UNESCO

UNESCO SCIENCE REPORT

The race against time for smarter development

Chapter 5: UNITED STATES OF AMERICA

Published in 2021 by the United Nations Educational,
Scientific and Cultural Organization
7, place de Fontenoy, 75352 Paris 07 SP, France

ISBN: 978-92-3-100450-6

Suggested citation: Vorontas, N. with Hoban, B. and C. Rabb (2021) United States of America. In *UNESCO Science Report: the Race Against Time for Smarter Development*. Schneegans, S.; Straza, T. and J. Lewis (eds). UNESCO Publishing: Paris.

Design, typeset, data visualization and pre-press production:
Baseline Arts Ltd, Oxford, United Kingdom

Cover design: Eric Frogé, UNESCO

Cover photo: A medical operator hands a box of Covid-19 test samples collected from rural hospitals to a drone flight operator at Zipline's distribution centre in Omenako for delivery to the Noguchi Memorial Institute for Medical Research in Accra, in this composite image.
© Zipline International Inc.

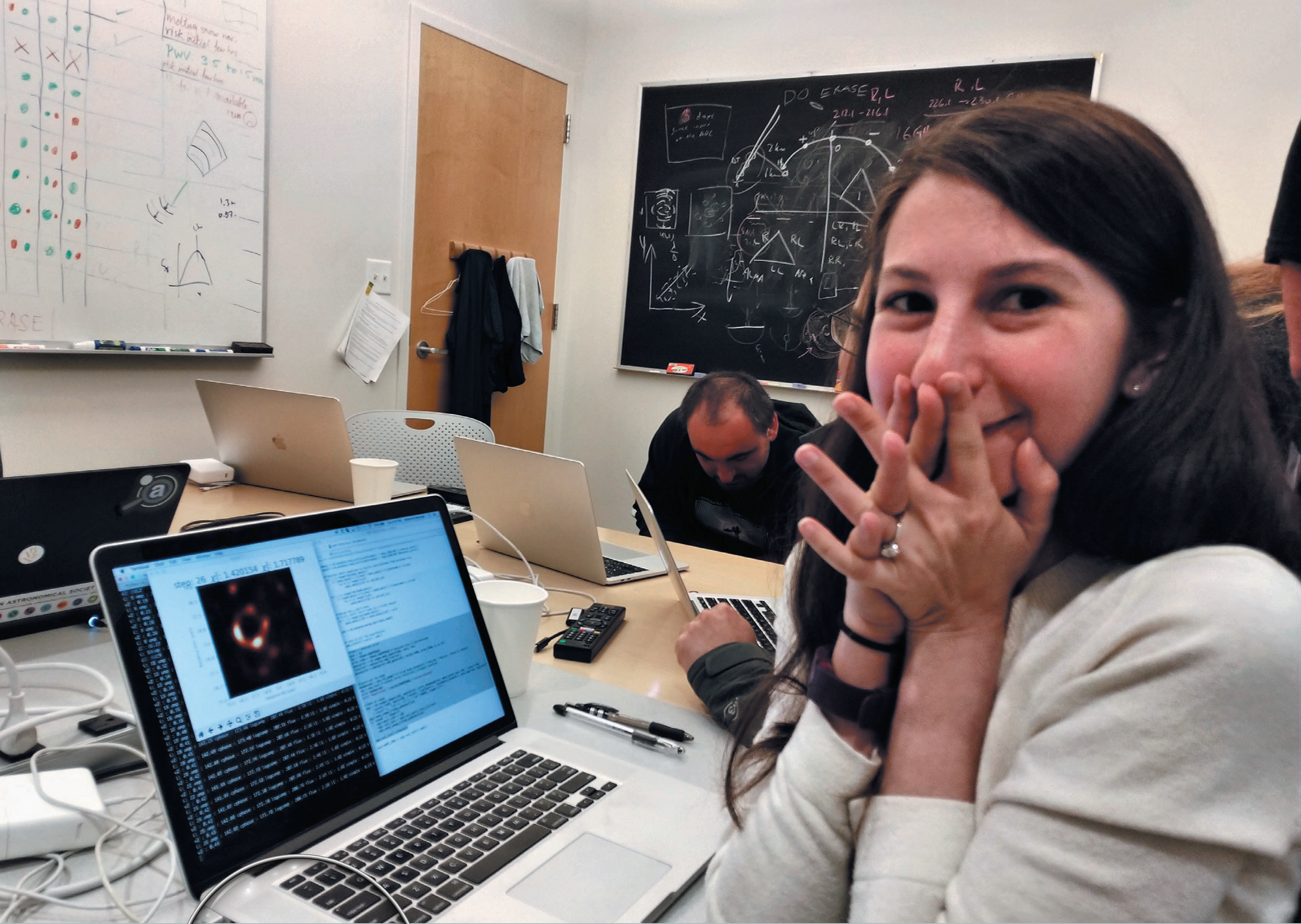
Printed in France

UNESCO SCIENCE REPORT

The race against time for smarter development

Chapter 5: UNITED STATES OF AMERICA

unesco



Dr Katie Bouman, an engineer and computer scientist from the California Institute of Technology, reacts as a composite image of a black hole forms on her computer, in a world first in April 2019. This accomplishment was the culmination of the work of a global team of more than 200 scientists.
© Andrew Chael

AT A GLANCE

- The federal research budget for 2021 proposes raising investment in cutting-edge technologies such as artificial intelligence and quantum computing.
- Burgeoning digital start-ups have become tech giants amid growing concern about market monopolization.
- There has been a surge in applicants for new company registrations in 2020, even as the amount of venture capital available to start-ups has dropped as a consequence of the Covid-19 epidemic.
- The America First policy agenda has led to new sector-specific policy goals, such as that of addressing the US trade deficit, and to a US withdrawal from the Paris Agreement and other multilateral agreements. A number of states are, nonetheless, respecting their commitments to the Paris Agreement.
- Technological advances have reduced the price of renewables and natural gas, making coal less economic. Carbon emissions have, consequently, dropped but the rollback of federal environmental protections is cause for concern.

5 · United States of America

Nicolas Vorontas, with Brennan Hoban and Connor Rabb

INTRODUCTION

A crisis 'like no other'

The USA[1] enjoyed economic growth rates well above 2% over the 2016–2019 period (Figure 5.1). For 2020, by contrast, the median expectation is for a 6.5% decline in GDP, according to the Federal Reserve, the country's central bank. Forecasts run as low as -10% (Cox, 2020).

At the global level, the year 2020 shaped into an economic 'crisis like no other'. As the Covid-19 pandemic tightened its stranglehold on the global economy in June 2020, the International Monetary Fund felt obliged to revise its projection for global growth down to -4.9% (IMF, 2020).

As of late April 2021, Covid-19 has claimed the lives of more than 570 000 US citizens according to the Johns Hopkins Coronavirus Resource Center. The US death rate of 175 per 100 000 inhabitants is one of the highest in the world.[2]

The impact of the coronavirus has been compounded by conflicting messages emanating from the government and scientific community, with the former striving to downplay the gravity of the pandemic and the latter recommending that measures such as social distancing and mask-wearing be generalized to limit the spread of infection. This fits a pattern, whereby the government has sought to restrict scientific research and the discussion and publication of scientific information, in an attempt to control the narrative over Covid-19 but also other topics over the past four years, such as climate change and environmental protection, in the name of national security. Columbia Law School has established a Silencing Science Tracker to document this.[3]

The pandemic has exposed weak points in the response by federal science agencies. When Covid-19 was first detected in the USA, the Food and Drug Administration (FDA) applied an existing 'emergency use authorization' clause that had been used in past viral pandemics, such as with regard to Ebola, Zika and Swine Flu, to bypass the FDA's usual six-month review period. The aim was to accelerate approval of the Covid-19 diagnostic tests developed by the Centers for Disease Control and Prevention (CDC) for rapid distribution to health laboratories across the country. However, many laboratories reported problems with validating the test results. Since tests cleared by the Emergency Use Authorization during past pandemics had always been successful, there was no contingency plan or alternative test immediately available. This set the USA back months in obtaining reliable diagnostic tests, hindering the country's pandemic response.

Unemployment trends on a roller coaster

Employment numbers are indicative of the pandemic's impact: the US unemployment rate, which had been at a 50-year low of 3.5% as recently as February 2020, leapt in April to 14.7%, an 80-year high, before falling back to 10.2% in July, according to the Bureau of Labor Statistics. A staggering 20.5 million jobs were lost in April alone, the steepest decline in payrolls since the Great Depression of the 1930s. More jobs were lost in March and April 2020 than had been created in the previous nine years combined, according to the Vice-Chair of the Board of Governors of the Federal Reserve System (Clarida, 2020).

By November 2020, however, the unemployment rate had already dropped back to 6.9%, after a surge in nonfarm payroll employment added 638 000 additional jobs in October.[4]

To counter the vertiginous rise in unemployment, the Federal Reserve cut its key overnight interest rate to almost zero in March 2020 and, the following month, rolled out up to US$ 2.3 trillion in loans to bolster local governments, households and employers. In parallel, the federal government approved a US$ 2.2 trillion relief package covering the period to the end of August 2020, which consisted of a combination of aid and loans for state, local and tribal governments, households and employers, with a particular focus on small and medium-sized enterprises (SMEs).

The uncertainty as to the depth and duration of the economic downturn, which largely depend on the course of the coronavirus and the public health policies to contain it, make it nearly impossible to project the economic situation until mid-2021 beyond constructing scenarios for the months and years ahead (Deloitte, 2020). Released in June 2020, the Federal Reserve's projections for growth in the next calendar year range from -1% to +7%; officials are divided on whether 2021 will see a continued recession or the biggest rebound since the mid-1980s (Cox, 2020).

An unprecedented mobilization by the bioscience industry

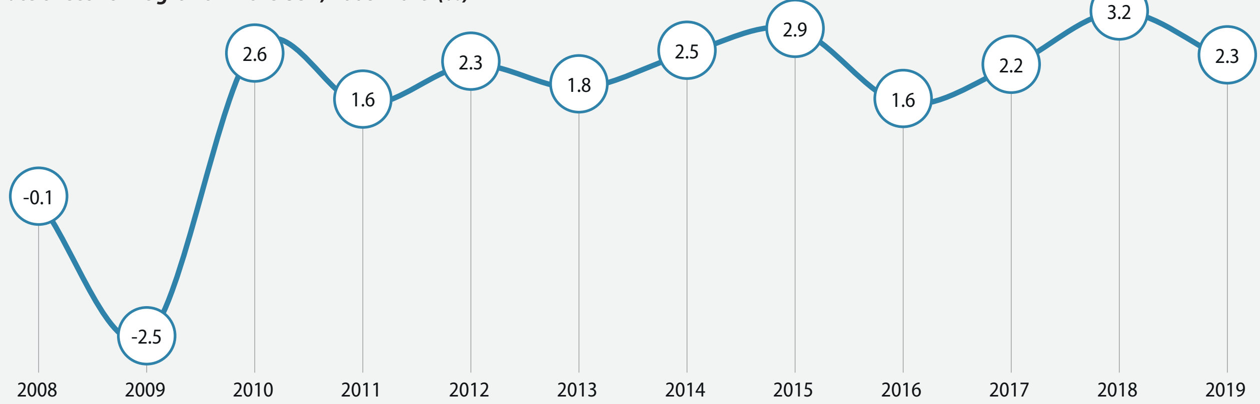
The Covid-19 pandemic has mobilized America's bioscience industry in an unprecedented manner. It has been estimated that there are more than 400 drug programmes in development in the USA aimed at eradicating the disease, including over 100 vaccine programmes and 135 antiviral programmes (TEConomy and BIO, 2020).

These efforts are grounded in the White House's Operation Warp Speed, a public–private partnership infused with a sense of urgency, as its name suggests. The federal government has allocated more than US$ 9 billion to develop and manufacture candidate vaccines. An additional US$ 2.5 billion has been earmarked for vials to store the vaccines and syringes to deliver them, as well as to pay for efforts to ramp up manufacturing capacity.

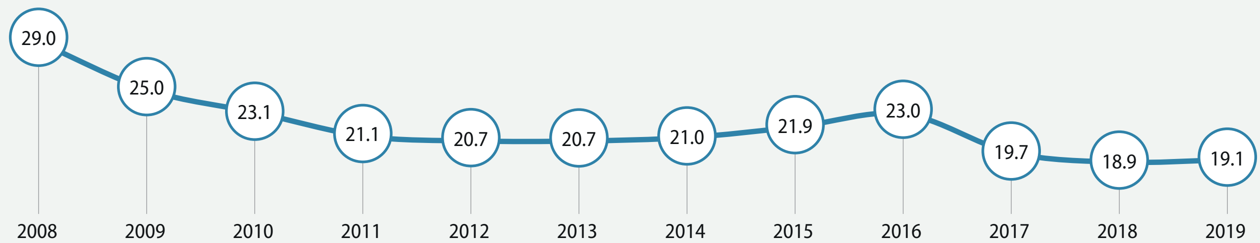
The list of bioscience companies receiving government funding covers a range of companies of different sizes and geographical origins, including AstraZeneca, BioNTech, GlaxoSmithKline, Pfizer, Janssen, Moderna, Merck, Novavax

Figure 5.1: **Socio-economic trends in the United States of America**

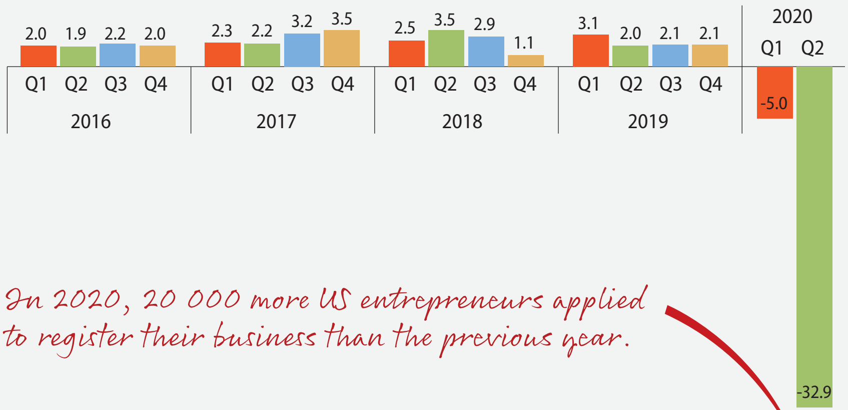
Rate of economic growth in the USA, 2008–2019 (%)



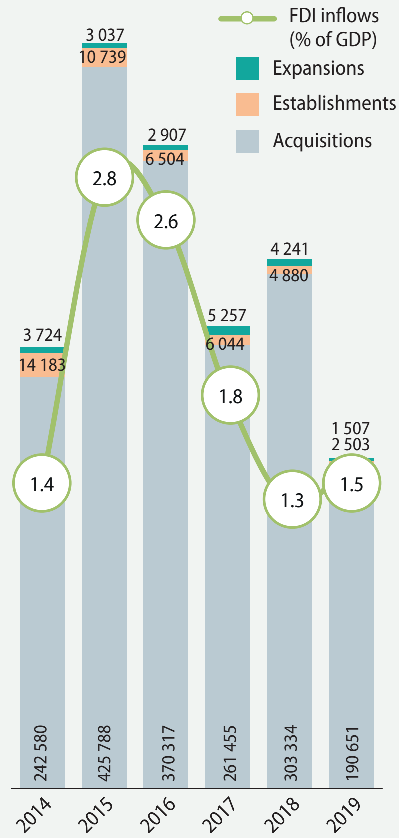
High-tech exports from the USA as a share of manufactured exports, 2008–2019 (%)



Change in real US GDP from the preceding quarter, 2016–2020 (%)

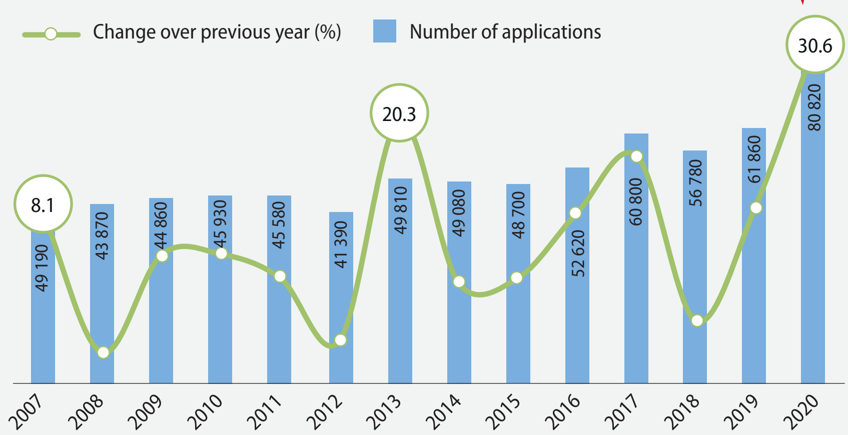


FDI flows to the USA as a share of GDP and new FDI expenditure by type, 2014–2019
Expenditure by type in US$ millions



In 2020, 20 000 more US entrepreneurs applied to register their business than the previous year.

