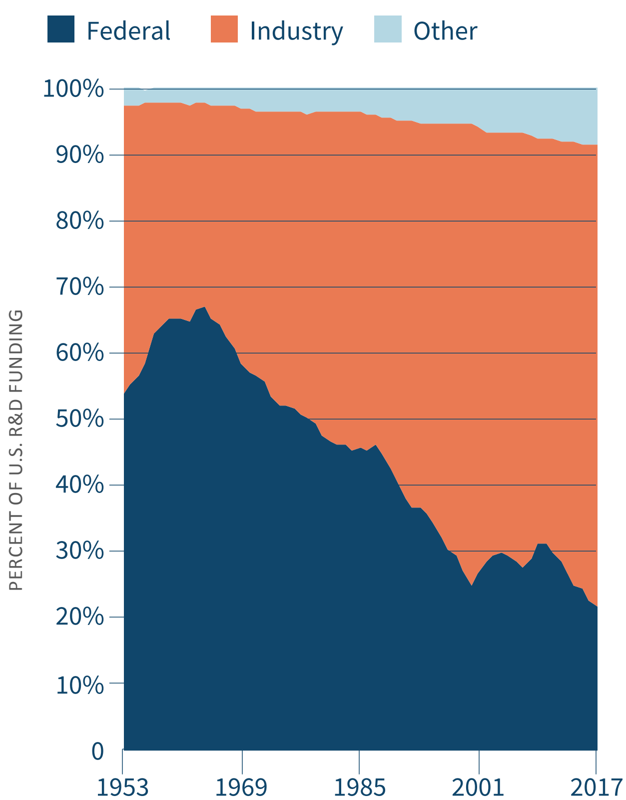
FIGURE 2 / **U.S. R&D Funding as a Percentage of GDP**



Source: "Historical Trends in Federal R&D," American Association for the Advancement of Science, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

spending can "crowd in" private investment, and one study found that every federal dollar spent on R&D spurs an additional 30 cents of business R&D.[16] Government investments typically support higher-risk projects that may not have clear market viability and which businesses are unwilling to pursue alone. Businesses primarily focus on "safer" developmental R&D to bringing promising ideas—including those developed through federally funded research—to market, which has lower risk but is less likely to result in transformational breakthroughs usually associated with basic research. Notably, federally funded research projects, often in close collaboration with universities, developed the foundational knowledge behind the internet, advanced artificial intelligence (AI) algorithms, GPS, and Google's search algorithm, among many other technologies.[17]

FIGURE 3 / **U.S.R&D Funding by Source, 1953-2017**



Source: "Historical Trends in Federal R&D," American Association for the Advancement of Science, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

The Bayh-Dole Act

The Patent and Trademark Law Amendments Act of 1980, known as the Bayh-Dole Act, changed the landscape of R&D by allowing small businesses and non-profit institutions, including universities, to retain certain patent rights on inventions produced with federal financial assistance.[18] Prior to the legislation, researchers using federal funding were obliged to assign patent ownership of any breakthroughs to the government. The act led to a surge in university patenting, with activity increasing an estimated 10-fold between 1980 and 1999.[19]

Despite the successful track record of government R&D investment, sequestration after the 2008–2009 global financial crisis and high-profile failures likely limited funding agencies' risk appetite. Massachusetts Institute of Technology professors Jonathan Gruber and Simon Johnson warn that U.S. government R&D funding agencies have become too risk averse, focusing on achievable projects rather than ambitious projects that offer potential breakthroughs.[20] A 2013 review observed that recent National Institutes of Health grants were scored based more on "doability" than innovation. The study concluded that agencies had a stronger preference to fund "doable" research, an inclination which increased in times of budget cuts or sequestration, when they faced greater pressure to report results to preserve limited funding.[21]

Beyond increased federal R&D funding, policymakers can promote private innovation through structural tax and infrastructure policy. U.S. R&D tax credits amount to 0.07 percent of GDP, behind the Organisation for Economic Co-operation and Development

(OECD) median of 0.11 percent.[22] In 2018, the United States ranked 26th out of 36 OECD countries in the value of R&D tax incentives.[23] The Tax Cuts and Jobs Act of 2017 curtailed some existing benefits by prohibiting companies from immediately deducting R&D expenses and instead requiring amortization over five years. Once implemented in 2022, the United States would be the only advanced economy requiring the amortization of R&D expenditures, and Ernst and Young estimates the change could reduce R&D by $71 billion over 10 years.[24] In digital infrastructure, the United States ranked 4th among OECD countries in mobile broadband penetration rates in 2019 but only 18th in fixed broadband penetration.[25] Beneath the headline numbers, there remains a significant digital divide, with a 2019 Pew survey reporting that only two-thirds of rural adults had a home broadband connection, 12 percentage points lower than urban adults.[26]

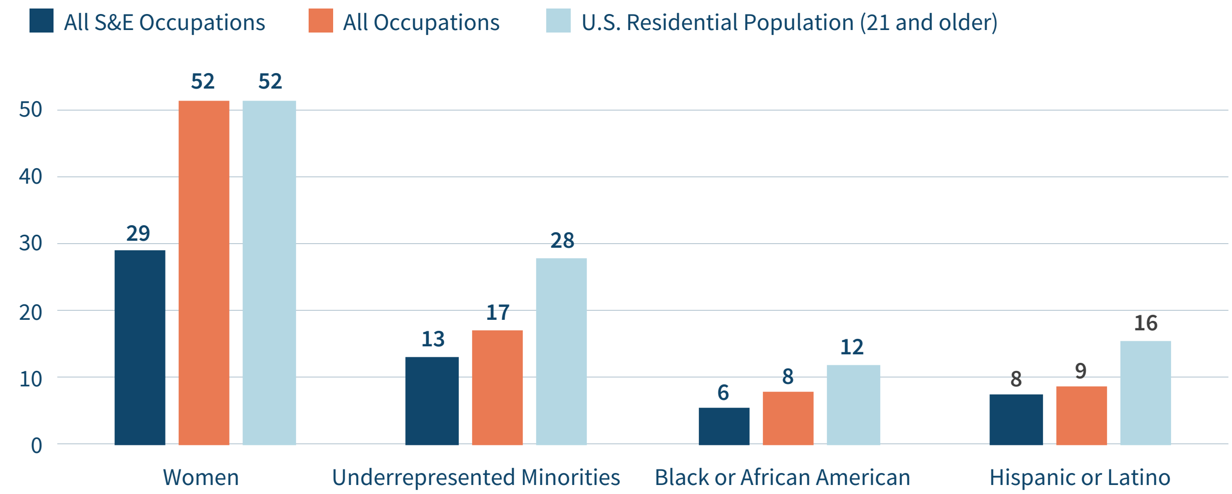
The Importance of Human Capital

The U.S. innovation system relies on training and attracting the best minds in the world. As of 2016, the United States awarded the most science and engineering (S&E) doctoral degrees of any country.[27] However, as with general R&D spending, other countries are catching up. In 2015, China awarded 34,000 S&E doctoral degrees (up from under 8,000 in 2000), compared to 40,000 in the United States, and has surpassed the United States in annual doctoral degrees awarded in natural sciences and engineering since 2007.[28] A comprehensive innovation strategy must focus on both improving educational outcomes and opportunities at home, especially in STEM fields, and continuing to attract foreign talent.

Despite relatively high levels of education spending compared to other advanced economies, U.S. STEM outcomes are average and contain racial and socioeconomic gaps. Out of 35 advanced economies, the United States spent the fourth-most on primary and secondary education per student in 2018 but only achieved average rankings on science and math assessments.[29] Data show that persistent achievement gaps by racial and socioeconomic status in the United States expand as students get older. In a national cohort of students, the mathematics score gap between those of high and low socioeconomic backgrounds rose from 9 points in kindergarten to 29 points in eighth grade. Gaps between white and Black or Hispanic students showed similar patterns.[30] Recent studies have shown that lockdowns to contain the spread of Covid-19 have led to learning loss among students and likely widened racial and economic gaps in outcomes, underscoring the urgency for more equitable primary education opportunities.[31]

Special attention must be paid to attracting and retaining more women and underrepresented minorities in STEM fields. Women are 52 percent of the U.S. population but in 2017 held only 29 percent of S&E jobs in the United States, compared with 22 percent in 1995. This anemic progress is especially evident in computer and mathematical sciences, where the proportion of women declined from 31 percent in 1993 to 27 percent in 2017.[32] Underrepresented minorities from the Black, Hispanic, and Indigenous communities account for an even smaller share of S&E jobs, holding 13.3 percent of occupations in 2017 despite representing 28 percent of the population.[33] While notable progress has been made since the 1990s—the percentage of underrepresented minorities in S&E occupations more than doubled from 1995 to 2017—more action is necessary. In addition to structural factors, both women and underrepresented minorities in S&E fields generally receive lower salaries than male and white or Asian counterparts. Although direct salary comparison is difficult, the National Science Foundation recently concluded, "Women's salary differentials remain at all degree levels after adjustments for education, employment, demographic, and other characteristics."[34]