Applications by US start-ups to register their business, 2007–2020 (%)
Data for week 45



Note: Data represent new FDI used to acquire, establish or expand US businesses.

Source: for GDP growth and exports: World Bank's World Development Indicators, August 2020; for quarterly GDP and FDI: BEA (2020) New Foreign Direct Investment in the United States, 2019. U.S. Bureau of Economic Analysis: Maryland, USA; for business applications: US Census Bureau (2020) Business Formation Statistics and Sanofi. Some projects involve international collaboration, such as the experimental vaccine developed by the German firm BioNTech for Pfizer. In the UK, British multinational AstraZeneca has teamed up with Oxford University.

By September, scientists participating in the White House's Operation Warp Speed had reportedly identified 14 vaccines for development. In December, the FDA approved the BioNTech/Pfizer and Moderna vaccines. The government had already prepurchased millions of doses of each to offset some of the company costs in developing them. The BioNTech/Pfizer vaccine must be stored at -70°C, complicating its roll-out.

Meanwhile, AstraZeneca has signed a memorandum of understanding with the World Health Organization (WHO) committing the firm to supplying 300 million doses of Covid-19 vaccines to the Covid-19 Vaccines Global Access Facility (Covax), a mechanism designed to guarantee rapid, fair and equitable access to Covid-19 vaccines worldwide. In August 2020, the US government signalled that it would not be participating in Covax, shortly after announcing plans to withdraw from WHO.

America First

This position is consistent with the America First policy agenda adopted in 2017. This agenda has led to US withdrawal from a number of multilateral agreements, including the nascent Trans-Pacific Partnership for trade, the *Paris Agreement* on climate action and the *Joint Comprehensive Plan of Action*, also known as the Iran nuclear deal (see chapter 15).

Incoming President Joe Biden returned the USA to the *Paris Agreement* in February 2021. He has signalled his intention to use a planned massive infrastructure investment plan to support the development of 'green' industries.

The America First agenda has influenced domestic policy in broad strategic areas such as health, space and energy, as epitomized by the titles of the *America First Energy Plan* (2017) and *America First National Space Strategy* (The White House, 2018). These broad strategic areas will be discussed later.

In the realm of trade policy, the America First priority sought to reverse the country's persistent negative international trade balance in goods through the imposition of tariffs on several of its trading partners. In particular, the US and Chinese economies have been perturbed since 2018 by a trade dispute that has spilled over into the arena of high technology, technology transfer and intellectual property protection (see chapter 23).

The first negative trade balances in goods date from the early 1970s and have been quite severe since the turn of the century. By contrast, the USA has enjoyed significant trade surpluses in services, especially knowledge-intensive services.

Between 2015 and 2019, the negative balances of combined trade in goods and services rose from US$ 498.5 billion to US$ 616.4 billion. The biggest trade deficit, by far, was with China, which accounted for more than half of the total.[5]

In 2018, China was the USA's biggest supplier of goods and third-biggest market for US exports of the same. According to the Office of the United States Trade Representative (2020), the top export categories to China in 2018 were aircraft, machinery, electrical machinery, optical and medical instruments and vehicles. US exports of services to China grew by 272% between 2008 and 2018 to US$ 58.9 billion, topped by travel, intellectual property and transportation.

The volume of inward foreign direct investment (FDI) in the USA totalled US$ 312.5 billion in 2018, up 14.6% over the previous year. However, 2019 saw a steep fall in inward FDI of 37.7% (Figure 5.1). The vast majority of inward FDI has taken the form of acquisitions of US companies by foreign investors. In 2018, as part of the Foreign Investment Risk Review Modernization Act, the USA enacted the most sweeping reforms to the Committee on Foreign Investment since 2007, expanding its jurisdiction and providing a new level of scrutiny of FDI (CRS, 2020a).

Even though China and the USA were one another's largest trading partner in 2018, the level of bilateral FDI is relatively low. Increasingly stringent regulations on both sides have severely affected investment flows. In 2018, net FDI flows to China were down by 22.9% over the previous year to US$ 7.6 billion; net Chinese FDI flows into the USA turned negative (US$ -754 million, down from US$ 25.4 billion in 2016), reflecting the divestiture of assets (CRS, 2019a).[6] The difference with trade volumes is stark.

It is against this backdrop that science, technology and innovation (STI) policy has evolved since 2016 in the USA.

RESEARCH TRENDS

US research enterprise strong

In 2019, the USA crossed the 3% threshold for research intensity (Figure 5.2). The US national innovation system still performs the largest share of global research and development (R&D) and generates the largest share of research-intensive industrial output (Figures 5.2 and 5.3).

In relative terms, though, the picture is changing. The US share of global research expenditure has been shrinking as other countries ramp up their own efforts (see Figure 1.1).

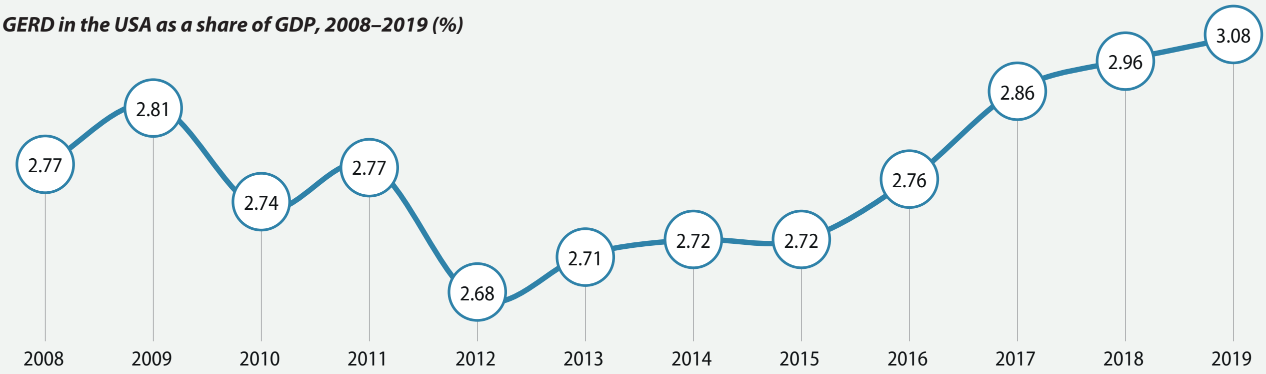
From 2003 to 2018, US value-added output by research-intensive industries almost doubled from US$ 570 billion to US$ 1.04 trillion (NSB, 2020). However, the US share of patents awarded by the top five patent offices remained stable at 22% between 2015 and 2019, even as China's share progressed from 27% to 32% (see chapter 23).

Business sector funding more basic research

In 1980, the business sector's share of research expenditure matched that of the federal government. Since then, the gap has widened. The National Science Board (NSB, 2020) estimates that the federal government funded 22% of gross domestic expenditure on R&D (GERD) in 2017, down from 31% in 2010. By 2017, the business sector was funding 70% of R&D and performing 73% (Figure 5.2). Of note is that the business enterprise sector, which prioritizes applied research and experimental development, extended its funding for basic research to 30% of the total in 2017. This is up from 23% in 2010 and 27% in 2013 (NSF, 2019).

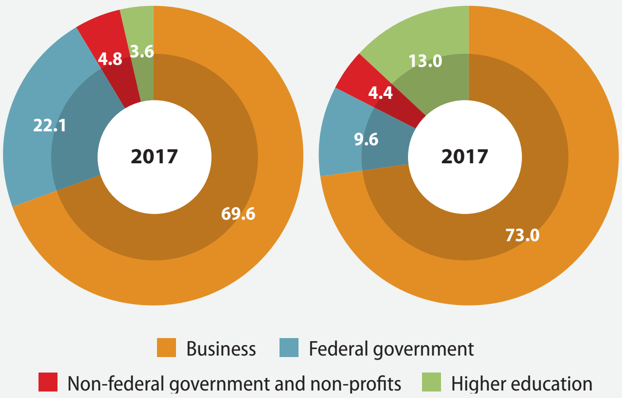
Figure 5.2: **Trends in research expenditure in the United States of America**

GERD in the USA as a share of GDP, 2008–2019 (%)

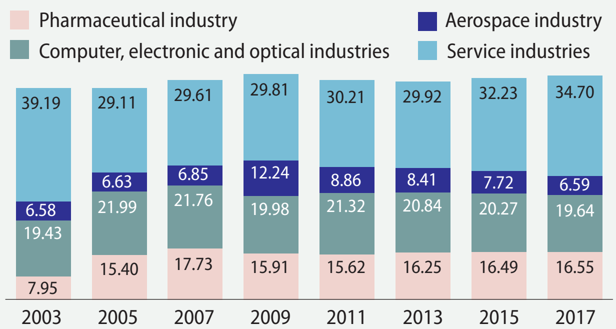


GERD in the USA by source of funds, 2017 (%)

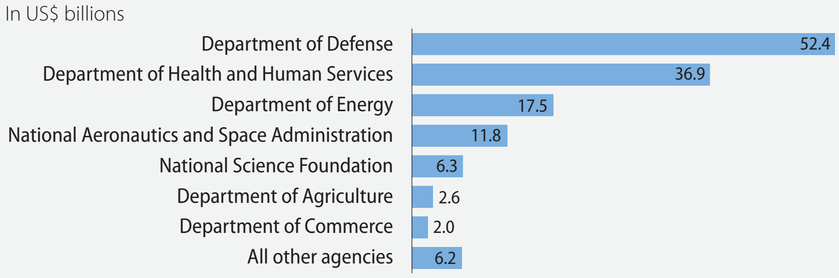
GERD in the USA by sector of performance, 2017 (%)



Share of business enterprise expenditure on R&D performed by industry in the USA, 2003–2017 (%)



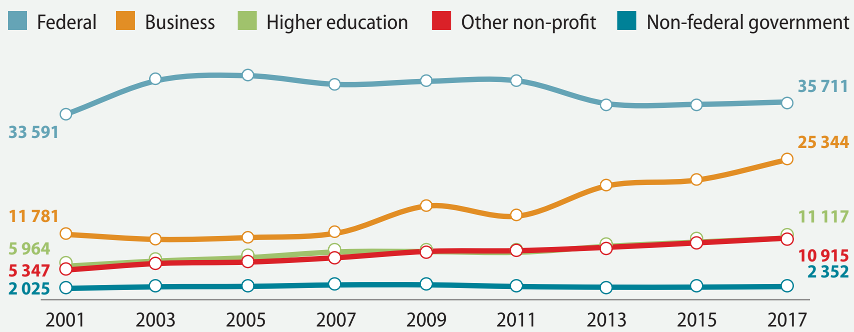
GERD by major US federal agency, 2018
In US$ billions



Note: Estimates are based on agency and Office of Management and Budget data. R&D includes conduct of R&D and facilities.

GERD per researcher (FTE) in the USA In PPP$ thousands, constant 2005 prices

Expenditure on basic research in the USA by sector, 2001–2017
In US$ millions, constant 2012 values



In dollar terms, business spending on basic research has doubled since 2007. By contrast, federal spending levels for the same have remained stable since 2013.

Source: NSB (2020); for expenditure by federal agency: CRS (2020) Federal Research and Development (R&D) Funding: FY2020. Congressional Research Service Report R45715; for GERD as a share of GDP: UNESCO Institute for Statistics; for expenditure on basic research: Boroush, M. (2019) *U.S. R&D Increased by $22 Billion in 2016, to $515 Billion; Estimates for 2017 Indicate a Rise to $542 Billion*. National Center for Science and Engineering Statistics. National Science Foundation: Alexandria, Virginia, USA; for business expenditure on R&D by subject: OECD Main Science and Technology Indicators

Federal government sticking to core missions
The bulk (93.2%) of federal research expenditure was allocated to five federal agencies in 2020 (CRS, 2020b). Two-thirds went to the Department of Defense (41.4%) and the Department of Health and Human Services (26.2%), which administers the National Institutes of Health. The other three were the Department of Energy, the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF). This allocation reflects the three core national missions of the US federal research system since the 1940s: basic research, health and defence.

More funding for strategic technologies
The White House's 2021 research budget proposes[7] an 8.8% drop for federal agencies relative to the 2020 enacted level. Should Congress endorse this proposal, all but the Department of Veterans Affairs will see a decline in research funding. The biggest cuts in percentage terms would affect the Department of Transportation (-47.6%) and the Environmental Protection Agency (-35.4%). The biggest cuts in monetary terms would affect the Departments of Defense, Energy and Health and Human Services (CRS, 2020b).

The White House's 2020 research budget proposal (US$ 162 billion) targeted strategically important technologies underpinning the industries of the future: artificial intelligence (AI), quantum information science (QIS), fifth-generation wireless technology (5G), biotechnology and advanced manufacturing (OMB, 2019).

The budget proposal for 2021 has again included major increases for QIS and AI as part of the Administration's goal of doubling government-wide investment in R&D in these two areas by 2022 relative to 2019 levels (OMB, 2020).

A less generous tax environment for firms
The private sector has developed a large research presence, despite relatively anaemic tax incentives for R&D. The USA ranked 26th for this indicator among members of the Organisation for Economic Co-operation and Development (OECD) in 2018,[8] compared to 10th in 2000.

The Tax Cuts and Jobs Act (2017) has made provision for reducing this generosity further from 2022 onwards. This change will require companies to amortize research over a five-year period, instead of counting it among their expenses in their tax return (Kennedy, 2019). Expert projections indicate that this change is likely to discourage business R&D (Bellafiore, 2019).

A surge in new business registration
Entrepreneurship and knowledge-intensive start-ups are a vital component of the US high-tech scene. The Great Recession of the late 2000s sent start-up activity into a tailspin that culminated in a 20-year low for the share of new entrepreneurs in 2009 (Kauffman *et al*., 2017).

In subsequent years, the number of new start-ups started to recover slowly again – as did their positive outlook on business conditions. According to the *2020 Startup Outlook US Report* published by the Silicon Valley Bank, more than two-thirds of all start-ups were in this optimistic frame of mind by 2020.

An exciting phenomenon during the year of the pandemic has been the surge in the number of new businesses, as reported by the US Census Bureau. Some 80 820 applications had been received by November 2020, a year-on-year increase of 30.6%. This is a major reversal of the trends of the previous decade when applications only twice exceeded 60 000, in 2017 and 2019 (Figure 5.1).[9]

Less venture capital for start-ups since pandemic
The long-term effect of Covid-19 on risk capital may be chilling. The PitchBook Financial Database anticipates a drop in both the volume and value of transactions into 2021. However, although the number of deals had dropped as of the second quarter of 2020, the value of transactions was holding steady (Figure 5.3).

The reality of venture capital investment typically diverges from entrepreneurs' expectations. Venture capitalists tend to favour certain economic activities which receive the lion's share of investment. According to the Kauffman Capital Report of March 2019, only 0.5% of all start-ups manage to attract venture capital. Even in good times, the level of this type of investment is insignificant, with rare exceptions: in 2018, there were fewer than 7 000 venture capital deals for a total value of US$ 130 billion; of these, 191 deals were worth US$ 100 million or more (what are known as megarounds). The pandemic will provide opportunities for entrepreneurs in fields of direct relevance to the treatment of Covid-19.

Venture capital funding is also subject to significant regional disparities. Traditionally, Silicon Valley, San Francisco and Orange County (Los Angeles) in the State of California and metropolitan New York and the Boston area on the Eastern Seaboard have attracted by far the most venture capital. This was still the case in 2020 (PwC, 2020). On aggregate, over two-thirds of all start-ups are fully dependent on personal or family sources and over 16% are dependent on business loans from banks or other financial institutions.

The availability of venture capital, coupled with centres of excellence such as the Massachusetts Institute of Technology (Boston area) or Stanford University (California), makes the States of California, Maryland, Massachusetts, Delaware, Michigan and Washington best-positioned to support future growth in knowledge-based industries, both in terms of research funding and human resources (Figure 5.4).

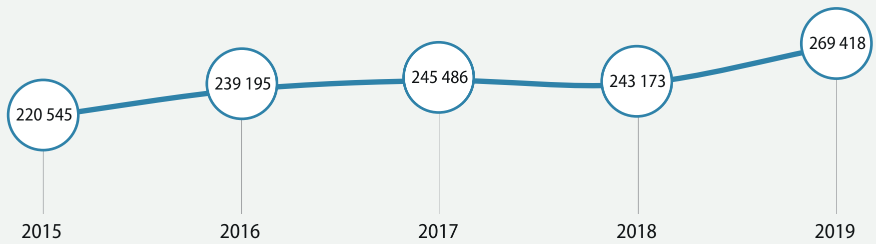
STRATEGIC PLATFORMS IN DIGITAL TECHNOLOGY

An AI strategy since 2016
There is a broad consensus between federal agencies and the executive and legislative[10] branches that the USA needs to adapt to an increasingly competitive international environment. In response, the federal government has prioritized key strategic platforms in digital technology since 2016 in fields that include AI, quantum computing, advanced mobile network technology and cybersecurity.

In recognition of the growing importance of AI for economic growth and national security, the National Science

Figure 5.3: **Trends in innovation in the United States of America**

Number of IP5 patents granted to the USA, 2015–2019

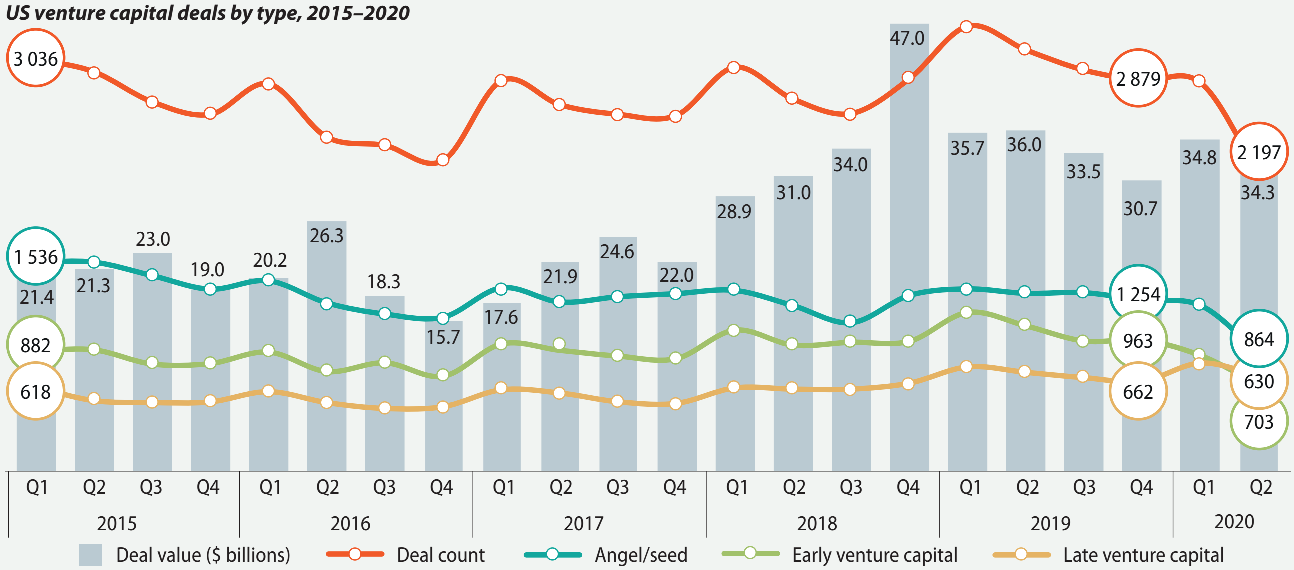


Share of IP5 patents granted to US inventors

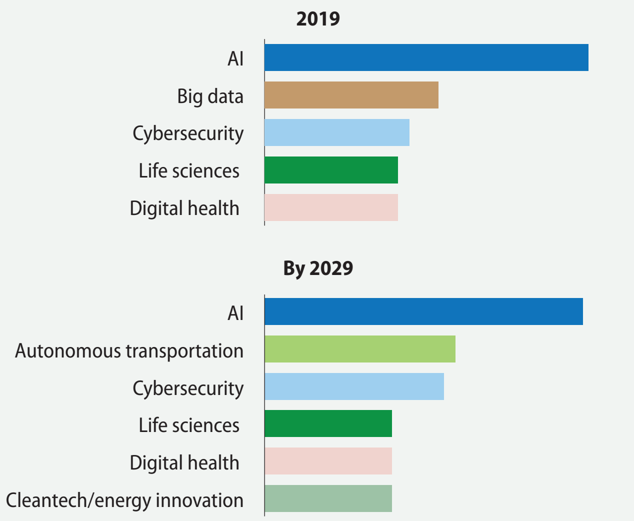
22.5%
in 2015

21.7%
in 2019

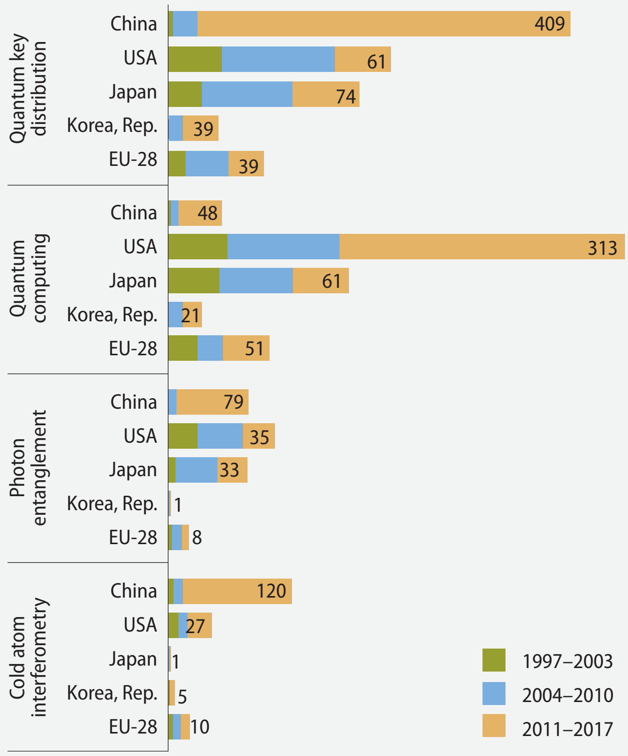
US venture capital deals by type, 2015–2020



Survey responses from US entrepreneurs and start-ups asked to identify promising fields in the innovation economy in 2019 and by 2029



Quantum patents granted to selected countries and regions, 1997–2017



Note: Respondents (1 377) in Canada, China, USA and UK were asked to identify up to three technologies they felt were the most promising in 2019 and those that would be most promising by 2029.

Note: IP5 refers to the US Patent and Trademark Office, European Patent Office, Japanese Patent Office, Korean Intellectual Property Office and State Intellectual Property Office of the People's Republic of China. For venture capital deals by type, data are available only for the first two quarters of 2020.

Source: for IP5: PATSTAT, data treatment by Science-Metrix; for venture capital: PitchBook (2020) *Venture Monitor: Q2 2020*. PitchBook Data, Inc.: Seattle, USA; for survey of entrepreneurs: Silicon Valley Bank (2019) *US Startup Outlook 2019*. Silicon Valley Bank: Santa Clara, California, USA; for quantum patents: Travagnin (2019) and Technology Council (NSTC) published the first *National Artificial Intelligence Research and Development Strategic Plan* for the USA in 2016.

The *Plan* identifies scientific and technological requirements for the development of AI. It advocates a public-sector strategy focusing primarily on areas in which industry would be less likely to invest but which could be transformational in the long term. Seven broad action themes have been proposed (NSTC, 2016):

- making a long-term investment in AI research;
- developing effective methods for human–AI interaction;
- understanding and addressing the ethical, legal and societal implications of AI;
- ensuring the safety and security of AI systems;
- developing shared public datasets and environments for AI training and testing;
- measuring and evaluating AI technologies through standards and benchmarks; and
- better understanding the needs of the national AI research workforce.

In August 2018, the government asked the NSTC Select Committee on Artificial Intelligence to update the 2016 *Plan*. Based on responses to a public request for information, the updated 2019 plan includes an eighth theme, namely that of expanding public–private partnerships to accelerate advances in AI (NSTC, 2019a).

In February 2019, the *National Artificial Intelligence Research and Development Strategic Plan* became part of the broader American Artificial Intelligence Initiative, which itself originated from President Trump's executive order[11] on Maintaining American Leadership in Artificial Intelligence. This initiative serves to co-ordinate efforts to promote AI technology and innovation across federal agencies, the private sector, academia and the public.[12] In November 2019, the NSTC published a progress report on the status of implementation in each of the aforementioned eight areas and concluded that the federal agencies were playing a critical role in promoting research in AI (NSTC, 2019a and 2019b).

Funding for research on AI has trended upwards in recent years, leading to a growing number of publications on this topic (Figure 5.5). The White House's budget request for 2020 even included AI as a separate category, allocating US$ 973.5 million to non-defence research in AI. Although defence-related research in AI remains classified, the US Chief Technology Officer, Michael Kratsios, hinted at the size of the increase in total research funding for AI when he stated that, 'in 2016, the federal government spent US$ 1 billion on AI R&D in total, including defense spending. Today's nearly US$ 1 billion figure doesn't include defense' (Castellanos, 2019).

Recent initiatives have also highlighted the extent to which the Department of Defense values AI technology. In 2018, the Defense Advanced Research Projects Agency (DARPA) announced a US$ 2 billion investment in a new AI Next campaign, stating that 'DARPA sees this next generation of AI as a third wave of technological advance, one of contextual adaptation' (DARPA, 2018).

In May 2020, Congress unveiled a major bipartisan proposal to bolster US technology leadership. Championed in both the House of Representatives and the Senate, the Endless Frontier Act would provide a major funding boost to US innovation efforts. The role of the National Science Foundation would be expanded and its name would be changed to the National Science and Technology Foundation as a consequence.
A new Technology Directorate would also be established with a budget of US$ 100 billion over five years to lead investment and research in ten areas, including AI and machine learning, high-performance computing, robotics, automation and advanced manufacturing.

Although this legislation was not put to a vote during that particular session of Congress, it is indicative of the impetus in both Congress and throughout the government to shore up the federal research enterprise and expand efforts to develop technologies deemed strategically important, accompanied by dramatic reforms if necessary.

Meanwhile, the 2021 budget request from the White House (OMB, 2020) has proposed significant increases for non-defence AI, including a more than 70% increase over the previous year for the National Science Foundation (NSF). This increase will enable the NSF to create several national AI research institutes, in collaboration with the Departments of Agriculture, Homeland Security, Transportation and Veterans Affairs. These institutes will serve as focal points for multisector, multidisciplinary research involving academia, industry, federal agencies and non-profit organizations.

On 7 January 2020, the White House (2020a) published the latest addition to the American Artificial Intelligence Initiative. In a Memorandum for the Heads of Executive Departments and Agencies, it conveyed ten principles designed to deter agencies from adopting any regulations that might stifle innovation in AI (Table 5.1).

Central to these principles (Table 5.1) is the need for AI to be developed in accordance with human rights and democratic values, to ensure public confidence and trust in the technology. The USA is one of the founding members of the Global Partnership on Artificial Intelligence launched in June 2020,[13] which espouses these same values, as outlined in the *OECD Principles on Artificial Intelligence* (2019).

The USA is, of course, far from the only country focusing on AI. Half of the top 20 universities and public research organizations for scientific publications on AI are located in China, compared to just six in the USA (Figure 5.6). Of the 30 leading patent-holders, only five are US companies – but these include IBM and Microsoft, those with the biggest AI portfolios (Figure 5.6).

Universities are a particular strength of the Chinese system: no fewer than 150 Chinese universities are ranked among the top 500 for the number of patent applicants in AI, including all top 10 positions. Twenty US universities have also made it onto this list, with the University of California leading in 15th place, followed by the Massachusetts Institute of Technology in 17th place (WIPO, 2019).

Competition has also extended to venture capital. In 2012, venture capitalists poured US$ 282 million into AI. By 2017, this amount had almost doubled to US$ 5 billion but China had still overtaken the USA by this point (Deloitte, 2019). A year later, the USA had reclaimed the top spot with US$ 9.7 billion in AI investment, which translated into 52.3% of global venture capital investment in AI. This investment gap is projected to grow further (ABI Research, 2019).

According to Deloitte (2019), this wave of investment has helped to transform many US firms into sophisticated users of AI technology: 30% of those responding to the Deloitte survey were managing 11 or more AI production systems. The primary difficulty for these firms appeared to be the lack of human resources, with 68% of respondents qualifying the talent gap as being moderate to extreme.

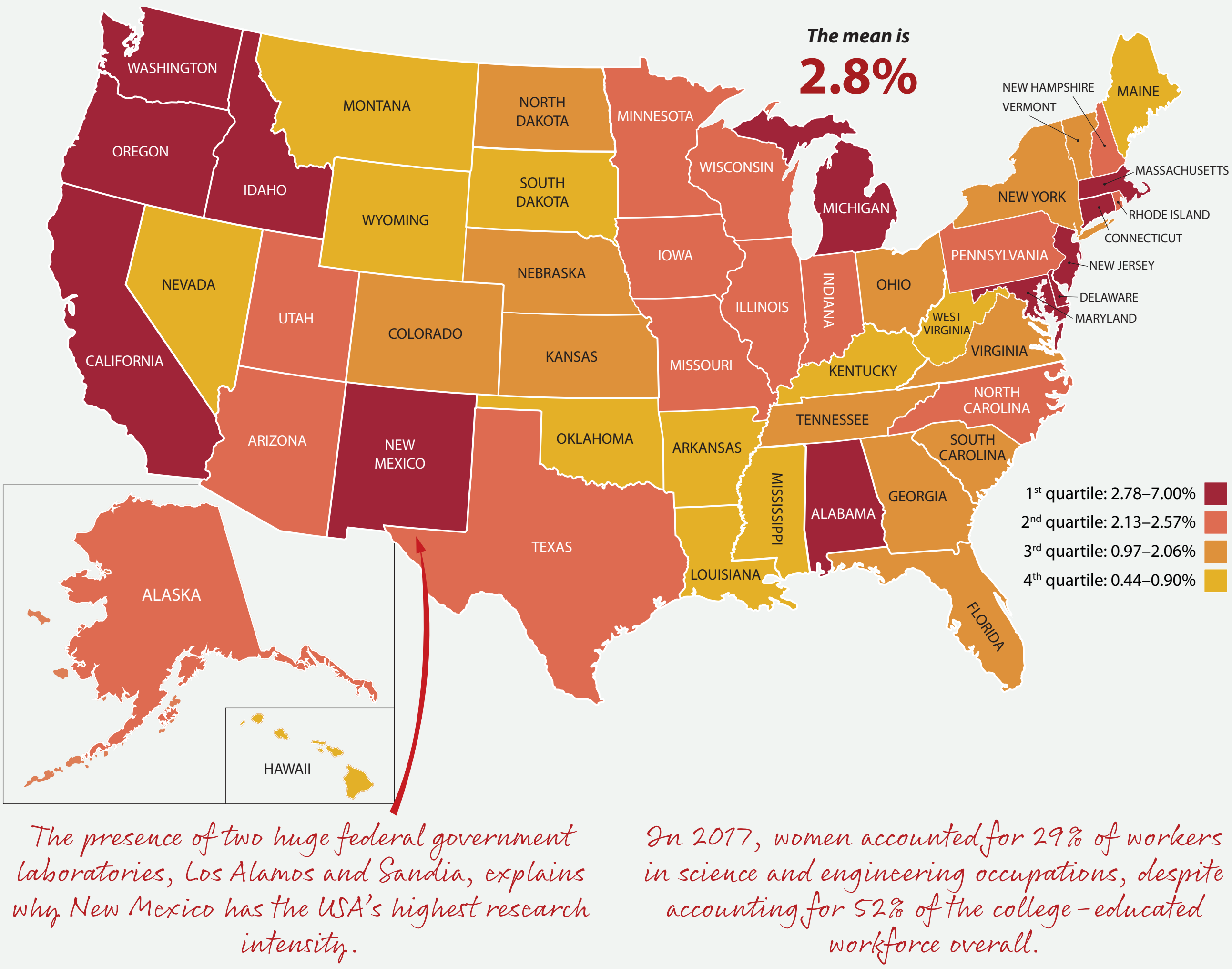
Quantum information science: a public and private priority

In September 2018, the US National Science and Technology Council (NSTC) published the *National Strategic Overview for Quantum Information Science*. This document attempts to create a systematic national approach to quantum information R&D co-ordinated by NSTC's Subcommittee on Quantum Information Science (NSTC, 2018a). The report identifies six policy areas for QIS: a science-first approach; the workforce; federal engagement with industry; critical infrastructure; national security; and international co-operation.

Shortly thereafter, Congress passed the National Quantum Initiative Act with overwhelming support from both the Senate and House of Representatives. President Trump signed the legislation into law on 21 December 2018, formalizing a multi-agency effort to develop research and a skilled workforce in QIS. Additionally, the legislation requires that the National Science Foundation and the Department of Energy each establish between two and five 'multidisciplinary centers for quantum research and education,' with each receiving approximately US$ 10 million in funding (Thomas, 2019).

Figure 5.4: **Science and engineering in the United States of America, by state**

R&D performed as a share of state GDP in the USA, 2017 (%)



Note: R&D includes R&D performed by federal agencies, businesses, universities, other non-profit organizations, federally funded research and development centres and state agencies. US total R&D reported here includes US territories.

UN Disclaimer

Although it is difficult to determine the exact amount spent by the federal government as a whole on QIS research, estimates for 2018 range between US$ 200 million and US$ 250 million (CRS, 2018b). This figure may swell with the new National Quantum Initiative and the growing recognition of the importance of QIS for the USA.

As with AI, the White House's budget proposal for 2021 has reflected this reprioritization. The requested budget allocation for QIS has increased by 50% over the previous year on the path to doubling the level of investment by 2022. The NSF's investment in QIS is set to more than double with an additional US$ 120 million to support the National Quantum Initiative. As for the Department of Energy, it should be in a position to bolster quantum efforts at the national laboratories and in academia and industry, thanks to an increase of US$ 75 million (OMB, 2020).