FIGURE 4 / **Representation Share in S&E Occupations**



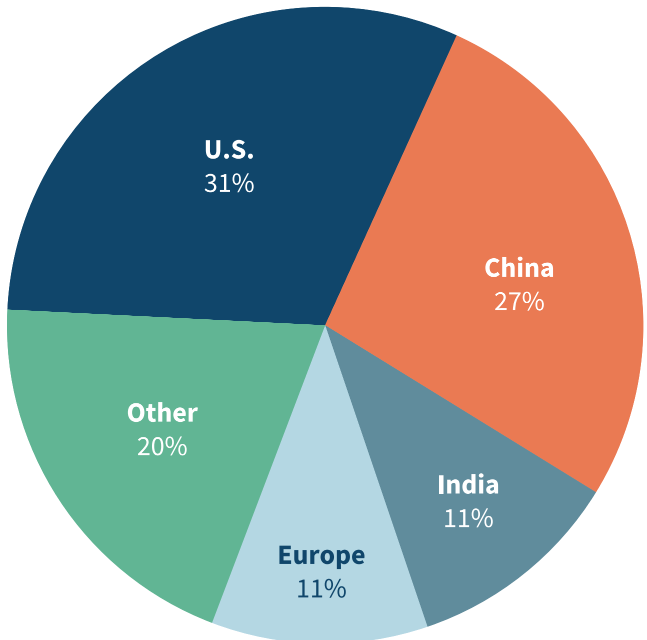
Source: Beethika Khan, Carol Robbins, and Abigail Okrent, The State of Science and Engineering 2020 (Alexandria, VA: National Science Foundation Science & Engineering Indicators, January 15, 2020), https://ncses.nsf.gov/pubs/nsb20201/global-r-d.

To complement domestic talent, the United States attracts highly skilled international students, scientists, and entrepreneurs.[35] Without foreign students, the United States would lag far behind China in S&E doctoral degrees awarded. Foreign students are overrepresented in science and engineering fields, and about a third of U.S. S&E doctoral degrees conferred in 2017 were awarded to temporary visa holders. Concerns about foreign students leaving the country after their education are exaggerated. As of 2017, roughly two-thirds of U.S. S&E PhD recipients with temporary visas stayed in the country for at least five years after graduating, including 90 percent of students from China.[36]

It is difficult to overstate the importance of highly skilled immigrants for U.S. technological leadership. Although only 18 percent of the U.S. population is foreign born, 30 percent of workers in S&E occupations are foreign born, with higher numbers in engineering and computer science.[37] From 1901 to 2019, immigrants accounted for 35 percent (105 of 302) of the Nobel Prizes in chemistry, medicine, and physics won by U.S. citizens.[38] The importance of foreign talent is especially evident in emerging technologies. According to a June 2020 report from the Macro Polo think tank, 59 percent of the world's top-tier AI researchers work in the United States, but only one-third of those had received their undergraduate degree in the United States.[39] First- and second-generation immigrants have helped launch 60 percent of the most valuable U.S. technology companies, and an October 2018 study found that 50 of the 91 U.S. "unicorn" tech startups—those valued above $1 billion—had at least one founder who was an immigrant.[40] As discussed in detail in the workforce chapter of this report, attracting and retaining world-class human capital is essential for technological leadership, and the immigration system should reflect that reality while mitigating potential security risks. Actions to exclude broad groups of foreign researchers will only hamstring U.S. scientific development.[41]

Unfortunately, barriers in the national immigration system make it hard for talent to stay, which puts the United States at a competitive disadvantage. The H-1B visa program—the primary means for U.S. companies to attract high-skilled immigrants—is oversubscribed. In 2019, 105,000 more H-1B applications were submitted beyond the 85,000 statutory

FIGURE 5 / **Top U.S. AI Talent by Country of Origin**



Source: "The Global AI Talent Tracker," Macro Polo, https://macropolo.org/digital-projects/the-global-ai-talent-tracker/.

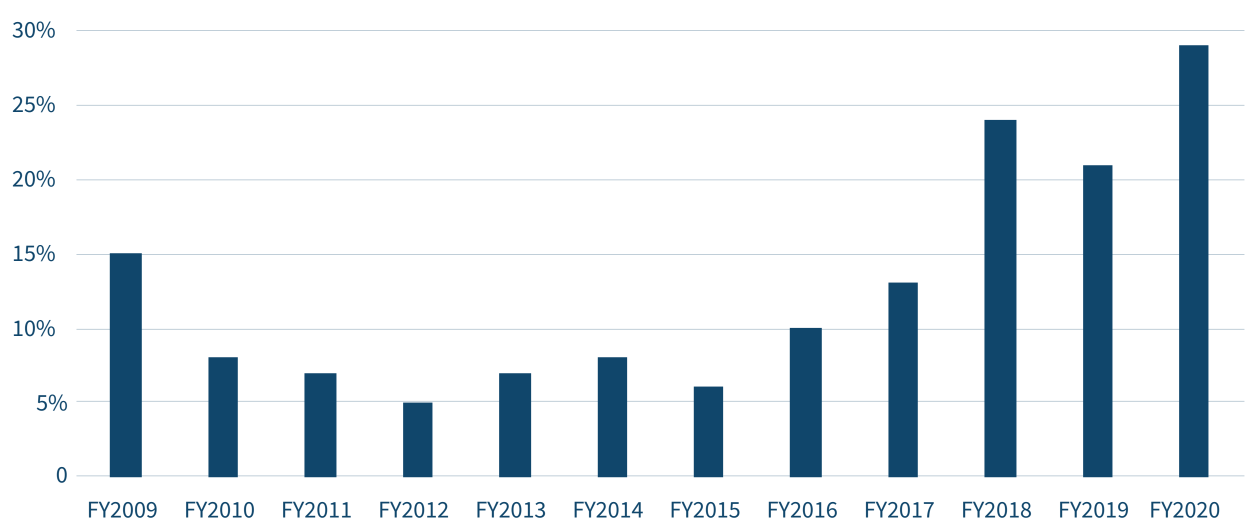
limit. The denial rate for initial H-1B visas reached 29 percent in the first two quarters of FY 2020, up from 6 percent in FY 2015 and 13 percent in FY 2017.[42] Similarly, foreign graduate students at U.S. universities face barriers to obtaining full-time work authorization. A 2015 study found that 90 percent of foreign science and engineering doctorate recipients pursuing non-academic careers wanted to stay in the United States to work but only 50 percent were able to do so.[43]

In contrast with the United States, other countries seek to attract foreign talent. From 2013 to 2015, Canada and Australia admitted 9 and 11 times as many immigrants, respectively, than the United States, as a share of their overall population, through high-skilled visa programs.[44] China has many national and local programs to attract talent, including the flagship Thousand Talents Program.[45]

Targeted Federal Support

Broad federal investments in research and STEM education are necessary to sharpen America's innovative edge and address societal challenges, including climate change. In certain cases, critical technology sectors may merit additional government support, such as demand creation through federal purchasing

FIGURE 6 / **Denial Rate for H-1B Petitions for Initial Employment**



Source: "H-1B Denial Rates Through the Second Quarter of FY 2020," National Foundation for American Policy, August 2020, https://nfap.com/wp-cont tent/uploads/2020/08/H-1B-Denial-Rates-Analysis-Through-The-Second-Quarter-Of-FY-2020.NFAP-Policy-Brief.August-2020.pdf.

and closer cooperation with industry on applied research and early-stage development.

Despite recent distaste for government intervention in private markets, Washington has a successful history of supporting key industries.[46] Since World War II, the government has used procurement and large R&D budgets to harness market forces and accelerate development of cutting-edge technologies. Federal investment was integral to foundational inventions, including the internet, satellites, supercomputing, and the components of smart phones. Initial federal investment and research contracts awarded to Stanford University in the 1950s and 1960s helped build Silicon Valley, just as the Apollo and Minuteman programs drove the growth of the semiconductor industry.[47] Operation Warp Speed, the $9.5 billion U.S. government initiative to deliver 300 million doses of a Covid-19 vaccine by January 2021, is a current-day test of the continued effectiveness of public-private cooperation.[48] If successful, the initiative will develop a vaccine in record time through robust public-private cooperation backed by significant federal investment.