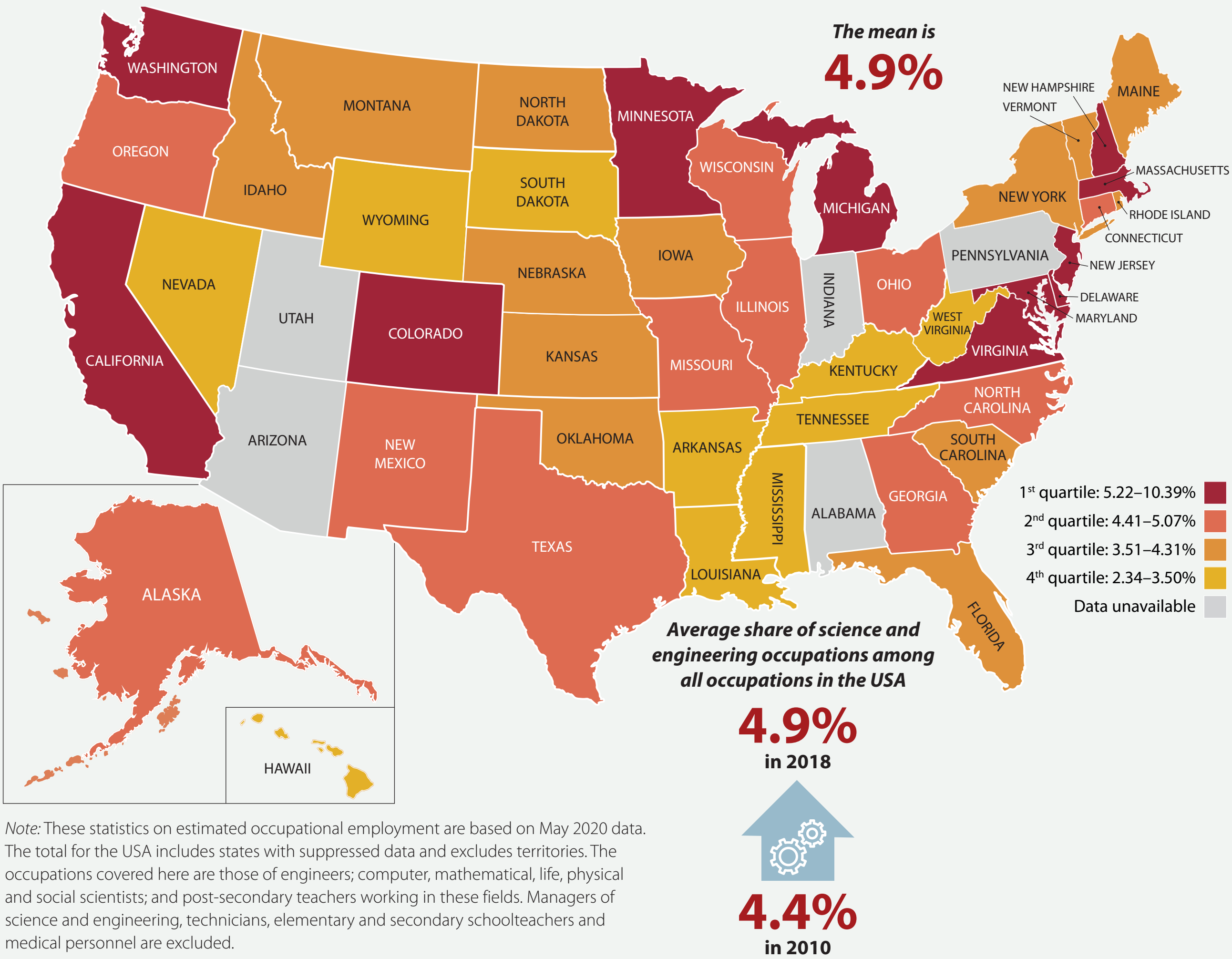
The private sector has already established itself as a world leader in this field. For instance, Google claimed to have achieved 'quantum supremacy' when announcing in 2019 that its 54-Qubit Sycamore processor had performed a calculation in 200 seconds that would have taken the world's most powerful supercomputer 10 000 years (Metz, 2019; Porter, 2019).

Patents also reflect the strong US position in quantum computing. Using European Patent Office data, Travagnin (2019) estimated that, although China led for the overall number of QIS patents, particularly when it came to quantum communication, the USA had the largest number of patents in quantum computing (Figure 5.3).

Likewise, a higher proportion of known global private-sector investment in quantum computing in the USA reflects both the number and quality of US technology giants and the volume of venture capital flowing towards start-ups in quantum computing since 2016 (Gibney, 2019).

The US lead is increasingly being challenged by other nations, such as Australia, Canada and China, as well as by countries in Europe (Kania *et al*., 2018).

Individuals in science and engineering occupations as a share of all occupations in the USA, 2018 (%)



Note: These statistics on estimated occupational employment are based on May 2020 data. The total for the USA includes states with suppressed data and excludes territories. The occupations covered here are those of engineers; computer, mathematical, life, physical and social scientists; and post-secondary teachers working in these fields. Managers of science and engineering, technicians, elementary and secondary schoolteachers and medical personnel are excluded.

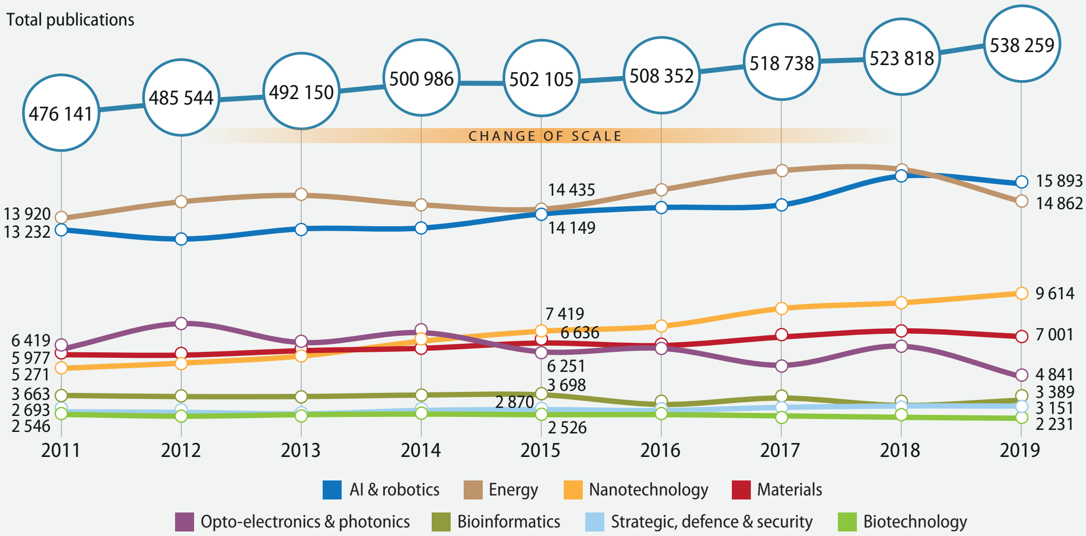
Source: National Science Board (2020) *S-41 R&D as a Percentage of Gross Domestic Product*. Science & Engineering Indicators: State Indicators. National Science Foundation: Alexandria, Virginia, USA; National Science Board (2019) *S-32 Individuals in Science and Engineering Occupations as a Percentage of All Occupations*. Science & Engineering Indicators: State Indicators. National Science Foundation: Alexandria, Virginia, USA

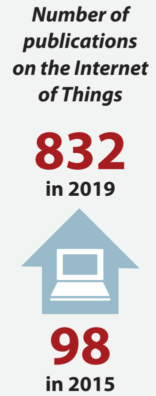
UN Disclaimer

Figure 5.5: **Trends in scientific publishing in the United States of America**

Volume of scientific publications in the USA, 2011–2019

Total publications and output on cross-cutting strategic technologies

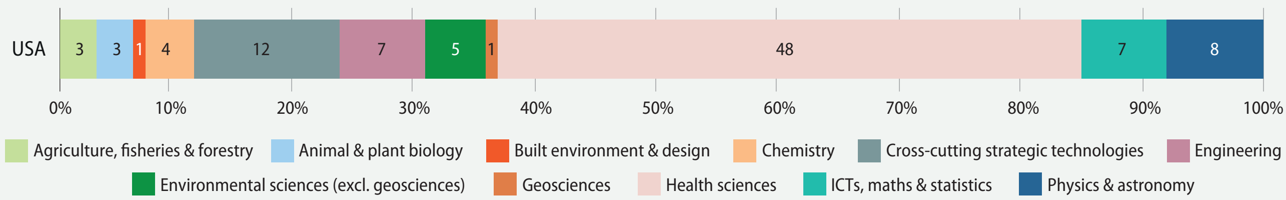




The USA's publication output accounted for 30% of the world total in health sciences in 2019.

The first journals on blockchain technology date from 2018. US researchers produced 10 publications in those journals in 2018 and 76 in 2019.

Scientific publications in the USA by broad field of science, 2017–2019 (%)



1.32

Average of relative citations for the USA, 2014–2016; the OECD average is 1.11

40%

Share of publications with foreign co-authors in the USA, 2017–2019; the OECD average is 34%

Scientific publications per million inhabitants in the USA, 2011, 2015 and 2019

How has output on SDG-related topics evolved since 2012?

Scientists in the USA are publishing more on the following topics than would be expected, relative to global averages: HIV (1.9 times the global average intensity), invasive species, ocean acidification and new or re-emerging viruses that can infect humans. They have published extensively on the Zika virus (see chapter 8).

Scientists produced less than would be expected on the clean energy topics studied. Output grew substantially between 2012–2015 and 2016–2019 only on battery efficiency (from 7 479 to 10 647 publications) and smart-grid technologies (from 5 801 to 7 369). Output even dropped on biofuels and biomass (from 8 675 to 7 820), photovoltaics (from 8 661 to 7 647), wind-turbine technologies (from 4 289 to 4 092), hydrogen energy (from 4 115 to 4 034) and cleaner fossil fuel technology (from 1 334 to 1 116).

Among the selected topics with at least 1 000 publications during the period under study, the fastest-growing topic was that of sustainable transportation (+162%), with output rising from 4 871 (2012–2015) to 7 869 (2016–2019) publications.

For details, see chapter 2

USA's top five partners for scientific co-authorship, 2017–2019 (number of publications)

	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
USA	China (158 219)	UK (83 678)	Germany (69 443)	Canada (65 364)	France (45 675)

Source: Scopus (excluding Arts, Humanities and Social Sciences); data treatment by Science-Metrix

Table 5.1: **Ten principles to ensure agency support for innovation in the USA**

Public Trust in AI	The government's approaches to AI should promote reliable, robust and trustworthy AI applications which will contribute to public trust in AI.
Public Participation	Agencies should provide ample opportunities for the public to provide information and participate in the rule-making process.
Scientific Integrity and Information Quality	Agencies should hold information that is likely to have a clear and substantial influence on public policy or private-sector decisions to a high standard of quality, transparency and compliance.
Risk Assessment and Management	Regulatory and non-regulatory approaches to AI should be based on a consistent application of risk assessment and risk management.
Benefits and Costs	Agencies should carefully consider the full societal costs, benefits and distributional effects before implementing regulations related to the development and deployment of AI applications.
Flexibility	Agencies should pursue performance-based, flexible approaches that can adapt to rapid changes and updates to AI applications.
Fairness and Non-discrimination	Agencies should consider in a transparent manner the possible impact of AI applications on discrimination.
Disclosure and Transparency	Transparency and disclosure can increase public trust and confidence in AI applications
Safety and Security	Agencies should promote AI systems that are safe, secure and operate as intended, while encouraging the consideration of safety and security issues throughout the process of AI design, development, deployment and operation.
Inter-agency Co-ordination	Agencies should co-ordinate with each other to share experiences and ensure consistency and predictability of AI-related policies, while protecting privacy and civil liberties and allowing for sector- and application-specific approaches, where appropriate.

Source: The White House (2020a)

QIS is seen as being of critical importance not only in terms of economic competitiveness but also cybersecurity. This concern reflects a broad sentiment underlying the US intelligence community's *Worldwide Threat Assessment* identifying emerging and disruptive technologies and threats (Coats, 2019):

> *For 2019 and beyond, the innovation that drives military and economic competitiveness will increasingly originate outside the USA, as the overall US lead in science and technology shrinks; the capability gap between commercial and military technologies evaporates; and foreign actors increase their efforts to acquire top talent, companies, data, and intellectual property via licit and illicit means [...] Advances in quantum computing foreshadow challenges to current methods of protecting data and transactions [...] Foreign deployment of a large-scale quantum computer, even ten or more years in the future, would put sensitive information encrypted with today's most widely used algorithms at a greatly increased risk of decryption.*

Challenges in deploying 5G technology

There is little doubt that the fifth generation of mobile network technology (5G) will be one of the main drivers of economic growth for years to come. This next generation of wireless infrastructure will offer new and improved capabilities – such as lower latency, flexibility, adaptability, higher capacity and support for a larger number of connections – and it will underwrite a continuing frenzy in the digitization and automation of systems. It will allow for the seamless connection of smart sensors with AI. It will enable connectivity to be tailored to a much wider variety of uses, including machine-to-machine interaction. As a consequence, it is expected to enable the Internet of Things (Brake, 2020).

The strategic importance of 5G has captured the imagination of policy-makers and private-sector strategists alike and is constantly being touted in penned strategies and the popular media. The impression given is that we are engaged in a competitive race to develop and deploy 5G.

The USA faces a variety of unique challenges in the deployment of 5G. The domestic telecommunications equipment industry has declined from its peak in 2001 and the country no longer has comparably sizable companies to provide the necessary equipment for 5G (Brake, 2020).

This lack of major vendors is particularly acute when it comes to Radio Access Network (RAN) equipment, which connects wireless devices to the main core network and comprises more than two-thirds of the total cost of the 5G network. The USA also faces challenges in deploying 5G to geographically dispersed populations and in making critical portions of the spectrum available for commercial use (Brake, 2020).

Base stations offer one example. It is estimated that Chinese mobile providers have, so far, deployed about 15 times as many 5G base stations as US providers. They have done so by utilizing the C-band allowing each base station to cover a wider area than those in the USA which use the mmWave (Brake, 2020). The US lacks a company that can compete with Huawei for the manufacture of base stations. The shorter propagation range, higher manufacturing and supply costs and lagging deployment in the USA mean that America pays more for fewer, shorter-ranged 5G base stations. This is coupled with pre-existing challenges in deploying wireless capabilities to rural populations. Together, these challenges make deploying 5G base stations in the USA relatively difficult and expensive (DIB, 2019).

The public sector has initiated moves to accelerate 5G deployment. Despite an ongoing effort to provide a unified policy front, Brake (2020) characterizes efforts to date as taking a 'scattershot' approach that seeks to focus on infrastructure and spectrum policy, while managing national security concerns associated with utilizing the telecommunications equipment of certain foreign companies.

The strategy of the Federal Communications Commission (FCC, 2016) to *Facilitate America's Superiority in 5G Technology* (*5G FAST Plan*) focuses on making additional bandwidths available for commercial use, developing infrastructure and updating regulations. A highlight of the spectrum policy is that it makes available the sub-6 spectrum, in particular the C-band of 3.7–4.2 GHz. In December 2020, the FCC plans to auction 280 megahertz of satellite C-band spectrum to 5G cellular networks (Henry, 2020). The proceeds from these auctions will then be used to incentivize the incumbents to co-operate in a swift transition so that they are ready to relinquish the spectrum completely by September 2023.

The FCC has also adopted new rules to reduce federal regulatory impediments to deploying 5G infrastructure and has taken steps to prevent cities from imposing excessive fees on the deployment of 5G equipment. One such move was the 2017 Restoring Internet Freedom Order repealing the 2015 Title II regulations on Internet service providers to ensure what has been termed 'net neutrality' (FCC, 2016). Citing the benefits of moving away from Title II regulations, the FCC Chairman announced the agency's intention of giving broadband providers stronger incentives to build networks, especially in 'unserved areas, and upgrade networks to reach gigabit speeds and offer 5G' (FCC, 2018).

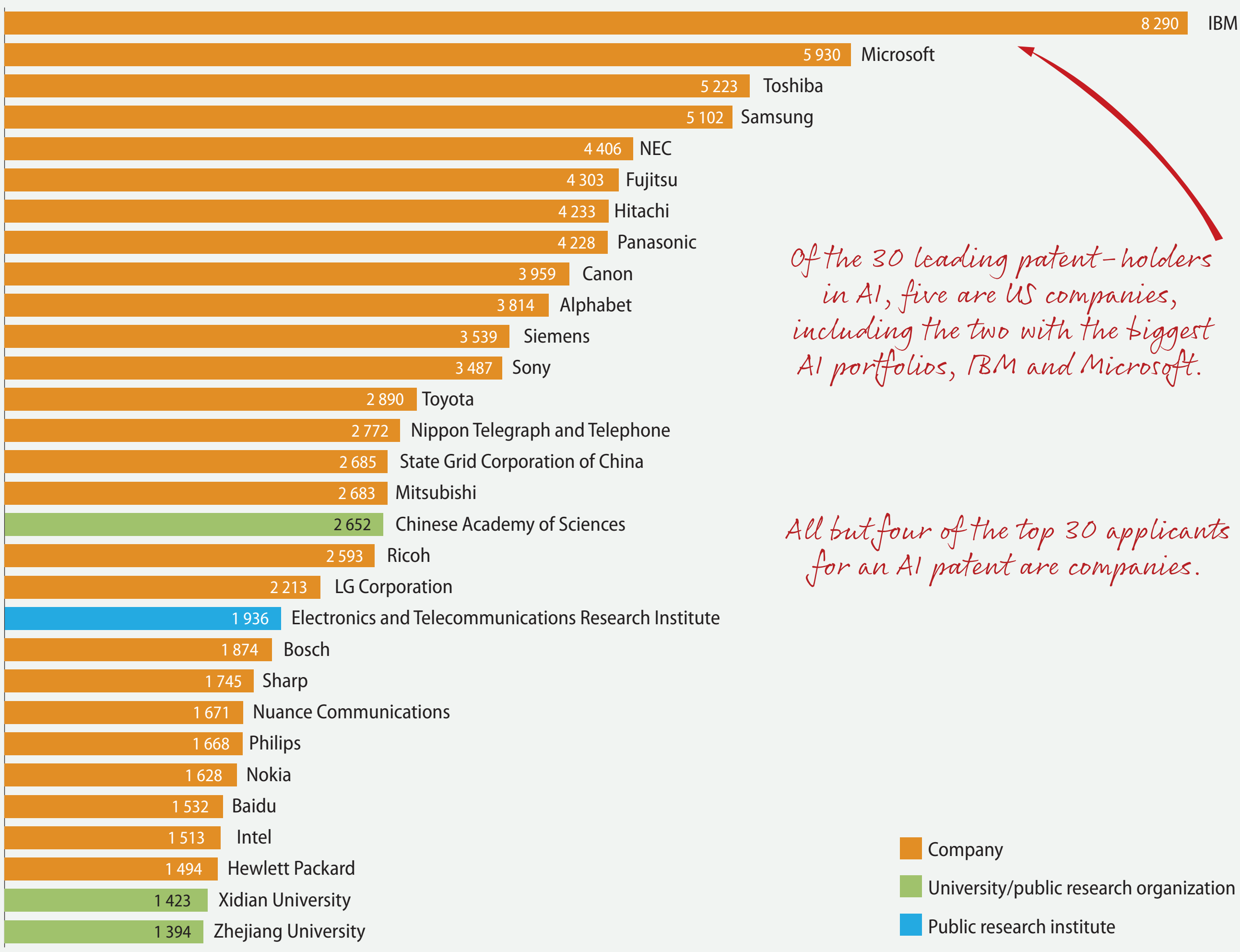
Another regulatory change by the FCC has been to ensure that equipment purchased through the Universal Service Fund does not pose a national security risk. Managed by the FCC, this fund enables interstate long-distance carriers[14] to subsidize telephone service delivery to low-income households and high-cost areas.

Legislation passed by Congress has also emphasized national security; it has established similar security standards for telecommunications equipment across the federal government. Most recently in March 2020, President Trump signed the Secure 5G and Beyond Act, which requires the development of a more comprehensive national strategy for 5G deployment, competitiveness and security.

The same month, the White House released the *National Strategy to Secure 5G*. It identifies four missions for the

Figure 5.6: **Top companies and research institutions publishing and patenting in artificial intelligence worldwide**

Top 30 applicants for patents in artificial intelligence, 2018
By number of patent families within their portfolio



administration: facilitate domestic 5G rollout; assess risks to, and identify, core security principles of 5G infrastructure; address risks to the US economic and national security in 5G infrastructure development and deployment; and promote responsible global development and deployment of 5G (The White House, 2020b).

The push for security in telecommunications equipment has been central to the administration's trade and diplomatic efforts related to 5G. In May 2019, President Trump signed an executive order to prevent the importation and use of 5G equipment that pose a national security threat. The administration has also added China's leading telecommunications company Huawei to the Department of Commerce's Entity List, barring US companies from selling technology to the company. Simultaneously, the USA has been urging allies to adopt similar national security requirements around 5G equipment.

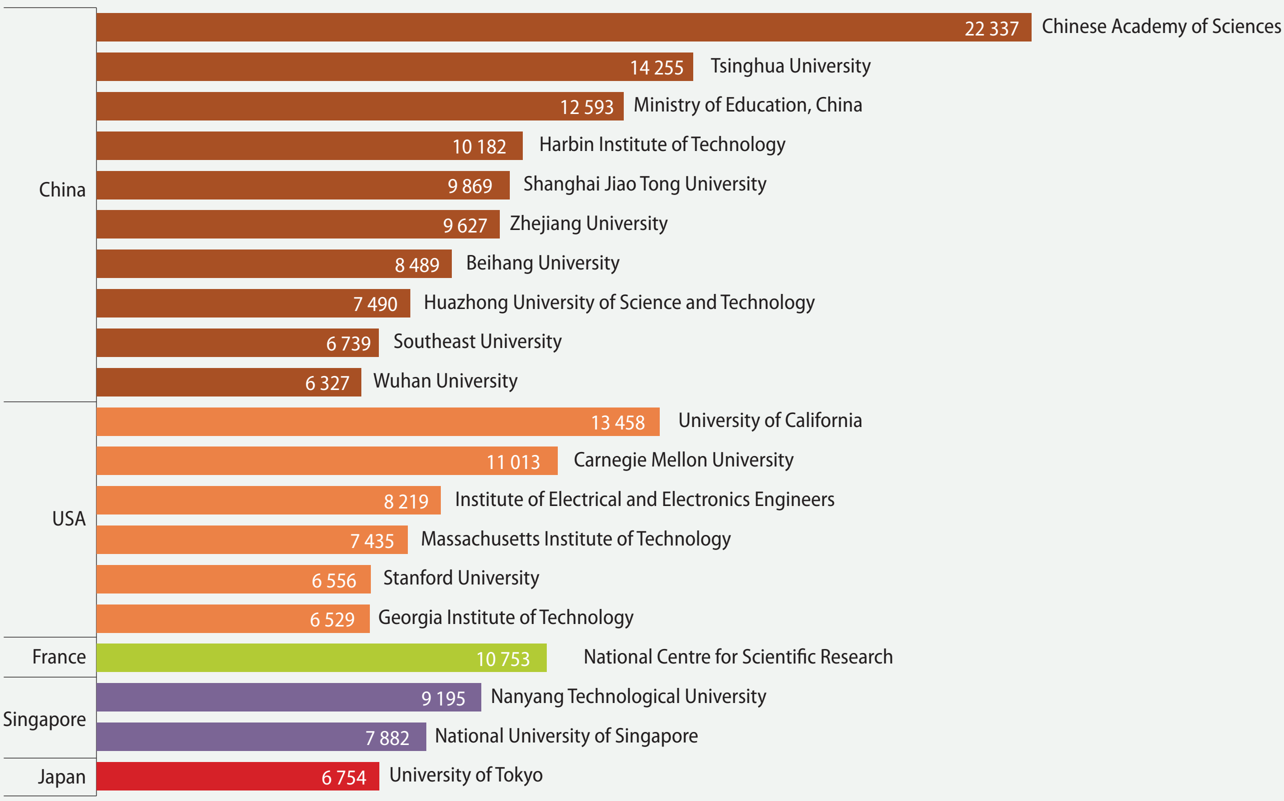
The *National Strategy to Secure 5G*, combined with the legislative requirement for the government to develop a comprehensive national strategy for 5G, suggests that the various scattershot policies may soon coalesce into a more unified effort.

So far, various federal agencies have approached 5G in accordance with each agency's mandate. With the Department of Defense occupying large portions of the sub-6 spectrum and the FCC moving to clear sub-6 spectrum for commercial use, a unified approach to spectrum policy and 5G may offer a viable policy response. Overcoming the spectrum, security and geographical challenges will be vital for the development of 5G networks. In this effort, the USA expects to benefit from its strong advantages in terms of the dynamic competition among private actors, its proven innovative capacity and leading semiconductor sector.

Steps to improve cybersecurity readiness

Federal budgets for cybersecurity have been growing rapidly. Although cybersecurity is not a new concern, the significant breaches surrounding the 2016 US presidential election have shone a spotlight on cybersecurity for the American public (Geller, 2019). According to a 2019 survey by

Top 20 universities and public research organizations publishing on artificial intelligence, by number of publications, 2018



Note: Fujitsu includes PFU; Panasonic includes Sanyo; Alphabet includes Google, Deepmind Technologies, Waymo and X Development; Toyota includes Denso; and Nokia includes Alcatel.

Source: for universities and public research organizations publishing on AI: Scopus (Elsevier) data collated in WIPO (2019) *Technology Trends 2019: Artificial Intelligence*, see their Figure 4.4; for AI patent applications: WIPO (2019) *Technology Trends 2019: Artificial Intelligence*, using the Questel Orbit Intelligence, Fampat Database, March 2018 the Pew Research Center, Americans see cyberattacks from other countries as the top international threat, above that of terrorist militant groups and global climate change. (Poushter and Huang, 2019). Data privacy has also become an issue of major public importance (Box 5.1).

Despite cybersecurity being an issue of growing importance for US citizens, companies and the government, leadership on cybersecurity in the US federal government remains decentralized. This has created a fairly disjointed system, with overlap among multiple federal agencies creating cracks in government oversight. The most notable of these agencies are the Department of Defense's Cyber Command and the Department of Homeland Security's Cybersecurity and Infrastructure Security Agency.

The USA does not yet have a federal-level consumer data privacy law or a data security law. Instead, it relies on a patchwork of regulations from various levels of government and domains to cover its cybersecurity and data privacy legal framework.

A recent report by the Center for a New American Security found that the USA's current cybersecurity legal framework 'is ill-suited to address cybersecurity questions either for legislative oversight or effective policy-making' and that 'existing laws, executive structure and congressional oversight mechanisms are a mismatch for the nature of the cybersecurity challenges presented by a complex, technologically integrated society' (Cordero and Thaw, 2020).

The federal government has taken steps to improve the country's cybersecurity readiness by increasing funding and setting up a Cyberspace Solarium Commission in 2020. The federal budget has increased from US$ 15 billion in 2018 to US$ 18.8 billion in 2021. A majority of this funding goes to the Departments of Defense and Homeland Security.

The Cyberspace Solarium Commission has been created to 'develop a consensus on a strategic approach to defending the USA in cyberspace against cyberattacks of significant consequences' (CSC, 2020). It makes recommendations to Congress around five pillars: government reform; strengthening norms; promoting resilience; operationalizing work with the private sector; and using military power. The focus is on working with allies and partners to shape and promote responsible behaviour in cyberspace, frustrating adversaries who exploit cyberspace to American disadvantage and imposing costs on actors who target the USA in, and through, cyberspace. There is a strong emphasis on defence against catastrophic cyberattacks (Lewis, 2020).

With regard to the first pillar on government reform, one key recommendation by the Solarium concerns the appointment of a National Cyber Director. Supported by dedicated staff within the Executive Office of the President, he or she would serve as the president's principal advisor for cybersecurity-related issues and lead national-level co-ordination of related policies both within the government and with the private sector.

A second key recommendation is for a select committee to be established in both the House and Senate to provide integrated oversight of the cybersecurity efforts dispersed across the federal government.

Further recommendations are for Congress and the executive branch to pass legislation and implement policies designed to recruit, develop and retain cybertalent more effectively to deepen the pool of candidates in the federal government.

All of these recommendations were published in a report by the Solarium in 2020 but have not yet been acted upon (CSC, 2020).

Box 5.1: **Are tech giants monopolizing the information technology sector in the USA?**

Just before the Covid-19 pandemic hit the USA in early 2020, a growing public outcry against what many perceive as the monopolization of the information technology sector led federal regulators to start a wide-ranging effort to determine whether the acquisition strategies of the five US giants were harming competition and, thereby, penalizing consumers, while evading regulatory scrutiny.

These five giants are Alphabet (Google's parent company), Amazon, Apple, Facebook and Microsoft. They had a combined net worth over US$ 5.6 trillion in 2018 that grew by more than 52% in 2019 (The Economist, 2020a). An unbroken flow of mergers in the information technology sector has contributed significantly to this market concentration.

The 'big five' are able to amass and access reams of personal data that are a commercial goldmine but also raise ethical issues about data privacy. They support social media platforms that have been used for political advertising and to disseminate disinformation, with the potential to sway voters. A scandal involving the usage of Americans' data by British political consulting firm Cambridge Analytica to influence the 2016 US presidential election has opened a fierce debate about how major tech companies use and store Americans' data.

This dominant position has raised concerns in Congress and beyond about the 'big five's' growing influence on American society, the economy and politics.

In 2020, the Federal Trade Commission (FTC) ordered the 'big five' to provide detailed information of their acquisitions of smaller rivals. These investigations are being shared with the Department of Justice (DOJ) and the US Congress, who are conducting their own independent antitrust reviews of these technology companies.

The FTC has the power to sue companies to put an end to anti-competitive behaviour. It can take them to court or agree to a settlement that may include a financial penalty. The FTC can block mergers or acquisitions and can even unwind acquisitions or mergers that have already been consummated.

For its part, the DOJ's Antitrust Division can prosecute antitrust violations in criminal court.

The outcome of these investigations was pending as of early November 2020.

Source: compiled by authors

BROAD PRIORITIES: ADVANCED MANUFACTURING

Advanced manufacturing to bolster sector

Beyond the aforementioned strategic platforms in digital technology, American core policy efforts extend to broader fields that include advanced manufacturing, energy and the environment, health and space.

The decline of traditional manufacturing has become a sensitive issue in the USA. Manufacturing output in 2017 was at least 5% greater than in 2000 but the sector has become more capital-intensive and less labour-intensive, owing to the widespread introduction of automation. Some 5.5 million manufacturing jobs were lost between 2000 and 2017. This drop can also be attributed to a skills mismatch for today's more sophisticated manufacturing sector (Hernandez, 2018).

The manufacture of modern devices such as smartphones and medical equipment, but also household items such as desk lamps equipped with light-emitting diode bulbs, requires considerable specialization, owing to the complexity of their components. Manufacturers, thus, have recourse to subcontractors who specialize in a narrow field and who, themselves, rely on other suppliers for essential materials such as display driver chips made in semiconductor factories ('fabs') around the world. Having such a tiered supply system, or value chain, makes it very difficult to reshore manufacturing, or to repurpose a production plant overnight (Shih, 2020).

Manufacturing contributed 11.2% of national GDP in 2017, compared to 12.8% a decade earlier. This decline is of policy concern, even though the sector still plays a large role in the economy. In 2018, the USA had the second-largest manufacturing output in the world (US$ 1.9 trillion) after China (US$ 2.1 trillion). US manufacturing output accounts for 16% of the global total (Manufacturing USA, 2019).

Manufacturing also figures high on the policy agenda on account of the sector's importance to science and technology, high value-added jobs and security concerns (Bonvillian and Singer, 2018; Ramaswamy *et al.,* 2017). It is the manufacturing sector that attracts the lion's share (70%) of private-sector funding and where the bulk of private-sector research is performed. It is, thus, hardly surprising that most new products and processes have historically originated in the manufacturing sector.

Fourteen institutes in advanced manufacturing

In light of such concerns, the Obama Administration embarked on an ambitious Manufacturing USA programme in 2014, the year that Congress passed the Revitalize American Manufacturing and Innovation Act. This programme set out to blend industry, academia and government in a network of advanced manufacturing institutes to promote US competitiveness. Headquartered in the National Institutes of Standards and Technology, Manufacturing USA brought together the National Aeronautics and Space Agency (NASA), the National Science Foundation and the Departments of Commerce, Defense, Energy, Education, Agriculture and Labor.

Fourteen Manufacturing USA institutes were established between 2012 and 2017, sponsored by the Departments of Defense, Energy and Commerce (Figure 5.7). Collectively, these institutes reach 1 291 member organizations, of which 844 are manufacturing firms and 65% are small- and medium-sized manufacturers. These 14 institutes cover a broad range of technological fields ranging from fabrics and lightweight materials to integrated photonics and advanced robotics (Figure 5.7).

An Industry 4.0 campaign

Advanced manufacturing has attracted policy attention throughout the White House's Industry 4.0 campaign, which is using a combination of emerging digital technologies to transform industry. These include industrial robotics, AI, additive manufacturing (also known as 3D printing), high-performance materials, semiconductor and hybrid electronics, photonics, advanced textiles, biomanufacturing and agrifood.

Developed by the National Science and Technology Council (NSTC, 2018b), the Industry 4.0 strategic plan presents a vision for American leadership in advanced manufacturing across industrial sectors to ensure national security and economic prosperity. Its three goals are: to develop and transition to new manufacturing technologies; to educate, train and connect the manufacturing workforce; and to expand the capabilities of the domestic manufacturing supply chain. It is not yet clear which instruments will be used to implement the plan.