Many successful government initiatives leveraged massive federal purchasing power to generate demand in early-stage technologies and support the application of basic research. In the 1950s and 1960s, the Department of Defense and space program were essential customers for emerging technologies, including advanced computers, materials, and semiconductors. For example, U.S. government purchases accounted for all U.S. sales of integrated circuits from their invention in 1958 through 1963.[49] Rather than explicitly subsidize individual companies, U.S. government spending created consistent, large demand signals that generated market incentives for technological development.

Innovation Strategy for 2030

In response to today's most pressing challenges—a global pandemic, climate change, and the rise of economic competitors—prominent U.S. policymakers on both sides of the aisle, as well as business leaders, have called for more active government efforts to boost innovation.[50] Federal funding for basic research, education, and infrastructure is essential but not sufficient to ensure the United States strengthens its technological edge. To supplement broad investment, U.S. policymakers should consider a proactive and targeted innovation strategy to support development of critical technologies through demand incentives and enhanced public-private partnerships. An innovation strategy should focus on emerging technologies, including AI, quantum computing, and semiconductors, along with climate adaptation and advanced manufacturing where relevant.

On the demand side, federal purchasing can create markets for early-stage technologies with insufficient private demand. This helps stimulate investment and production using market mechanisms, rather than "picking winners" among individual companies or technologies. Further, a clear federal market allows the private sector to scale and overcome initial cost structures too immature to permit commercial viability. Critically, federal purchasing will help bridge the gap between basic research and commercialization to ensure the United States translates its lead in basic R&D to market results. Federal purcahsing can encourage not only product innovation but also process innovation through the accumulation of deep technical knowledge associated with advanced manufacturing. Such support is especially important to offset subsidized international competitors in technology categories with significant first-mover advantages or winner-take-all biases.[51] As technologies reach scale, private actors will eventually replace the government as the consumer, creating off-ramps for federal spending.

On the supply side, Washington should rationalize regulatory processes to encourage innovation in and production of emerging technologies. The Global Innovation Index ranks the United States 16th in regulatory quality, based on a World Bank survey of "perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private-sector development."[52]

In many cases, national regulators lag behind technological development. This results in a patchwork of state regulations that can slow the roll-out of emerging technologies such as autonomous vehicles and drones.[53] Similarly, the lack of a federal data privacy and security framework has left states to enact individual legislation, creating unnecessary costs for companies to comply with different provisions and regulatory complexity. The lack of federal U.S. regulation cedes competitive advantage to companies from countries with unified guidelines.

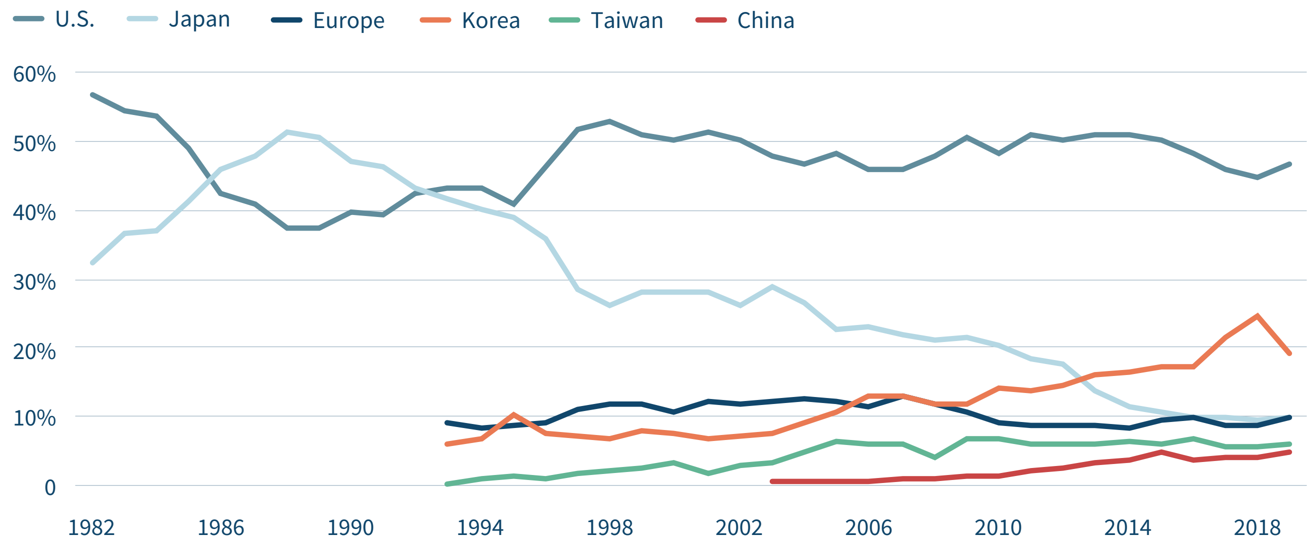
Public-private partnerships help bridge demand- and supply-side incentives and maximize government resources. Enhanced cooperation can build on several recently launched initiatives. The Quantum Economic Development Consortium (QED-C), established in 2018, seeks to bring together diverse stakeholders to grow the U.S. quantum industry. [54] In August 2020, the Trump administration announced a $1 billion investment to establish 12 AI and quantum information science R&D institues, which would build collaborative research teams across science and engineering disciplines.[55] Future partnerships should focus on pre-competitive technologies where firms have an incentive to cooperate, not compete, and benefit from shared innovation.[56]

SEMATECH: Successful Public-Private Cooperation

In the 1980s, the U.S. semiconductor industry faced intense competition from Japanese companies producing higher-quality chips, in part due to Japanese government support. In response, Washington and U.S. semiconductor producers launched several initiatives to revive the industry, most notably the SEMATECH (short for "semiconductor manufacturing technology") R&D consortium. SEMATECH brought together 14 U.S. corporate members with leading universities and national laboratories to rationalize supply chains, share know-how, and collaborate to reduce product costs and defects. SEMATECH was designed as a temporary, five-year project with equal funding from the Department of Defense and industry.[57] To comply with anti-trust law, SEMATECH was explicitly barred from manufacturing chips for sale and focused instead on generic technology and development processes.[58]

Despite initial friction within SEMATECH between chip designers and equipment manufacturers, U.S. semiconductor manufacturers improved productivity and achieved technical goals. Aided by the emergence of the Korean semiconductor industry, U.S. equipment suppliers achieved market share parity with Japanese competitors by 1992. More broadly, SEMATECH helped rally an industry under considerable pressure from Japanese competitors that had their government's support, accelerated U.S. technological advances, and established institutional best practices and standards with long-term significance.[59] A National Academies' study attributed SEMATECH's success to several factors, especially private sector commitment to the effort, buy-in of top scientists and engineers, and agreement on technology roadmaps between chip designers and equipment manufacturers.[60]

FIGURE 7 / **Global Semiconductor Market Share, 1982-2019**



Source: Semiconductor Industry Association, 2019 SIA Factbook (Washington, DC: 2019), https://www.semiconductors.org/the-2019-sia-factbook-your-top-source-for-semiconductor-industry-data/; Chart reproduced with permission.

Guardrails are necessary to ensure that federal programs have clear missions, build cooperation with the private sector, and maintain flexibility to adapt to changing market conditions. Generally, government purchasing is a more effective tool than subsidies and should support early-stage technology categories, not specific companies or technologies. Federal investments should focus on riskier projects to crowd-in private funding. Some failures will be inevitable, but they should be seen as a reflection of a program's ambition, not a defect or cause for policy reversal. Policymakers crafting such investments should have a baseline technical understanding of the U.S. competitive position in global markets.

Similarly, supporting key technology categories should not serve as a pretext to broadly restrict international trade or investment beyond narrow national security-related concerns (discussed in Chapter 2). Any U.S. innovation strategy should adhere to agreed-upon international rules, notably the WTO's Agreement on Subsidies and Countervailing Measures and the Government Procurement Agreement.[61] Policies that violate such conventions will undermine efforts to discipline unfair trading practices and will alienate allies and partners.

The Covid-19 pandemic has elevated debates about the role of government in securing supply chains and critical national functions. When assessing this question, U.S. policymakers should consider the narrow set of critical functions that require a domestic supply base, what industries can leverage supply chains across allied countries, and whether excessive concentration for certain products or inputs exists and creates vulnerabilities. Washington has rightly increased direct support for production of critical medical equipment and vaccines. However, other proposals risk doing more harm than good, such as expansive "Buy American" rules that require federal agencies to purchase medical supplies and other mature technologies made in the United States.[62] Such preferential policies could reinforce reliance on limited sources of supply, which will increase vulnerability to "black swan" events such as natural disasters or pandemics. In addition, while they may marginally reduce foreign dependence, they could also raise product costs and violate international agreements. Efforts to stockpile emergency equipment, create emergency production plans with allies and partners, and learn from public health response successes and failures will better position the United States to lead global responses to future pandemics.