BROAD PRIORITIES: ENERGY AND ENVIRONMENT

Rapid growth in natural gas and renewables

The US energy system has undergone a metamorphosis over the past couple of decades, thanks to technological advances in energy production and efficiency. This has led to steep drops in the price of renewables and to exploitation of huge oil and natural gas deposits in unconventional formations like shale, through hydraulic fracturing (fracking) and horizontal drilling, which have raised environmental concerns; widespread fracking has, in turn, reduced the price of natural gas.

Coupled with changes in consumption patterns, these trends have reversed the course of the country from being a growing importer of most forms of energy to a declining importer and even net exporter of oil, natural gas and natural gas liquids.

Since 2017, the government has been pushing hard for energy pre-eminence and security. Although the rise in fossil-fuel production has taken place mostly on onshore non-federal lands, legislation adopted since 2017 has opened up vast public lands to energy prospecting. For instance, nearly 80 million acres of federal waters off the Gulf of Mexico were leased in 2019 for the purpose of oil and gas drilling. This reverses the trend between 2008 and 2017, which saw the share of total gross withdrawals of oil and gas from federal public lands drop from 25% to 13% (CRS, 2018a).

The expansion of oil, natural gas and renewables has been supported by active private- and public-sector investment, including generous tax incentives and steady increases in research funding at the Department of Energy. Between 2015 and 2020, this agency saw its overall research funding increase by 22% to about US$ 19.2 billion (AAAS, 2019).

Between 2010 and 2018, the USA accounted for the most growth in investment in the global energy supply. In 2018, the USA was the second-largest market for investment in energy after China (Figure 5.8) but the lion's share of this investment flowed towards the supply of fossil fuels.

Major transformations are anticipated in the electric power sector, especially. This is because the current infrastructure is ageing and the relative shares of fuel types are changing. There are also considerable uncertainties about how to modernize the power grid by improving transmission and reliability in the face of potential cybersecurity threats and growing interest in renewable energy.

US investment in renewable power has remained high since 2015 (IEA, 2019). It even jumped by 16% in 2018. Investment in distributed solar photovoltaics that year amounted to around US$ 15 billion, second only to China. Investment in renewables is being bolstered by falling costs, federal tax credits that were extended by five more years in December 2015, state portfolio standards and corporate procurement (IEA, 2019; Mai *et al*., 2016).

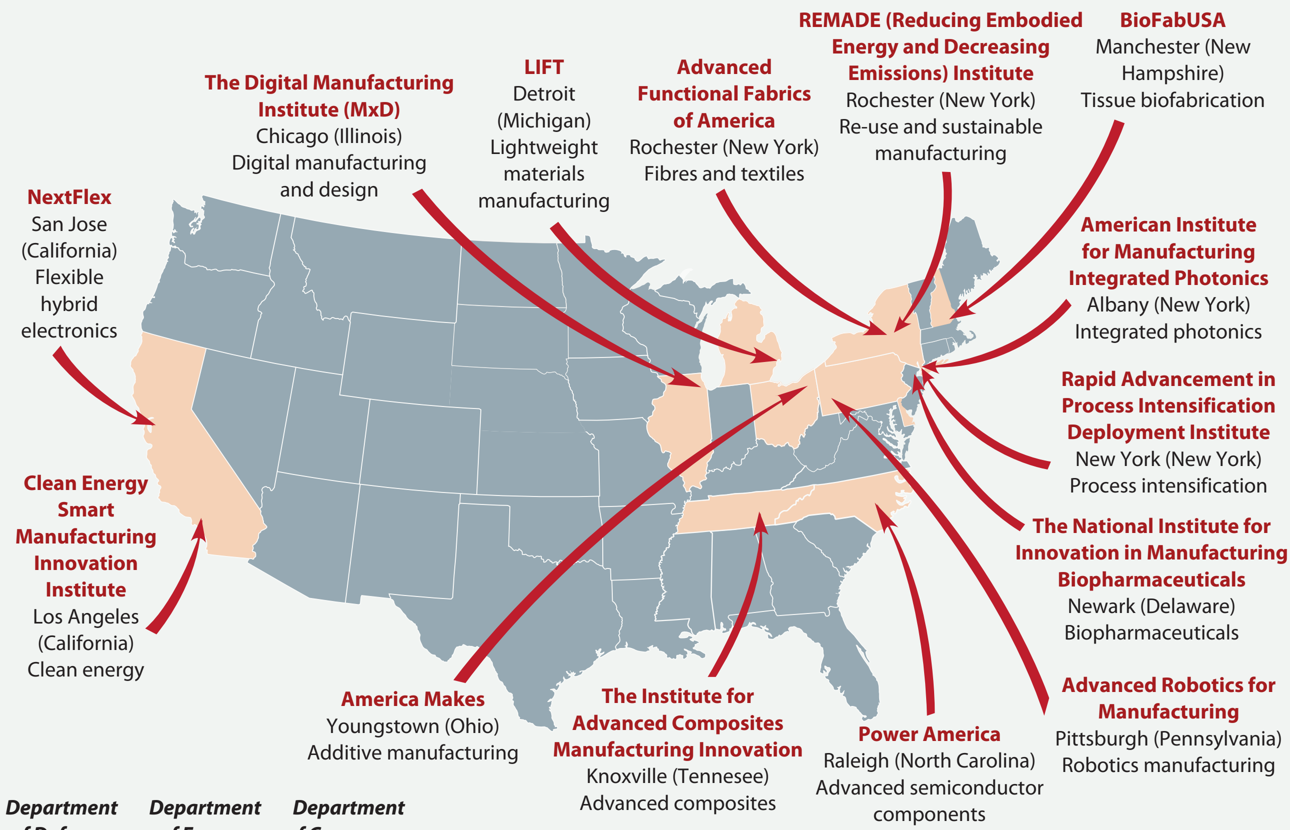
A serious roadblock to encouraging renewable energy deployment has been the huge legacy investments of large established energy companies (Pickl, 2019). US supermajors Chevron and ExxonMobil, for instance, have not followed the path of Royal Dutch Shell, Total, BP, Eni and Equinor in transitioning to broader energy companies with portfolios that include a much larger proportion of renewables.

Greater federal spending on energy research

The amount of federal spending on overall energy R&D has steadily increased since the 1990s, with research on renewables and efficiency gains making up a greater proportion of spending over time. This increase has continued unabated since 2017, despite the large cuts proposed in each of the Administration's annual budget requests, because Congress has not endorsed these proposals. For instance, under the White House's budget proposal for 2021, the allocation for energy research would drop by 45.0% over the enacted 2020 level.[15] 'Funding for energy efficiency and renewable energy R&D would decrease by 70.1% and the

Figure 5.7: **Manufacturing USA institutes, 2017**

The Manufacturing USA institutes are collaborating on over 270 major research projects of priority to broad industrial sectors. They have leveraged US$ 2 billion in private investment and US$ 1 billion in federal funds. More than 200 000 employees have acquired advanced manufacturing skills.



Department of Defense:	Department of Energy:	Department of Commerce:
8 institutes	**5** institutes	**1** institutes

Note: States in California, New York, Ohio, Pennsylvania, New Hampshire, Tennessee, Michigan, Illinois, Delaware and North Carolina host a Manufacturing USA institute

Source: Manufacturing USA. See: https://www.manufacturingusa.com/institutes

Advanced Research Projects Agency-Energy (ARPA-E), would be terminated. ARPA-E has funded more than 800 'potentially transformational' energy technology projects for US$ 2.3 billion since its inception in 2009 (CRS, 2020b).

The Department of Energy accounts for about three-quarters of the federal government's annual investment in clean energy innovation, estimated at US$ 6.4 billion.[16] Investment in clean energy innovation accounted for more than 90% of the department's total investment at the stages of basic and applied research in 2016. Since 2014, funding for energy efficiency and renewable energy R&D at the Department of Energy has more than doubled, steadily increasing each year from US$ 961 million in 2014 to over US$ 2 billion in 2020 (AAAS, 2020).

Most of the business sector's funding of basic and applied research was complemented by federal funding in 2016. More than half of funding at this stage concerns generation technologies (Breakthrough Energy, 2019). Taken together, the public and private sectors invested about US$ 55.5 billion in clean energy in 2019. This places the US second in the world for the size of overall investment in clean energy, trailing China's US$ 83.4 billion investment the same year.

A rollback of environmental protections

Although investment in clean energy and R&D has increased, the USA has also seen a widespread rollback of environmental protections since 2017. Popovich *et al.* (2019) identified more than 90 environmental rules and regulations which had been rolled back by mid-2019. The Trump Administration is promoting deregulation on economic grounds, arguing that this will bring greater choice, productivity and competition and less red tape for businesses.

The decision to withdraw from the *Paris Agreement* was made on similar grounds (Pompeo, 2019). This move has been highly contested, including by several states which have committed to respecting their share of the USA's *Nationally Determined Contribution* under the *Paris Agreement* (Figure 5.8).

For example, the California Air Resources Board signed an agreement with four automakers – Ford, Honda, Volkswagen and BMW – in July 2019 to increase fuel-efficiency standards gradually and support the transition to electric vehicles. This agreement covers about 30% of new cars and sport utility vehicles sold in the USA. In parallel, a California programme is helping to fund the development of hydrogen refuelling stations for zero-emission fuel-cell vehicles. According to the US Energy Information Administration, about 40 of the country's 60 or so hydrogen refuelling stations are situated in the State of California. Transportation accounted for 28% of energy consumption in the USA in 2019 according to the US Energy Information Administration's website.

On 8 July 2019, the US Environmental Protection Agency published its final Affordable Clean Energy Rule to regulate greenhouse gas emissions from certain existing coal-fired power plants (EPA, 2019). This rule is part of the *America First Energy Plan* (2017) and replaces the former administration's *Clean Power Plan* (2015). The *Clean Power Plan* set emissions reduction goals for each state, allowing flexibility on how to meet those goals, thus putting pressure on high-emitting coal plants.

The Affordable Clean Energy Rule has a narrower scope than the *Clean Power Plan*, in that it will regulate the emissions of individual power plants. Although it is unlikely that this regulatory relief will save the coal industry from being marginalized by the burgeoning oil, natural gas, wind and solar industries, the new rule does remove some regulatory pressure from coal plants (EPA, 2019).

The USA has achieved significant reductions in carbon dioxide (CO_2) emissions. These are approximately at the level of the early 1990s, despite the economy having doubled in size since then (Breakthrough Energy, 2019). In addition to efficiency gains, this trend is largely due to the shift away from coal in electricity generation in favour of the cheaper options of natural gas and renewables (Figure 5.8).

This shift is reflected in the *US Energy and Employment Report* (2020). It relates that, in 2019 alone, 8 000 jobs were lost in coal-fired generation, even as 11 000 jobs were created in the renewable technology sector and 9 100 jobs in the natural gas sector (Brady, 2020). In Congress, there are signs of a growing bipartisan consensus on the need to address climate change, leaving room for additional policy support to lower emissions and increased production.

BROAD PRIORITIES: HEALTH

Pandemic has brought remote health technologies to the fore

Besides pharmaceutical compounds, US industry is playing a leading role in advancing health care technology in fields that include automation, robotics and AI. Robotic surgical machines are already a regular presence in American operating rooms, the fruit of billions of dollars of investment by US companies such as Intuitive Surgical, Johnson & Johnson, Medtronic and Stryker.

The Covid-19 pandemic has demonstrated the importance of remote health technologies, which are destined to outlive it. These include technologies for monitoring and diagnosis such as wearables and mobile phone applications that have originated from other sectors. General Electric's Mural virtual care is being used for remote monitoring of ventilated Covid-19 patients, for instance.

Life expectancy is not rising

Despite these achievements, recent health statistics call into question whether the country is using its well-oiled and expensive health machine effectively, especially against the backdrop of the Covid-19 pandemic. Life expectancy is not rising and deaths and morbidity from cardiovascular disease are not falling. Four in ten (42.4%) adults were obese in 2017–2018, up from three in ten (30.5%) in 2000, according to the CDC. A recent study by the University of North Carolina at Chapel Hill found that obese patients (those with a body mass index of 30 or more) were 48% more likely to die from Covid-19. For the authors, 'a major concern is that vaccines will be less effective for the individuals with obesity' (Popkin *et al*., 2020).

The USA is also experiencing an opioid epidemic. Doctors prescribe opioids to treat chronic and acute pain but these substances can lead to addiction. Opioids were involved in 46 802 overdose deaths in 2018, according to the CDC, representing 70% of all deaths from a drug overdose that year. The Administration's research budget for 2021 proposes a specific allocation of US$ 1.4 billion to the National Institutes of Health 'for the opioid and methamphetamine epidemic' (CRS, 2020b).

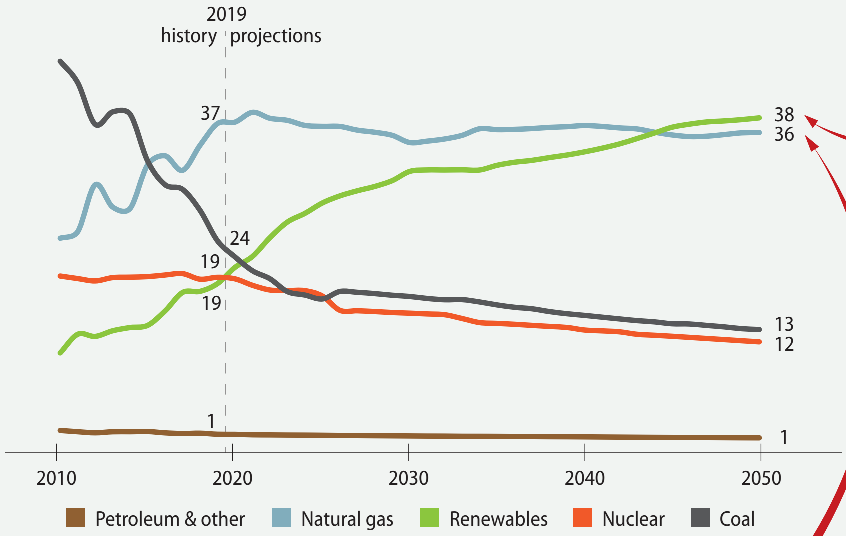
An inequitable health system

The health system suffers from issues of access and equity. The USA spends more per capita on prescription drugs than any other OECD country.[17] The 2018 *National Healthcare Quality and Disparities Report* underlines financial reasons as a major factor for lesser care among populations of lower income levels and ethnic backgrounds (AHRQ, 2018). An estimated 14% of the population remains uninsured (Maddox, 2019).

The formal request by the Trump Administration on 25 June 2020 for the Supreme Court to strike down the Patient Protection and Affordable Care Act (2010, familiarly known as Obamacare), which has extended access to health insurance,[18] sparked a heated debate. Such a move has been possible since 2017 when the US Congress removed the penalty for Americans

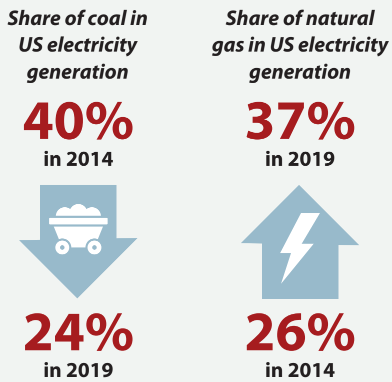
Figure 5.8: **Trends in energy in the United States of America**

Share of electricity generation by source in the USA, 2019 and projection to 2050 (%)
2020 reference case,



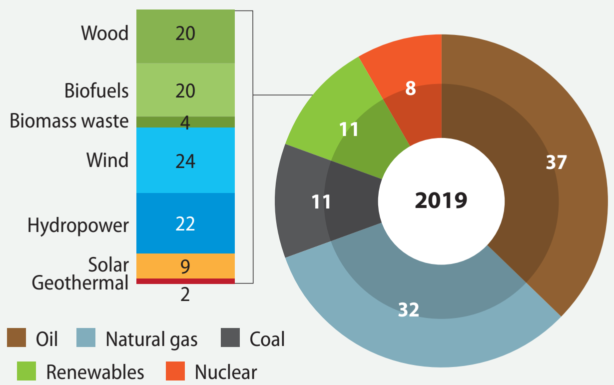
Electricity generation from renewable sources such as wind and solar is projected to surpass nuclear power and coal by 2021 and natural gas by 2045.

The share of renewables in the US electricity generation mix is projected to rise from 19% in 2019 to 38% by 2050.



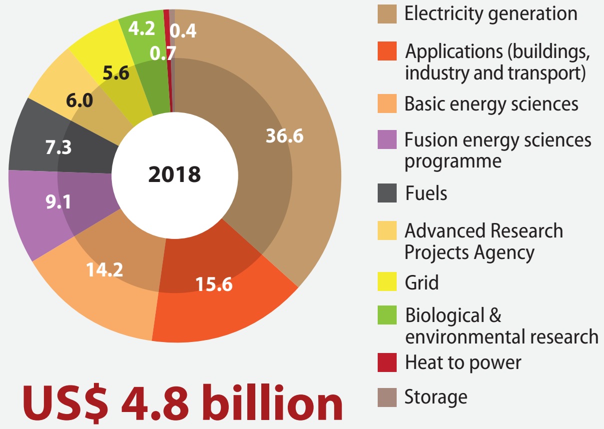
About 28% of total US energy consumption in 2019 was used to transport people and goods.

US primary energy consumption by source, 2019 (%)



100.2
Total consumption: quadrillion British thermal units

Department of Energy budgetary structure, by application, 2018
In US$ millions



US$ 4.8 billion
Total

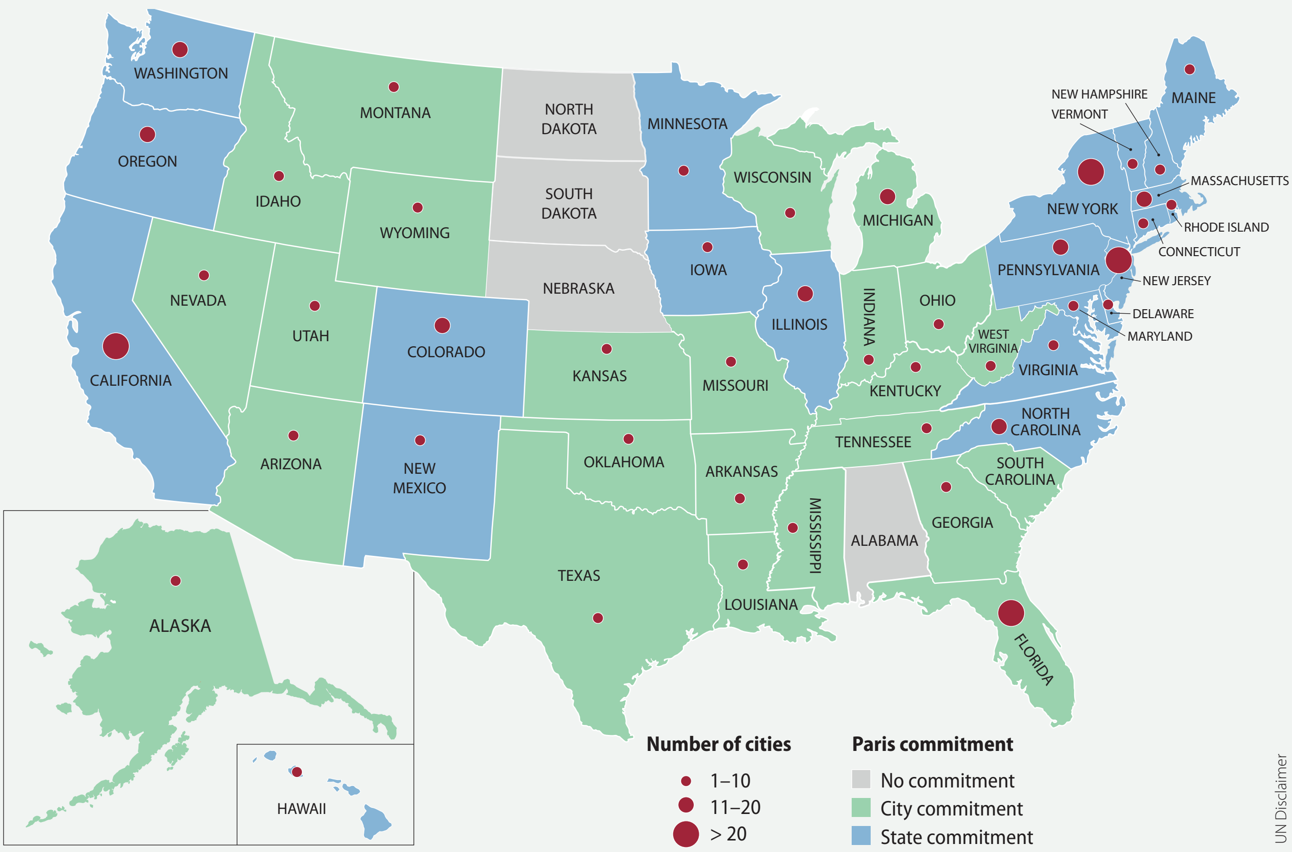
without health insurance. Two lower federal courts have already ruled that this action made the Affordable Care Act's individual mandate unconstitutional, an argument seized upon by the solicitor-general when he filed the legal brief on behalf of the government in 2020 (Dwyer, 2020).

An unsustainable trajectory?

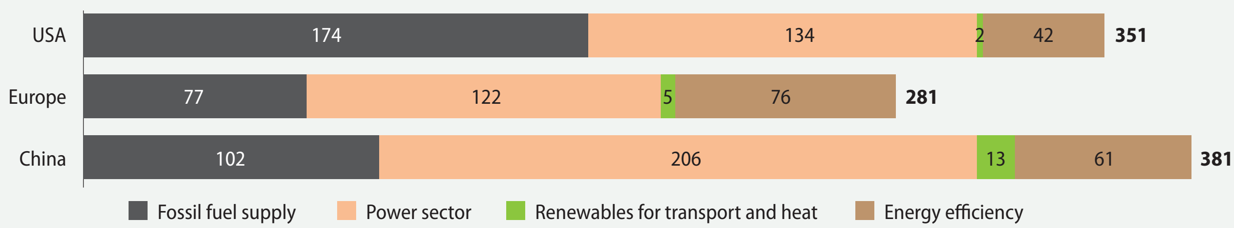
US health care spending reached an astronomical US$ 3.5 trillion in 2017, about 18% of GDP (Maddox, 2019; CMS, 2019). Recent projections are for national health expenditure to grow at an average annual rate of 5.4% between 2018 and 2028 and represent 19.7% of GDP by the end of this period (US$ 6 192.5 trillion), while the insured share of the population is expected to fall from 90.6% to 89.4% over the same period (Figure 5.9).

The share of health care financed by federal, state and local governments is expected to rise by 2% to 47% by 2028, with the cost of Medicare being instrumental in driving up the federal government's share from 28% to 31%. The projected business and household share is expected to fall from 55% to 53% over the same period (Keehan *et al.*, 2020). This appears to be an unsustainable trajectory.

Subnational commitments to meeting the USA's Nationally Determined Contribution under the Paris Agreement



Energy investment by sector in selected markets, 2018
In US$ billions



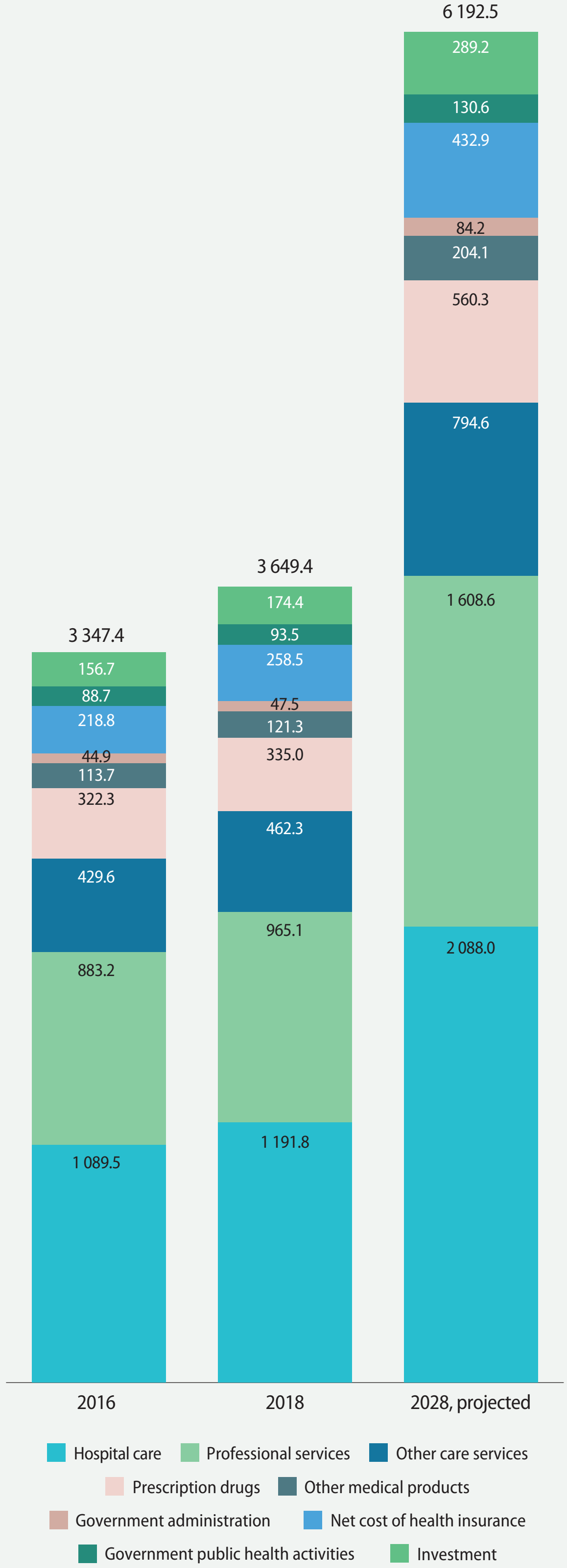
Note: Renewables for transport and heat include transport biofuels and solar thermal heating. Here, Europe covers Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Source: Capuano, L. and EIA (2020) *Annual Energy Outlook 2020*. Presentation by Dr Linda Capuano. US Energy Information Administration; EIA (2020) *April 2020: Monthly Energy Review*; for DOE budget and Paris Agreement commitments: Breakthrough Energy (2019), Figures 1–4 and 1–7; for energy investment: International Energy Agency (2019) *World Energy Investment 2019*. All rights reserved

UN Disclaimer

Figure 5.9: **US national expenditure on health care by spending category, 2016, 2018 and projections to 2028**

In US$ billions



Note: Other care refers here to health, residential and personal care, home health care, nursing care facilities and continuing care retirement communities.

Source: Adapted from Keehan *et al.* (2020), Exhibit 4, p. 708

Hospitals account for about one-third of the budget, physician and clinical services for another one-fifth and prescription drugs for almost another one-fifth (Figure 5.9). An additional significant cost relates to medical devices. It is projected that both the cost of these devices and the cost of drugs will increase substantially in the coming years. It is in these two areas that much of scientific research and innovation is taking place, as we shall see in the following paragraphs.

How much innovation are Americans prepared to pay for?

Prescription drugs typically cost more in the USA than elsewhere (Kliff, 2018). The USA is exceptional, in that it neither regulates, nor negotiates the prices of new prescription drugs. Other countries employ public agencies to negotiate with pharmaceutical companies an appropriate price, typically on the basis of the incremental benefits of the new drug over extant medication.[19] The USA has no such agency.

Medicare, which covers about 55 million Americans over the age of 65 years and which, together with Medicaid, shoulders a substantial share of medical expenses (Figure 5.9), is prohibited by federal law from negotiating drug prices or making decisions about drug coverage. Medicare is, instead, required to cover nearly all drugs approved by the FDA, irrespective of whether these constitute an improvement over extant medication.

Thousands of other health insurance plans negotiate their own prices with pharmaceutical producers separately. The exception is the Veterans Health Administration, which can negotiate drug prices and, as a result, covers fewer products at prices usually one-third or more cheaper than Medicare.

The rationale is industry profitability: the expectation of higher profits, the argument goes, makes the pharmaceutical industry attractive to investors; higher investment, in turn, means more research towards new and innovative cures.

This generous subsidy at the back end is supplemented by another sizeable subsidy at the front end, in the form of the investment in basic research provided by the National Institutes of Health and, thus, by the American taxpayer. This translates into approximately US$ 31 billion in expenditure on basic research to assist the pharmaceutical sector.

US consumers pay the highest prices in the world for the medication they buy over the counter. These high drug prices help to subsidize pharmaceuticals research in the rest of the world but this model is reaching its limits as health care costs spiral upward. The question for policy-makers is: how much innovation are Americans comfortable paying for?

Intellectual property protection is a salient part of this system. Intellectual property rights play an important role in the development and pricing of pharmaceutical products. Patents give inventors temporary monopolies, allowing them to charge less competitive prices by delaying the entry of competitors manufacturing generic drugs and biosimilars.[20] Congress has legislated on both, with the Hatch-Waxman Act (1984) serving to speed up the introduction of generics and the Biologics Price Competition and Innovation Act (2009) doing the same for biologics (CRS, 2019b).

Precision medicine gaining traction

Twenty years on from the first sequence of a human genome, and at huge expense, we now know that the vast majority of diseases do not depend on individual genes. Rather, everyone's genome is unique. This has led to precision medicine. The 21st Century Cures Act (2016) was a milestone, in that it allowed new clinical trials to factor in personalized parameters, such as biomarkers and genetics.

The 21st Century Cures Act established four projects under the National Institutes of Health, namely, the Cancer Moonshot, the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, the Precision Medicine Initiative and Regenerative Medicine. These research programmes have no statutory basis,[21] meaning that they may be eliminated at the discretion of the president (CRS, 2018a). Between 2017 and 2020, all budgetary amounts authorized by the 21st Century Cures Act were fully appropriated (CRS, 2020b).

In 2019, 25% of the 48 new molecular entities approved by the FDA's Center for Drug Evaluation and Research for therapeutics (44) and diagnostics (4) were personalized medicines, according to the Personalized Medicine Coalition. These approvals are part of a trend that began in 2014, when the Coalition classified 21% as personalized medicines. The share of personalized medicines peaked at 42% in 2018.

Precision, of course, brings complexity, namely, the need to understand the molecular variation of individual patients, in order to develop ever-more effective treatments. A drug that works well on one subtype of a disease might fail in a trial that includes patients with another subtype. Cancer, diabetes and Parkinson's disease have already benefitted extensively from precision medicine (*The Economist*, 2020b).

Under the Precision Medicine Initiative, the All of Us Research Program began enrolling volunteers in May 2018 in a study which prioritizes populations traditionally underrepresented in biomedical research (Whitsel *et al.*, 2019).[22] The aim is to compile a vast database to inform research on a wide variety of health conditions. The data platform will be open to researchers worldwide. By September 2020, the programme had recruited 225 000 volunteers out of the 1 million it hopes to enrol in the programme.

The Million Veteran Program launched in 2011 takes a broadly similar approach to the All of Us Research Program, gathering reams of data from individuals but with an additional emphasis on conditions that disproportionately affect veterans, such as post-traumatic stress disorder. This programme is still active; it is part of the president's budget request for 2018 for the Department of Veterans Affairs.

As costs have dropped with the growing sophistication of genome-sequencing technologies, related programmes in the USA and elsewhere have produced torrents of data on individual human genomes, spawning a booming pharmacogenetic industry. In order to analyse this burgeoning volume of data, pharmaceutical companies will become highly dependent on artificial intelligence and cloud computing. They will need to work together with data giants.

New biological insights, new ways of analysing patients and new forms of drugs are opening up a wide range of therapeutic possibilities. Unfortunately, that does not automatically translate into profitable opportunities, since precision medicine also raises costs.

This may help to explain at least part of the cost projections (Figure 5.9). It also suggests that the public health system will need a master plan in order to avoid a situation in which an inordinate share of the public health budget is monopolized by a single disease affecting only a few thousand citizens (orphan drugs).

BROAD PRIORITIES: SPACE EXPLORATION

An America First space policy

Since taking office in January 2017, the Trump Administration has released four space policy directives. The first announced the *National Space Policy* focusing on pioneering and exploration, peace through strength and improving space architecture and capabilities. This directive announced the intent to create policies supporting the US commercial space industry over foreign companies while continuing to rely on foreign partners for burden-sharing on larger, more ambitious projects like the International Space Station.

The next three directives addressed the commercialization of space, space traffic management and the creation of a US Space Force military corps, respectively. The Administration has announced plans to return to the Moon and to be the first to 'set foot' on Mars (Box 5.2).

Released in February 2019, the Space Policy Directive-4 (The White House, 2019) announced the creation of a sixth service of the US military, the Space Force. It will be structured as a corps within the US Air Force.

In support of these ambitious plans, the NASA budget received a 5% boost between 2019 and 2020 to US$ 22.6 billion. In the government's budget proposal for the 2021 fiscal year, NASA was one of only four agencies to receive an increase in its overall budget, with the government proposing a 14% jump.

A Space Force

The goal of the Space Force is 'to consolidate authority and responsibility for national security space in a single chain of command, to build a robust cadre of space professionals who can develop space-centric strategy and doctrine and to avoid the conflicts of interest inherent in the other services that have short-changed space programs for decades' (Harrison, 2018).

Several other countries have already announced similar space commands, including China, France and the Russian Federation. The weaponization of space is rapidly becoming a serious geopolitical and security concern, complicating international relations (The Economist, 2019).

NASA tasking commercial partners with space economy

NASA is returning human spaceflight capabilities to the USA for the first time in nearly a decade. Since the retirement of the Space Shuttle Program in 2011, American astronauts have relied on the Russian Federation for launches to the International Space Station orbiting Earth at an altitude of 400 km.