Setting Global Standards

Standards are an essential, if often underappreciated, aspect of technology innovation. Standards codify design and safety elements for products, procedures, and personnel. Standards underpin technological development and facilitate commercialization of a wide range of activities, such as interoperability of telecommunications equipment. To ensure smooth global trade, standards are often set by international organizations with membership from companies or national governments. Standards organizations help determine whose technology is used—leading to highly profitable licensing fees and significant competitive advantage for winning companies—and how it is used. Once standards are established, they are difficult to uproot, which locks in advantages for companies whose preferences are adopted. Many U.S. semiconductor giants established their dominant positions in part by ensuring their chip standards were adopted.

The U.S. approach to standards has typically been fron the bottom up, with industry taking the lead in setting standards based on technical knowledge and market demands and government taking a largely hands-off approach. In contrast, China and the European Union have taken a more state-led approach to standard-setting, more tightly controlling standard setting through government-blessed bodies and supporting active industry participation in standards-setting groups. Recognizing the importance of standards, in 2020 Beijing's formalized its "China Standards 2035" plan to set global rules in emerging technologies, including those listed in the "Made in China 2025" industrial strategy.[63]

The current approach worked well in an era when U.S. companies dominated critical technologies, but market realities have changed and competitors have taken more strategic approaches. The U.S. government needs to develop and implement proactive strategies to push back on this state-led approach and support U.S.-developed standards and the private-sector-led standards system.

China has been a particular challenge in this space. Chinese companies' expanded market share in emerging technologies, supported by conscious government policy, has brought Beijing increased representation in standard-setting bodies. According to a U.S.-China Business Council report, from 2011 to 2020, China's secretariat positions in the technical committees or subcommittees increased by 73 percent in the International Standardization Organization. The number of Chinese companies participating as voting members in the Third Generation Partnership Project, a fifth-generation (5G) telecommunications standards-setting group, doubled in recent years to 110 in January 2020, more than double the 54 U.S. voting members.[64] Chinese companies are very active in certain standards bodies, and in December 2019, the *Financial Times* reported that only Chinese companies (and none from any other countries) had submitted proposals for surveillance technology standards to the International Telecommunications Union since 2016.[65]

Experts debate whether China's increased participation in standards-setting processes threatens U.S. interests. A U.S.-China Economic and Security Review Commission report warned that Beijing "is actively attempting to influence international technical standards for the IoT [Internet of Things] that would benefit Chinese companies at the expense of U.S. and other foreign counterparts."[66] Chinese companies have been criticized for "flooding the zone" with proposals to create confusion and exhaustion in technical working groups. Chinese companies are reportedly trying to influence standards-setting bodies to adopt protocols friendly to state control of technology, raising security as well as economic concerns.[67] However, others maintain that standards-setting decisions are ultimately technical in nature and benefit from constructive Chinese cooperation.[68] Further, discouraging Chinese participation in standards-setting groups could limit the number of international standards adopted in China, leading to a more fragmented world. The United States should not oppose China's productive participation in international standards-setting processes. Instead, Washington should urge and support renewed active participation in the technical process by domestic companies and experts.

03

Protecting Critical Technologies

While investing in innovation, policymakers should seek to ensure that sensitive technology developed by that investment does not flow to adversaries. The United States has long maintained a relatively open trade, investment, and research environment. Successive U.S. administrations since World War II have sought to liberalize economic relations with other countries under the assumption that lower barriers would support U.S. workers, businesses, and scientific leadership. To mitigate leakage of critical technology, Washington adopted an array of tailored controls on the flow of products or information directly related to national security, including[69]:

- The Committee on Foreign Investment in the United States (CFIUS), to screen foreign investment in and acquisitions of U.S. companies;
- Export controls, to regulate transactions with foreign buyers, including "deemed" exports of knowledge;
- Visa policies, to regulate who can enter the country;
- Economic sanctions, to regulate U.S. private sector interactions with foreign entities; and
- Counterespionage, to thwart cybertheft and other illegal transfer of intellectual property (IP) and trade secrets.

At the multilateral level, there are several formal mechanisms to coordinate export controls: the Australia Group, which controls items useful for chemical or biological warfare; the Missile Technology Control Regime; the Nuclear Suppliers Group; and the Wassenaar Arrangement, which controls dual-use goods and technology.

These Cold War-era mechanisms worked well when the world was divided into two separate political blocs. The rise of China and other economic competitors has highlighted limitations of the U.S. control system. An influential 2017 report from the Department of Defense's Defense Innovation Unit Experimental (DIUx) warned that China was "executing a multi-decade plan to transfer [critical] technology" through legal and illegal means. The report demonstrated that Beijing exploited gaps in U.S. regulations to transfer knowledge through acquisitions of majority or partial stakes in U.S. companies, venture capital investment, purchases of non-controlled items, and talent recruitment programs.[70] Further, the report detailed that China engaged in rampant IP theft and commercial espionage by cyber and traditional means.

While the DIUx report and other strategic planning documents identified gaps in the U.S. technology control system, globalized commerce and supply chains have made it complicated to simply limit economic interactions with competitors. China is simultaneously a competitor in key technologies, a supplier of product inputs, and a vital market for U.S. companies, which rely on revenue earned in China to fund their R&D spending. Striking the correct balance between control and openness is best understood as a trade-off within national security, not just between national security and economics. Decisions to limit openness could limit sensitive technology leakage in the short term, but overcontrol will hurt domestic industry by limiting sales and encouraging adversaries to develop their own competitors.

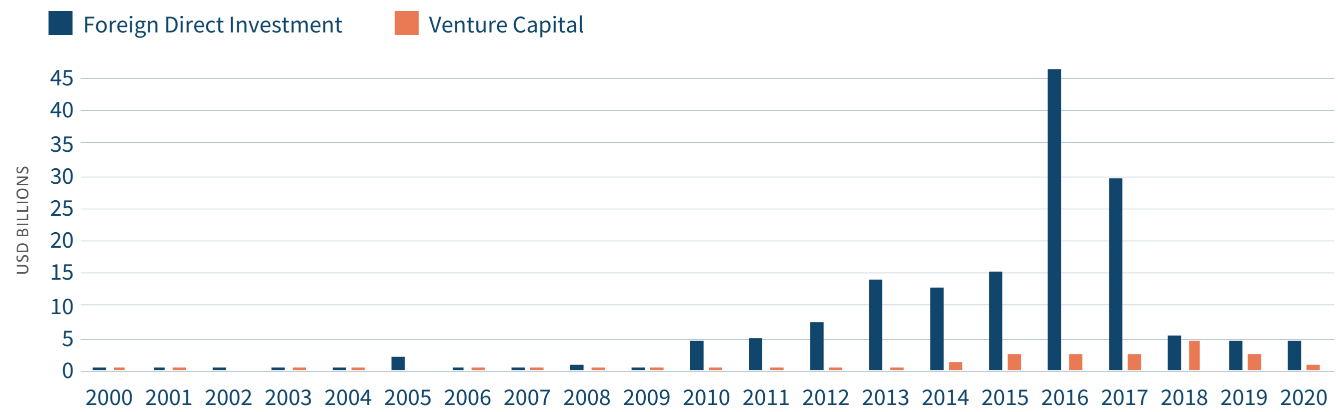
A March 2020 study from the Boston Consulting Group and the Semiconductor Industry Association illustrates the difficulty of severing ties with China in the semiconductor sector. The paper estimated that Beijing's "Made in China 2025" industrial plan to support domestic champions could reduce U.S. chip companies' global market share by 2 to 5 percentage points.[71] However, the report warned that broad U.S. restrictions on technology exports to China could cause far more immediate damage. Partial *unilateral* restrictions on sales to Chinese customers could cost U.S. companies 8 percentage points of global market share, and total restrictions on sales to China could cost them 16 percentage points, as Beijing turned to other suppliers and retaliated against American firms. As a result, the report concludes that a poorly executed control strategy could cede global semiconductor leadership to South Korea in the medium term and China in the long term.

Strengthening Existing Control Systems

During the Trump administration, Washington has strengthened existing technology control mechanisms. The Foreign Investment Risk Review Modernization Act of 2018 (FIRRMA), signed by President Trump in August 2018, expands the jurisdiction of CFIUS screening to "non-passive, non-controlling" investments in "critical technology" companies, including certain types of venture capital investment.[72] Since 2016, Chinese foreign direct investment in the United States has collapsed, primarily as a result of Beijing's stricter capital controls but also due to a tougher U.S. regulatory environment for advanced technology activity.[73] One study found that the CFIUS clearance rate of transactions related to China from 2017 to February 2020 is roughly 60 percent, down from more than 95 percent during the Obama administration.[74] Most of the rejected deals were in the technology sector, while non-technology transactions cleared at Obama-era levels.

In parallel with FIRRMA, Congress passed the Export Control Reform Act (ECRA) to expand export restric-

FIGURE 8 / **Chinese Investment Flows to the United States**



Source: "China Investment Monitor," Rhodium Group, https://rhg.com/impact/china-investment-monitor/.

tions to "emerging" and "foundational" technologies essential to U.S. national security. ECRA established guiding principles for the use of export controls, including taking action "only after full consideration of the impact on the economy of the United States" and tailoring national security controls on "core technologies and other items that are capable of being used to pose a serious national security threat to the United States."[75] ECRA also instructs the United States to coordinate export controls with multilateral export control regimes and recognizes that "export controls applied unilaterally to items widely available from foreign sources generally are less effective in preventing end-users from acquiring those items."[76]

ECRA requires the Department of Commerce, through the Bureau of Industry and Security (BIS), to identify products in each category through an interagency process in consultation with the private sector. While BIS published a broad list of 14 emerging technology categories subject to control, including biotechnology and artificial intelligence, final rules published thus far have been limited to narrow applications.[77] BIS has also released a request for comments on proposed rulemaking regarding controls on foundational technologies.[78] In addition to developing emerging and foundational technology control lists, BIS announced a slew of rules to reform existing export control regimes in spring 2020 to restrict advanced semiconductor sales to Huawei and its affiliates.[79] These expansions, applied broadly, could significantly disrupt U.S. innovation leadership. Commerce should work closely with industry and the academic research community to assess the implications of these expansions, clarify how they will be applied, and ensure they best address the specific national security risks of concern without unduly undermining U.S. competitiveness and innovation leadership.

At the agency level, the United States formalized efforts to combat cyber theft and review foreign research collaboration. In 2018, the Department of Justice (DOJ) launched its China Initiative, an agency-wide effort to prosecute cases of economic espionage, trade secret theft, hacking, and other economic crimes originating from China.[80] As of February 2020, the China Initiative had led to around 40 arrests.[81] However, cybertheft remains a significant problem, and it remains unclear how effective DOJ efforts have been to curtail it.

Science funding agencies have taken steps to increase scrutiny of foreign research linkages and conflicts of interest while reaffirming the benefits of open collaboration on basic research. Their efforts have generally focused on four areas: (1) improving enforcement of existing disclosure requirements; (2) preserving the confidentiality of the peer review process; (3) enforcing IP protection; and (4) putting restrictions on U.S. government researchers affiliated with foreign recruitment programs.[82] Although initial procedural changes were uncoordinated, the White House Office of Science and Technology Policy (OSTP) announced a Joint Committee on Research Environments in May 2019 to bring a "whole of government" approach to ensuring research integrity.[83] The National Institutes of Health has been especially vigilant: since 2018, the agency has dismissed 54 scientists as a result of violating disclosure rules, often by not reporting foreign research funding. In 93 percent of cases of concern, the hidden funding came from a Chinese institution.[84]

As with investment restrictions and export controls, closer scrutiny of foreign researchers involves tradeoffs. Universities and other institutions have often been too lax in enforcing funding disclosure guidelines, IP protections, and ethics rules due to an underappreciation of the risks posed by Chinese technology acquisition grand strategy. Still, overcorrecting could further jeopardize the U.S. research enterprise, which relies heavily on international collaboration. In 2018, 39 percent of U.S. science and engineering articles were developed with foreign scholars, up from 19 percent in 2000. U.S. scientists often work with Chinese researchers, and 26 percent of U.S. internationally coauthored articles in 2018 had a Chinese coauthor, the largest share of any country.[85] In 1985, the Reagan administration affirmed the value of open cooperation on fundamental research with National Security Decision Direction 189 (NSDD-189), which all future administrations subsequently endorsed.[86]

A New Approach to Managing Technology Transfer

For decades, the United States had allowed sales of critical, dual-use technologies to competitors, provided the products were at least a generation outdated. This approach allowed U.S. companies to maintain global market share while preserving their technological leadership. Purchasing countries begrudgingly tolerated the arrangement because of the high costs of localizing high-value production. Unlike previous challengers, Beijing has the intent and resources to indigenously innovate and develop advanced technologies, demanding a rethink of previous technology control strategy.

As a guiding principle, policymakers should reaffirm the benefits of open investment, trade, and research while tailoring control mechanisms to address specific vulnerabilities, using multilateral action where possible, as stipulated in ECRA. New restrictions on technology transfer—either for investment, export controls, or foreign research collaboration—should reflect three basic criteria. First, they must establish that the technology is essential to national security. Second, they must be effective. This means the United States should not act unilaterally without considering the presence of alternative foreign suppliers of a technology. A multilateral approach leverages relationships to increase efficacy, reduce enforcement costs, and prevent technology leakage to countries of concern. Finally, they should consult with industry and consider the costs of specific controls on U.S. economic and innovation leadership before taking action. Policymakers should ensure transparent due process procedures to incorporate stakeholder perspectives, such as through public comment periods, and continuously evaluate in consultation with industry whether existing controls are too broad or too narrow.

An effective approach would limit the sale of technologies essential to national security to certain end-users without cutting off broader economic linkages. Thus far, U.S. reforms have commendably balanced concerns of too much openness and overcontrol. Policymakers should continue working with experts to ensure effective implementation of FIRRMA and ECRA. BIS has reconstituted its technical advisory committee to assist with identifying emerging and foundational technologies, and OSTP has opened channels of communication with academia to craft new guidelines on foreign research collaboration while affirming NSDD-189.

In parallel to domestic reforms, policymakers should strengthen multilateral channels for coordination of technology control policies. Without cooperation with allies, the United States will not achieve its national security objectives and will risk undermining the competitiveness of U.S. companies, to the benefit of foreign companies, including Chinese firms. Washington has tried to convince allies to adopt stricter technology control policies, with some success.[87] Several key partners, including Germany and Japan, have expanded the jurisdiction of their foreign investment screening mechanisms, following the U.S. example.[88] Major education exporters, especially Australia, have increased scrutiny of foreign research collaborations.[89] Multilateral mechanisms have made some progress on defining export controls for emerging technologies, but consensus has been limited to niche applications, and the United States has taken unilateral action on more prevalent technologies.[90]

Going forward, Washington should work with its allies to develop a coordinated control system across the relevant policy mechanisms. In doing so, the United States should accept some flexibility from allies and partners in their policy design. Unfortunately, the frequent use or threat of U.S. sanctions has antagonized our allies, leading them to develop ways to get around these sanctions and limiting avenues for cooperation.

As a general rule, policymakers should use mechanisms that control technology transfer to support national security objectives. Keeping the scope of such tools narrow will facilitate multilateral cooperation and minimize disruptive impacts to the domestic economy and U.S. commercial sector. In certain cases, however, it may be appropriate to use export controls alongside sanctions to achieve foreign policy goals, as authorized under the Export Administration Act.[91] Foreign policy-based export controls should continue to be subject to annual review to ensure they are used judiciously.

04

Championing Data Governance

Sharpening the U.S. innovative edge requires engagement in global digital rulemaking to set a foundation for sustained leadership. It is not enough to invest at home and protect sensitive technologies. If America does not step up in discussions on the rules, standards, and norms that govern data privacy and digital trade, others will. This could create a balkanized world with competing governance regimes that disadvantage U.S. companies and the U.S. economy in a vital growth industry.

Why Data Governance Matters

Data has been called the "oil of the digital era" for its role as a driver of future economic growth and industry transformation.[92] The McKinsey Global Institute estimates that the value of cross-border data flows surpassed the impact of global goods trade in 2014, adding $2.8 trillion to global GDP.[93] The rollout of 5G telecommunications networks will accelerate the number of devices connected to the internet, which could generate $4—11 trillion in annual economic gains.[94] Cisco estimates that the number of devices connected to the internet will be triple that of the global population by 2023, half of which will be machine-to-machine linkages that could transform existing business models.[95] The Covid-19 pandemic has further accelerated digitalization across all sectors as companies shift to cloud-based storage and remote work where possible. Large data sets are also essential for training machine learning algorithms that will be vital to leadership in artificial intelligence applications.

As with other types of economic interactions, rules are necessary to protect against abuse of individual rights and ensure open commerce. Contact-tracing applications have taken center stage in the fight against Covid-19, and high-profile privacy violations and allegations of aggressive collection of personal data underscore the importance of regulations and strict enforcement to protect users.[96] In addition to privacy concerns, countries are increasingly limiting free flows of data and enacting localization requirements which require foreign companies to store data domestically, often justified on dubious cybersecurity grounds. Various studies have estimated that barriers to data flow and localization requirements reduce GDP and productivity.[97]

Competing Governance Regimes

Despite the importance of applications reliant on large data sets for future economic growth, there have been no successful international efforts to set rules directing its collection, processing, storage, and use. In the absence of global governance, countries have built their own regimes, which create overlapping, conflicting systems. Broadly, there are three main approaches: bureaucratic regulation and enforcement of privacy and competition law, championed by the European Union; state access to and control of data, supported by China; and relatively free-market systems, found at the U.S. federal level.

The European Union has pioneered a regulatory regime that seeks to enhance personal privacy rights and limit the market power of large firms. The landmark General Data Protection Regulation (GDPR), which came into effect in May 2018, establishes the principle that ownership of personal data remains with an individual, not with collectors or processors.[98] From this principle, GDPR requires companies to obtain user consent with "clear and plain language" before collecting or processing personal data and introduces a right for individuals to have data erased. Notably, GDPR imposes obligations on all companies that collect data related to people living in the European Union, even those headquartered outside the bloc.[99] GDPR authorizes cross-border data transfers for third countries with equivalent protections, and the European Commission conducts periodic adequacy assessments of other regimes to ensure EU rules are respected.[100] Alongside GDPR, European authorities have taken aggressive steps to penalize large (often American) tech giants. Since 2016, the European Commission has fined Google €8.2 billion ($8.9 billion) for violating anti-trust regulations.[101] Major European countries, including France and the United Kingdom, are threatening to impose digital services taxes on revenues deemed to have been generated domestically by all digital companies, irrespective of where they are based.[102]

China has long used a wide-ranging censorship regime, dubbed "the Great Firewall," to closely regulate internet content and access. Recently, Beijing has increased efforts to assert state control over the flow of online information while establishing some modest limits on the sale of personal data. The 2017 Cybersecurity Law establishes greater data localization requirements for "critical information infrastructure operators" but also bans online services providers from selling personal data without consent. However, the 2017 National Intelligence Law stipulates "any organization or citizen shall support, assist, and cooperate with state intelligence work according to law," enabling the state to access personal data at its discretion.[103] Both laws only vaguely define key concepts, giving regulators room to expand the scope of their authority. To complement legislative efforts, Beijing has instituted standards that force foreign companies to build China versions of their products and grant government regulators access to source code, raising concerns of foreign technology transfer and IP infringement.[104]

In contrast to other leading economies, Washington has taken a largely hands-off approach toward data governance and privacy protection. While Congress increasingly recognizes the importance of a national regulatory regime, it has failed to pass legislation. Absent federal action, state legislatures have taken steps to improve privacy, led by the California Consumer Privacy Act (CCPA), effective January 2020. As the first broad, horizontal privacy regulation in the United States, CCPA is narrower than GDPR but increases transparency and gives California residents the option to opt out of the sale of personal data to third parties (however, unlike GDPR, they cannot opt out of the collection of personal data).[105] Others states, from Nevada to New York, are independently considering a range of privacy regulations, underscoring the need for a national framework.

Risks of Data Balkanization

The patchwork of national and subnational laws governing the use, storage, and flow of data risks creating a balkanized, negative-sum outcome. Without federal regulation in the United States and alignment between national regimes, companies will have to comply with different, potentially contradictory legal guidelines to serve their customers. Restrictions on the free flow of data could limit the transfer of information, which will create challenges to financial stability and monitoring.[106] The lack of interoperability can impair sharing of electronic medical records, which are important to managing public health crises. Various localization requirements will force firms to build redundant storage facilities, raising costs and increasing physical access points for bad actors.

Many governments have recognized the undesirable outcome of data balkanization, yet progress on a common set of rules is anemic at best. The members of the WTO plurilateral working group on e-commerce account for over 90 percent of global trade but have not made notable progress since talks began in earnest in early 2019.[107] Given the diverse nature of the group, which includes China, the European Union, and the United States, as well as the broader issues facing the WTO, agreement on contentious issues is unlikely. Japan won endorsement of its "data free flow with trust" (DFFT) framework in the 2019 Group of Twenty (G20) communiqué, but alignment on any specific proposals is doubtful.[108]

Since the Osaka Summit, the United States and China have championed competing visions for data governance. The U.S. Clean Network initiative, announced in August 2020, seeks to protect personal privacy and sensitive corporate information from "aggressive intrusions by malign actors."[109] The Clean Network has the support of more than 30 countries and territories, but that does not include binding commitments. In response, Beijing unveiled its "Initiative on Global Data Security," which calls on countries to maintain open telecommunications supply chains while respecting state sovereignty over data flows.[110] Although China has urged other countries to join its program, support thus far has been limited.

Countries have made more progress toward regulatory alignment at the bilateral and regional level. The U.S.-Mexico-Canada Agreement (USMCA) restricts data localization requirements and endorses APEC's Cross-Border Privacy Rules as "a valid mechanism" to enable data flows while protecting privacy.[111] The "phase one" trade deal between the United States and Japan includes a side agreement that bans customs duties on digital products, facilitates cross-border data flows, and bans localization.[112] More significantly, in January 2019 the European Commission recognized "mutual adequacy" between GDPR and Japan's data protection, enabling the free flow of data between the two envisaged under their 2018 trade agreement.[113] Discussions on adequacy have helped promote harmonization based on mutual acceptance of first principles.

The United States and like-minded countries should build on recent momentum to promote a common approach to data governance. While there are important distinctions between the U.S. and EU views on data privacy, they are minor compared with the different philosophy underpinning the Chinese regime. Indeed, some elements of GDPR, such as mandatory breach notifications and child data protections, were inspired by U.S. law. Alignment between advanced economies can help support a "fifth pillar" of global economic governance for data issues, akin to the International Monetary Fund for global payments, the World Bank for development, the WTO for trade, and the arrangements governing energy set up in the 1970s.[114]

05

Recommendations

Continuing to lead at the technological frontier will require a sustained and coordinated effort at the national and international level. The Commission on Affirming American Leadership recommends the following seven elements of a national technology strategy, organized in three lines of effort: investing in innovation; protecting critical technologies; and championing data governance. If adopted, these recommendations would sharpen the U.S. innovative edge and position the country for long-term leadership.

Invest in Innovation

The United States is still the global leader in many cutting-edge technologies, but its position is perilous and competitors are rapidly catching up. Failure to strengthen key components of the U.S. innovation system will accelerate the United States' relative decline. As the United States emerges from the Covid-19 pandemic, policymakers should seize the moment to reaffirm U.S. leadership in innovation. Doing so will support rising living standards for Americans and position the country to address societal challenges, from the threat of economic adversaries, to climate change, to public health crises.

1. Recommit to the innovation base

During the Cold War, the United States built a national innovation system on collaboration between government, academia, and the private sector. Thanks to that foundation, the United States remains a leader in cutting-edge technology today. However, federal support for R&D has waned in recent decades, and policymakers have grown complacent about supporting a highly skilled workforce. Reaffirming U.S. leadership begins with reinvesting in the innovation base: increasing federal funding for R&D, strengthening and diversifying a world-class talent pipeline, encouraging business investment, and building digital infrastructure.

IMPLEMENTATION STEPS

a. Restore federal R&D funding to a minimum of 1 percent of GDP (its post-War World II average) over the next 5 to 10 years. This would involve increasing spending by roughly $100 billion per year, or about 80 percent of current expenditures ($127 billion in 2018).[115] Part of the increase should support projects and research that address climate, defense, and health challenges. Funding should go toward applied and basic research, as well as targeted support for early-stage development of critical technologies (discussed further in the next section).

   i. Support longer-term, predictable budgets for science agencies by extending funding cycles and placing an initial moratorium on budget cuts for five years. Limiting budgetary uncertainty would nudge federal R&D spending toward more ambitious research, rather than more "doable" projects undertaken to secure funding.

   ii. Empower younger scientists and tolerate failures. Directing more investment toward younger researchers will help recruit new talent and invest in human capital with a longer timeline of return.[116] Project managers should be encouraged to support riskier projects and continue to tolerate failure, which is inevitable with ambitious research. Individual, high-profile failures, such as the Solyndra project, should help managers refine their approach, not derail federal investment.[117]

   iii. Deepen public-private partnerships for pre-competitive technologies, especially with small and medium-sized enterprises (SMEs). Increase funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, which connect SMEs with federal resources, and expand the number of Manufacturing USA technology institutes, including to focus on climate adaptation and mitigation applications.[118]

b. Improve STEM education outcomes and workforce inclusiveness.

   i. Allocate funding for states and municipalities to upgrade STEM learning equipment at primary and secondary schools.

   ii. Increase funding for federal STEM development programs such as the National Defense Education Program and the Department of Education's Minority Science and Engineering Improvement Program.

   iii. Expand federal scholarship and debt forgiveness opportunities for women and underrepresented minorities pursuing STEM degrees.

   iv. Deepen mentoring and traineeship programs between federal research-funding agencies/national laboratories and historically black colleges and universities and high Hispanic enrollment institutions.[119]

c. Expand opportunities for highly skilled individuals to work and remain in the United States.[120]

i. Elminiate the cap on annual H-1B visas and regularly review the covered skills to ensure they keep up with rapidly developing technology.

ii. Eliminate the country cap and duration limit for H-1B visas.

iii. Extend the Optional Practical Training (OPT) period from one year to five years.

iv. Provide green cards to immigrants that receive advanced STEM degrees in the United States.

v. Create an abbreviated filing process for existing H-1B visa recipients seeking to change jobs between two U.S. employers.

d. Increase federal tax incentives for private sector R&D to the OECD median of 0.11 percent of GDP, up from 0.07 percent of GDP.

i. Reverse scheduled tax changes that would require companies to amortize domestic research expenditures over five years, rather than immediately deducting expenses.

ii. Invest in national digital infrastructure, especially by improving broadband access in rural and other underserved communities, to close connectivity gaps.

iii. Enable open access of public sector data, where possible. Open data will encourage firms to collaborate with peers rather than withhold data from them.[121] As data is more accessible, government must work to improve public trust around the issues of data privacy and ethics so that the data marketplace can thrive.

2. Support key technology categories

Broad investments in the innovation base are a necessary but not sufficient element of a national strategy. Targeted federal action can mobilize resources and catalyze efforts to develop and manufacture breakthrough technologies. Today's global technology race involves competitors that target favored industries and companies, providing massive support through a variety of mechanisms ranging from trade policy, to subsidies, to outright theft. All of the world's leading economies, including the United States, channel resources toward specific sectors. As U.S. competitors double down on government intervention, the United States should consider expanding targeted support or risk being at a disadvantage.

Within this environment, guardrails are necessary to ensure that federal programs have clear missions, build cooperation with industry, and maintain flexibility to adapt to changing market conditions. Government intervention should support critical sectors and broad technology categories (such as AI), not pick specific companies, technologies, or narrow applications (such as a certain machine learning algorithm). Government purchasing is generally a more effective tool than subsidies and should promote early-stage technology categories, not established industries. Policies should have clear sunset provisions and exit strategies to maintain urgency and mitigate long-term dependency. Any support should adhere to international law or plurilateral commitments. Finally, policies should be crafted with the input of industry and informed by technical expertise.

IMPLEMENTATION STEPS

a. Reconstitute the Congressional Office of Technology Assessment (OTA).[122] A revived OTA would provide robust and actionable briefings for legislators and their staff and would assess how emerging technologies impact U.S. competitiveness and national security, including which countries are leading. Such assessments would inform the development, implementation, and monitoring of a national innovation strategy.

b. Leverage government purchasing power to create markets for and stimulate investment in the development and production of early-stage technologies.

i. Potential examples include using AI to manage government tax records and detect fraud, enhancing power grids and transport networks with internet of things (IoT) applications, and incorporating electric- and battery-powered vehicles into national, state, and local government fleets.

c. Establish networks of universities for exploratory research and design of advanced technologies modeled on the Semiconductor Technology Advanced Research Network (STARnet).[123] Such networks could also help companies' prototype and beta-test new inventions and processes.

d. Expand nimble government funding programs for applied research and experimental development by expanding the DOD Defense Innovation Unit's National Security Investment Capital program and adopting pilot programs at the National Academy of Sciences and the Department of Energy.[124]

e. Accelerate regulatory processes and domestic standards-setting processes to facilitate commercialization of critical technologies earlier in innovation life cycles.[125] Such efforts should facilitate regulatory test beds to allow real-world prototyping of emerging technologies while minimizing safety risks.[126]

i. Improve technical capacity at national and state regulatory agencies by detailing experts from federal science agencies and national laboratories.

f. Direct the U.S. Export-Import Bank to consider U.S.-based intellectual property and R&D expenditures as qualifying content for financing to better account for value in the technology sector.[127]

g. Work with allies where possible, recognizing that there will be limits to this cooperation based on private-sector competition.

ii. Explore opportunities to share and pool large, non-sensitive data sets (e.g., weather data, epidemiological data, traffic data) between like-minded countries to improve machine learning algorithms.[128]

iii. Support and expand ongoing basic scientific collaboration, such as the EU-Japan-U.S. International Symposium on Quantum Technology, which encourages research partnerships and personnel exchanges.[129]

iv. Establish information-sharing mechanisms between like-minded governments to better understand the global emerging technology landscape.

3. Set global standards

The U.S. approach to international standards setting has typically been from the bottom up, allowing industry to take the lead in setting standards based on technical knowledge and market demands. In contrast, China and the European Union have taken a more state-led approach to standard-setting, prioritizing active participation in standards-setting bodies. To compete in today's standards environment, Washington needs to develop and implement proactive strategies to push back on this state-led approach in which it takes a stronger role in supporting U.S.-developed standards and domestic companies and experts' renewed active participation in the technical process.

IMPLEMENTATION STEPS

a. Uphold due process and consensus-based standards-setting processes.

i. Encourage reforms that limit the number of proposals submitted per company or country to address concerns of some participants "flooding the zone."

ii. Promote wider geographical participation in standards-setting bodies to include more voices that align with U.S. approaches.

b. Ensure future export controls and other restrictions on technology transfer do not limit U.S. participation in standards-setting processes. The Department of Commerce's June 2020 rule allowing U.S. companies to actively participate in standard-setting groups where Huawei is present should set a precedent for future engagement with companies on the entity list or that face sanctions.[130]

c. Ensure that U.S. trading partners meet their commitments under the WTO Agreement on Technical Barriers to Trade by recognizing international standards developed by the private sector, in addition to those developed by official-sector standard-setting bodies.

d. Adopt a more strategic approach to working within international standard-setting groups to promote outcomes that are acceptable to U.S. companies.

  i. Distinguish areas where the private sector can continue to lead from those where more government involvement is necessary to support key industries.

  ii. In cases where government involvement is necessary or viewed by private sector voices as additive, coordinate with allies to form coalitions in order to reinforce the desirability of standards that uphold shared values.

  iii. Constructively participate in higher-level standards-related discussions in the G20, the Asia-Pacific Economic Cooperation (APEC) forum, and the WTO.

e. Provide steady funding over complete standards-setting cycles to enable U.S. government representatives to participate fully in standards-setting discussions, and create competitive grants, where applicable, to facilitate academic and private sector expert participation.

Protect Critical Technologies

Openness to trade, investment, and research supports U.S. technological leadership and economic prosperity; yet some restrictions on the transfer of technologies that are essential to national security are necessary. Striking the correct balance between control and openness is best understood as a trade-off *within* national security, not just between national security and economics. Decisions to limit openness could limit technology leakage in the short term, but overcontrol will hurt U.S. industry and ultimately impair national security by limiting sales, market share, and future domestic R&D investment. Further, the global nature of trade, investment, and research means that the United States risks isolating itself and falling behind if it acts unilaterally. Poorly designed and overbroad unilateral controls will not achieve their underlying national security objectives and could compromise U.S. competitiveness and innovation leadership.

4. Promote whole-of-government technology control policy

As a guiding principle, policymakers should reaffirm the benefits of open investment, trade, and research while tailoring control mechanisms to address specific vulnerabilities and taking multilateral action where possible. Restrictions on technology transfer should reflect three basic criteria: First, they should only apply to technologies that are essential to national security. Second, they must be effective. This means the United States should not act unilaterally when there are alternate foreign suppliers of a technology. A multilateral approach leverages relationships to increase efficacy, reduce enforcement costs, and prevent technology leakage to countries of concern. Finally, the government should consult with industry and consider the costs to U.S. economic and innovation leadership. Some level of efficiency loss due to controls may be necessary, but policymakers should assess the impact on future U.S. competitiveness before taking action. Policymakers should ensure transparent due process procedures to engage stakeholders and should continuously evaluate the effectiveness of existing controls.

Recent reforms to U.S. technology control mechanisms through FIRRMA and ECRA legislation have sought to strike the appropriate balance to address specific national security concerns while preserving open foreign investment and research collaboration. As policymakers implement these reforms, they should continue to keep controls tailored to specific national security concerns and improve coordination between agencies in charge of technology transfer instruments.

IMPLEMENTATION STEPS

a. Maintain a standing White House-led interagency working group at the deputy level to set technology control strategy with participation from agencies tasked with implementing five main policy areas: investment screening; export controls; research collaboration; supply chain integrity; and cybersecurity.

  i. Such a group would meet quarterly to align on top-level objectives, standardize guidance, and share information on the effectiveness of current controls and outstanding vulnerabilities.

  - These meetings would expand on the agenda of existing interagency investment screening and export control working groups to encompass all mechanisms for managing critical technology transfer.

b. Define a common set of critical technologies vital to national security for use across agencies overseeing control mechanisms based on the definition and process specified in the FIRRMA legislation. A common list would help focus federal efforts and discourage self-defeating blanket restrictions.

  i. The list of critical technologies should be regularly updated, both to add new items and remove outdated ones.

  ii. Classification should reflect robust input from industry and academia, including by drawing on the Department of Commerce's Emerging Technology and Research Technical Advisory Committee.[131]

c. Identify critical technology hardware "choke-points," where control is both possible and effective in protecting essential national security interests, meaning there are a limited number of producers located domestically or in allied countries and there are high switching costs (such as extreme ultraviolet lithography machines used to manufacture semiconductors).

  i. Agencies could partner with the private sector to better understand supply chains of critical technologies and choke points that could be controlled through restrictions on limited, indispensable suppliers, in coordination with key allies.

d. Reaffirm NSDD-189, which limits restrictions on exchange of fundamental research to the maximum extent possible.

e. With respect to inbound investment, conduct risk mitigation exercises based on likely implications for access to critical technologies.

f. Ensure adequate due process and procedural protections through advanced notices of proposed rulemaking, sufficient public comment periods, and transparent implementing regulations. Final rules should be clear and precise to minimize uncertainty for U.S. businesses.

5. Work with allies on multilateral technology controls

The United States is the preeminent, but no longer dominant, actor in the global economy. In this environment, the unilateral use of economic tools risks isolating the United States without achieving specific national security goals. Unilateral decisions are both less effective (there are other producers) and more costly (the United States could divert benign or low-risk foreign capital, knowledge, and technology to other markets) than in previous decades. Multilateral cooperation is necessary both to maximize policy effectiveness and minimize negative spillover risks. Working with allies can be cumbersome and time consuming, but it is necessary to implement effective policy.

U.S. allies and partners share similar concerns with Washington about national security risks stemming from technology transfer, especially from China, but are earlier in their reform cycles. Washington and allied capitals have recently launched several formal channels for discussing policies related to China, and several U.S. partners have strengthened investment screening regimes and guidance for foreign research collaboration.[132] Policymakers should continue to invest in new and existing structures to deepen alignment between technology control systems.

IMPLEMENTATION STEPS

a. Establish an Allied Technology Control (ATC) group with like-minded countries to develop mechanisms for sharing information to better coordinate and manage technology transfer. The body would have a secretariat composed of senior officials and working groups for each control instrument (investment screening, export controls, research collaboration) with technical-level staff.

i. The secretariat would meet annually to align on goals, strategy, and understanding of technologies essential to national security. The working groups would meet at least biannually to discuss updates to member regimes, similar to the cadence of Group of Seven (G7) ministerial meetings.

ii. The investment screening working group would develop a multilateral investment review body, similar to the EU system, that would:

- Facilitate sharing of business confidential information between different governments for foreign inbound investments;
- Issue opinions to ATC members on the strategic implications of potential investments in and acquisitions of critical technology companies headquartered in allied countries, which would inform national approval decisions;
- Provide technical assistance to members seeking to establish and strengthen investment screening regimes; and
- Expedite transactions between companies from ATC members with adequate screening regimes, including by classifying ATC countries as "excepted foreign states" in U.S. regulations.

iii. The export control group would promote plurilateral controls by organizing "sprint groups" to identify potential technologies for control within broad critical technology categories.

- Each sprint group would convene technical experts and export control officials from ATC countries with significant market share in a specific technology category.
- Sprint groups would propose controls (and decontrols) to the relevant multilateral regime, such as the dual-use-focused Wassenaar Arrangement, and adopt plurilateral controls between sprint group countries if wider alignment is delayed.
- The export control working group would also discuss the multilateral use of export controls for foreign policy goals, such as anti-terrorism.

iv. The research collaboration group would encourage ongoing efforts by regulators and academia in ATC countries to share information on high-risk researchers and would establish common regulatory and disclosure guidelines to uphold research integrity.

b. Accelerate multilateral export control update cycles by convening plenaries for the four major existing regimes twice a year. This would better reflect the rapid pace of technological change and reduce incentives for provisional unilateral controls.

Champion Data Governance

Despite the role of data in driving future economic growth, there have been no successful international efforts to set rules directing its collection, processing, storage, and use. In the absence, countries have built their own regimes, which creates overlapping, conflicting systems, while the United States has taken a backseat. The lack of global agreement has fueled concerns of balkanized governance regimes that disadvantage U.S. companies in a vital growth industry.

In this context, the United States should take a leadership role in creating a more cohesive framework of rules, standards, and norms for the digital space as a "fifth pillar" of global governance, akin to the Bretton

Woods institutions and the 1970s energy arrangements. To do so, the United States must accelerate efforts to develop national privacy legislation. At the same time, Washington should work with like-minded countries to promote a shared approach to digital rules.

6. Adopt national data privacy regulation

If the United States does not step up in discussions on the rules, standards, and norms that govern data privacy and digital trade, others will. Beijing and Brussels have each articulated a data privacy framework, but Washington is conspicuously missing from the conversation. In the absence of national U.S. legislation, states are debating their own laws, risking a patchwork of guidance in the domestic market.

The Covid-19 pandemic and calls for contact-tracing applications underscore the importance of data privacy and should create urgency for a national framework. There has been momentum toward legislation, but proposals remain deeply partisan.[133] If lawmakers do not put aside these unproductive roadblocks, they risk diminishing U.S. capability to influence global digital governance, putting U.S. companies and the U.S. economy at a substantial competitive disadvantage.

IMPLEMENTATION STEPS

a. Create a bipartisan congressional task force mandated with drafting comprehensive personal data privacy legislation by the end of 2021, building on existing state-level legislation and bills under debate in Congress.

b. Continue to negotiate mutual adequacy with different privacy regimes, especially the European Union's GDPR, to support free flows of data.

  i. Establish formal bilateral or plurilateral mechanisms to monitor compliance with supplemental rules that bridge gaps between national privacy regimes.

  ii. Include discussions in trade negotiations on privacy and pathways to mutual adequacy agreements.

7. Align data governance principles with allies

To prevent data balkanization, Washington should seek to align data governance frameworks with allies, to the extent appropriate. As discussed in the global trade framework chapter of this report, the United States should two-track e-commerce and digital trade negotiations at the plurilateral and WTO level, building on momentum of recent agreements with Japan, Mexico, and Canada. Constructive U.S. leadership is necessary to support a "fifth pillar" of global economics governance for data issues, akin to the International Monetary Fund for global payments, the World Bank for development, the WTO for trade, and the arrangements governing energy set up in the 1970s.

IMPLEMENTATION STEPS

a. Establish a regular working group with the nine countries participating in the APEC Cross-Border Privacy Rules with the goal of aligning national data governance regimes based on APEC Cross-Border Privacy Rules and digital rules from the USMCA, U.S.-Japan digital trade agreement, and Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP).[134]

  i. The group would start with lower-hanging fruit, such as digital customs duties and processes for securely sharing data with other law enforcement or regulatory agencies, and progress to more contentious issues, such as cloud computing regulations and digital services taxation, recognizing that some differences will not be solved.[135]

    - The group should focus on regulations to promote interoperability in areas where alignment cannot be reached.

  ii. As part of negotiations, the plurilateral working group should establish mechanisms to monitor compliance and establish clear processes for enforcement.

iii. If alignment is reached, this group would bring proposals first to other U.S. allies and partners, especially the European Union, and later to the WTO.

b. Affirm and enforce preferred data governance principles through existing and future trade agreements, using the USMCA and the U.S.-Japan Digital Agreement as templates (as discussed in the global trade chapter of this report).

c. Establish a multilateral forum among like-minded countries designed to forge consensus around policy principles, specific standards, and regulatory approaches to broader digital governance. This would build on the efforts proposed in recommendations (a) and (b).

i. This forum would aspire to build an institutional structure to uphold a cohesive framework of rules, standards, and norms governing the digital space, just as existing international institutions oversee global finance, trade, development, and energy matters.

06

Conclusion

In the Cold War, the United Sates adopted a national strategy that established the country as the leader in cutting-edge technology and research and development. This approached leveraged the strengths of business, government, and academia while promoting an open trading system, supporting domestic education, and attracting foreign talent. In recent decades, policymakers have grown complacent, resting on the Cold War foundation without modernizing or maintaining it. Federal R&D funding as a percent of GDP has atrophied, breakthrough technological advances have stalled, and the United States has turned inward. Today's challenges—a global pandemic, China's emergence as a strategic and highly capable competitor, and the specter of climate change—underscore the need for an innovation strategy that adapts previously effective policy to the modern economy. Policymakers should marshal the resources necessary to meet and win the challenges of the twenty-first century and reaffirm U.S. technological leadership.

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