The retirement of the Space Shuttle Program was one consequence of years of budget cuts. This long period of austerity had left NASA's research budget smaller in 2014 than 20 years earlier (in billions of constant 2012 US$), obliging NASA to shift its focus 'away from human spaceflight, as part of a cost-cutting drive' (Stewart and Springs, 2015).

The retirement of the Space Shuttle was also part of NASA's effort to channel resources away from an old technological system to the next-generation Space Launch System (Box 5.2). The latter is now almost complete and should be far superior to the Space Shuttle.

NASA has adopted a strategy of increasingly tasking commercial partners with developing the space economy, while the agency focuses its own resources on deep space exploration. NASA said as much in a statement issued on 28 February 2017, in which the agency explained that it was 'changing the way it does business through its commercial partnerships to help build a strong American space economy and free the agency to focus on developing the next-generation rocket, spacecraft and systems to go beyond the Moon and sustain deep space exploration' (Thompson, 2017).

NASA's new Commercial Crew Program is partnering with the SpaceX and Boeing corporations. SpaceX transported astronauts Bob Behnken and Doug Hurley to the International Space Station on 3 June 2020, the first time that a private company had launched humans into space.

This feat has ushered in a new era. Public–private partnerships will enable NASA to offload some of its more regular space activities, in order to focus more on long-term, big budget projects such as Artemis and Moon to Mars (Box 5.2).

A space economy dominated by US firms?

The year 2019 marked a peak in global investment in space, with firms headquartered in the USA accounting for 55% of the total. The USA was followed by the UK (24%), France (7%) and China (5%) [Space Capital, 2020].

The US space industry was valued at approximately US$ 158 billion in 2016. It is estimated that 'space systems' within the aerospace and defence industries contributed US$ 39 billion to US economic output in 2018, making space commerce a lucrative industry for the US economy (Highfill *et al.*, 2019).

NASA's public–private partnerships have been key to the development of the private space industry in the USA. Currently valued at over US$ 33 billion, SpaceX is now one of the world's most valuable private companies; it has already launched the most powerful rocket in the world, Falcon Heavy, in February 2018.

SpaceX has even bigger plans, announcing its intention to develop Mars-destined rocket systems that it labels Starship. It also plans to roll out a constellation of 12 000 small satellites through its new Starlink system to provide global Internet connectivity. This system already has hundreds of satellites in orbit and has earned the support of the Federal Communications Commission.

Another US company, Blue Origin, is working on building and launching BE-4, a massive reusable rocket.

Boeing is the primary contractor for NASA's new Space Launch System rocket. The company is also competing with SpaceX to provide the necessary capabilities for a mission to Mars.

This reflects a growing private-sector focus on commercial space activities that range from space tourism to satellite communications and asteroid mining.

TRENDS IN HUMAN RESOURCES

Jobs in science and engineering pay better

There are about 7 million workers in the USA who employ their scientific expertise and technical knowledge in four broad occupational categories: construction and extraction (21%), health care (20%), installation, maintenance and repair (20%) and production (16%) [NSB, 2020].

Box 5.2: **The USA: back to the Moon then on to Mars**

Supporting the Administration's focus on space pioneering and exploration, NASA announced the Artemis project in 2018, as part of the *National Space Strategy*.

The Artemis project aspires to send the next man and the first woman to the Moon by 2024 (The White House, 2018). This mission will act as a testing ground for developing the capabilities necessary to reach Mars, making Artemis the foundation of NASA's Moon to Mars approach.

The project has been named after Artemis, the Greek goddess of wild animals, the hunt and the Moon, the twin sister of Apollo, god of the Sun. Apollo was the last NASA programme to land an astronaut on the Moon, Gene Cernan, in December 1972.

Unlike the Apollo missions of the 1960s and 1970s, the Artemis mission will aim to establish a sustainable presence on the Moon and will work in collaboration with commercial and international partners.

With an ambitious time-frame, Artemis will be powered by NASA's forthcoming Space Launch System. Artemis will include a new powerful rocket and command module, Orion, which will serve as an intermediary step for flying to the Moon then back to Earth. Orion will dock with another key component of the Artemis mission, a Lunar Gateway that will serve as an orbital outpost of the Moon to support human exploration there.

The development of a modern lunar lander and a new generation of spacesuits are also key elements to NASA's return to the Moon.

Beyond the Moon

Following a series of Artemis Moon missions over the next decade, NASA will aim to put astronauts on Mars in the 2030s.

Federal funding is also projected to support both an orbiter and a lander for Jupiter's moon Europa and Saturn's largest moon, Titan, not to mention a solar probe, a new Mars rover and research on the Kuiper Belt.

Source: compiled by authors

The great majority of these individuals work for the business enterprise sector (72%), followed by educational institutions (16%) and the government (12%). Many others with relevant training are employed in occupations not formally classified as science and engineering jobs (NSB, 2020).

Employment in science and engineering occupations has grown more rapidly than the workforce as a whole and now represents about 5% of all US jobs (Figure 5.4). In 2017, the median annual salary in science and engineering occupations across workers of all education levels was US$ 85 390, more than double the median salary for all US workers (US$ 37 690) [NSB, 2020].

Foreign-born workers employed in science and engineering occupations[23] tend to have higher levels of education than those born in the USA: 17% of foreign-born workers held a doctorate in 2017, compared to 9% of US native-born individuals in these same occupations, according to the National Science Board's science and engineering indicators. Among foreign-born computer scientists, mathematicians and engineers, more than half held a doctorate in 2017.

A need for greater inclusiveness

The number of underrepresented minorities – Blacks, Hispanics and American Indians or Alaskan Natives – working in science, technology and engineering in the USA has grown but these groups remain underrepresented, relative to their overall presence in the workforce and population. In 2017, they made up just 13% of the science and engineering workforce but 28% of the US workforce as a whole (NSB, 2020).

The number of women in science and engineering jobs rose from 1.3 million to 2 million between 2003 and 2017. However, even after this increase, women only accounted for 29% of the science and engineering workforce, despite making up 52% of the general workforce with tertiary education.

Many private companies and public agencies are currently making hiring a diverse workforce a pillar of their annual strategies (see chapter 3).

Distance learning imposed by the Covid-19 pandemic may accentuate the social divide in higher education. An April 2020 survey by McKinsey found that only 40% of students from low-income households were able to obtain the necessary equipment for distance learning, compared with 72% of students from high-income households. Only 56% of students from low-income households reported having reliable Internet access, compared with 77% of high-income students (Kim *et al*., 2020).

Automation and AI threatening jobs

The US science and engineering workforce is growing but the system faces major obstacles. Challenges include retraining workers displaced by automation, robotics and AI, encouraging students to enrol in science and engineering fields and recruiting a diverse workforce that is representative of the population.

Many workers are vulnerable to job displacement by automation, robotics or AI. Among those most likely to be displaced by automation are individuals with a high-school degree or less who are performing standardized tasks. These individuals are more than four times more likely to hold highly automatable jobs than those with bachelor's degrees (see also Figure 3.1). Twelve million such workers of Hispanic and Afro-American heritage have already been displaced by automation. In the coming decades, it is estimated that about 25% of US jobs (36 million in 2016) will face high exposure to automation (Muro *et al*., 2019a).

A relatively new phenomenon is that AI is threatening better-paid professional jobs in high-tech fields and metropolitan areas (Muro *et al*., 2019b). This trend will require considerable restructuring of career pathways and training programmes.

To compound matters, the Manufacturing Extension Partnership and the Economic Development Administration (est. 1965) were eliminated in 2019. The same White House budget also proposed a US$ 1.8 billion cut to the Trade Adjustment Assistance Program (TAA) over the next ten years, a 22.8% decrease. This move would severely cut funding to workers impacted by shifting trends in trade. The TAA is up for reauthorization in 2021.

Steady growth in doctorates

The USA will need to recruit new talent into science and engineering to maintain its technological pre-eminence and generate jobs for the industries of the future.

This starts as early as primary school, where the scores of US pupils participating in international assessments have seen little improvement over the past decade. Pupils perform above the OECD average for science but below the OECD average for mathematics, according to the 2018 edition of the OECD's Programme for International Student Assessment.

The higher education system does a much better job of preparing Americans to enter the science and engineering workforce. According to the Bureau of Labor Statistics, 66.2% of secondary school graduates in 2019 (aged 16–24 years) had enrolled in colleges or universities by October 2020 (NSB, 2020).

In 2016, the USA awarded nearly 800 000 bachelor's degrees in fields related to science and technology, compared to almost one million for the European Union. Community colleges play a key role in this achievement; among US students who earned this type of bachelor degree, almost half had done some coursework at a community college in 2016.

The number of doctoral degrees awarded has progressed steadily since 2000, with the exception of a dip in 2010 in the wake of recession. This growth trend is projected to continue. In 2017, the USA awarded almost 46 000 doctorates in science and engineering, 23% of which were conferred on engineers (Figure 5.10).

International students earning one-third of doctorates

One-third (34%) of doctoral degrees awarded in science and engineering went to international students holding a temporary visa in 2017, a stable proportion since 2015; half (54%) of these students came from just three countries: China, the Republic of Korea and India. By comparison, students on temporary visas earned just 6% of bachelor's degrees in science and engineering in 2017, even if their number has more than doubled over the past decade (NSB, 2020).

An April 2020 survey by the Institute of International Education found that 92% of all international students enrolled in US universities had decided to remain in the USA throughout the pandemic. It is likely, however, that the number of international students travelling to the USA for the new academic year will drop, especially those coming from China (Martel, 2020).

CONCLUSION

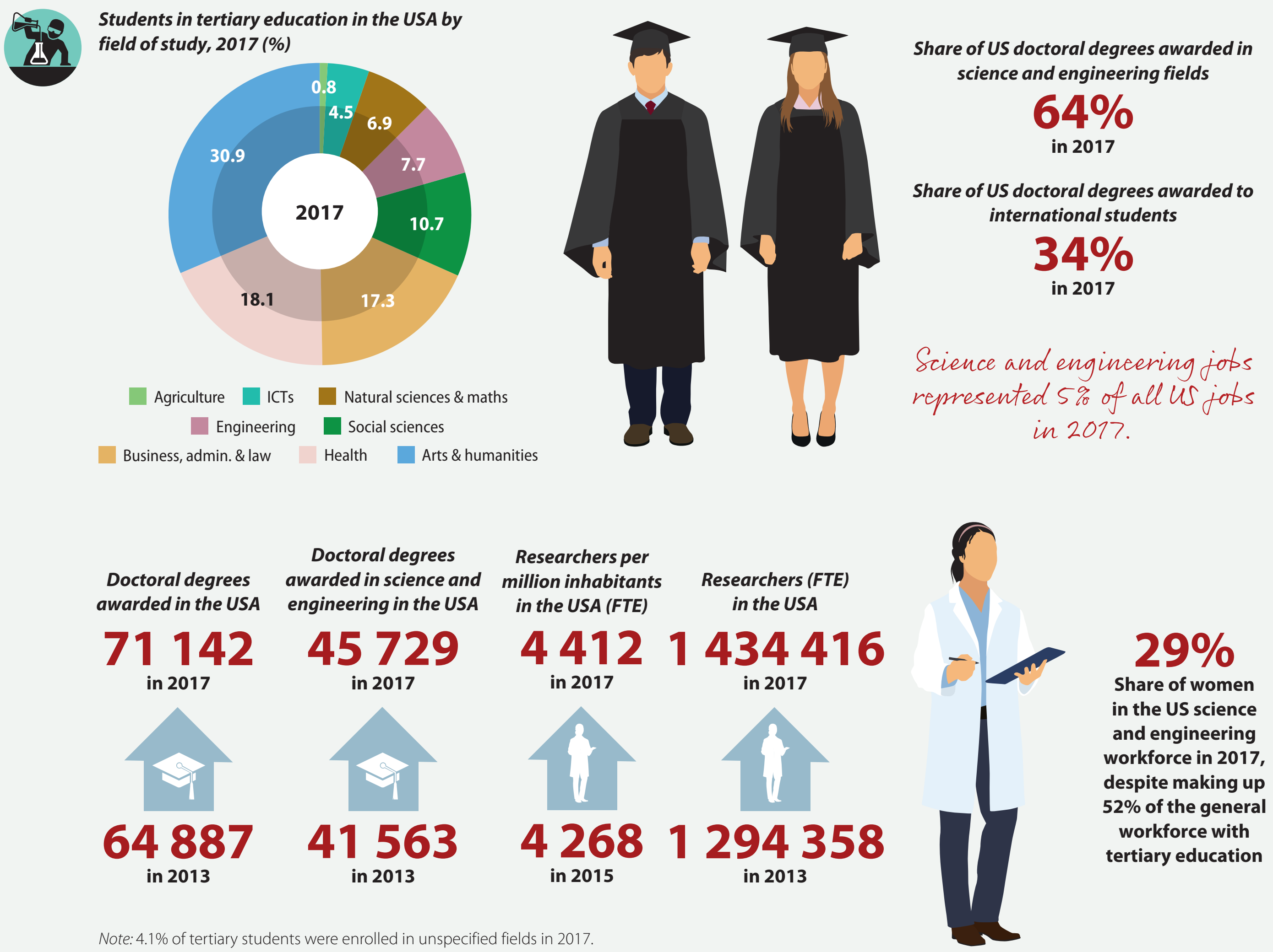
Putting the brakes on unfettered globalization

The national innovation system is being pulled in different directions by the naysayers and the champions of globalization. Totalling well over half a trillion dollars in annual expenditure on R&D alone, the national innovation system is a large 'ship' to manoeuvre. Notwithstanding this, the winds of change have been blowing over the policy ecosystem in the past five years. The USA faces increasing competition in science, technology and innovation from Asian players in particular, such as China, the Republic of Korea and India. This competition is likely to intensify.

To face that challenge, the USA is investing in cutting-edge technologies such as artificial intelligence, quantum computing, 5G technology and cybersecurity. At the same time, the country is training a diverse science and engineering workforce, developing green technology, building an advanced manufacturing industry and creating innovative and affordable health care to sustain the country's economy and workforce.

Looking back, although fears of a widespread increase in protectionism following the Great Recession of 2007–2009 did not materialize, the crisis did affect long-term trends underlying the process of globalization. Neither international trade, nor foreign direct investment and cross-border bank lending have returned to their peak of the early 2000s (The Economist, 2020c). Intensifying international competition, strong security concerns, the current pandemic and the inability of the global economy to completely recover from the Great

Figure 5.10: **Trends in human resources in the United States of America**



Note: 4.1% of tertiary students were enrolled in unspecified fields in 2017.

Source: UNESCO Institute for Statistics; for doctoral degrees: NSB (2019) *Trends in Undergraduate and Graduate S&E Degree Awards. Science and Engineering Indicators 2020.* NSB-2019-7, Table S2-10. See: https://tinyurl.com/y3qhswak

Recession a decade ago have sown doubts about the virtues of globalization for the US economy. Since 2017, protectionism has gained traction with the adoption of the America First policy agenda, one early expression of which has been the US withdrawal from plans for a Trans-Pacific Partnership, a major trading agreement that other countries have gone on to ratify. The process of globalization, which the USA had promoted since the end of the Second World War, is being severely tested.

Meanwhile, China has seized the window of opportunity offered by the Great Recession – from which it emerged largely unscathed – to pursue its rapid march towards the production of goods and services with a higher technology component. In so doing, it hopes to avoid the middle-income trap bedevilling so many other emerging economies (Lee, 2019). In the process, China has garnered new trading partners and become an economic heavyweight.

The economies of both the USA and China have been perturbed since 2018 by a trade dispute that has spilled over into the arena of high technology, technology transfer and intellectual property protection. There is a real risk of decoupling between the two countries in terms of technology and talent.

The virtues of a globalized research system

The emergence of Covid-19 in 2020, with its terrible consequences for the global economy, has provided additional fodder for the naysayers of globalization.

However, this knee-jerk reaction tends to overlook the other side of the coin. The Covid-19 pandemic has demonstrated the virtues of a globalized research system. In the USA and elsewhere, we have seen public and private actors working across borders and disciplines to come to grips with the complexity of this new coronavirus and accelerate the development of treatments, protective personal gear, medical equipment and vaccines for the public good. The current pandemic has made a convincing case for opening up research across borders and ensuring transparency in terms of data- and information-sharing. Be it related to public health, climate change, environmental degradation or other societal issues, scientific research must not be silenced under the pretext that this new knowledge represents a national security risk.

The full consequences of the Covid-19 pandemic are still unclear but there will most likely be major changes to all economic sectors that will affect the scale and direction of the 'technical enterprise'. The US higher education system, for instance, has been profoundly affected by the pandemic; more than half of universities reportedly do not meet basic remote learning preparedness metrics prior to the pandemic and are struggling to find viable ways to educate their students in a remote-only environment. In the current academic year, new enrolment in the US university system by international students, in particular, has taken a sharp downturn, a trend that could persist for years.

Another obvious consequence of the health crisis, as vividly projected in the White House's Operation Warp Speed, has been the pivot by many US experts in the biomedical sector away from long-term projects to short-term support in creating, producing and distributing vaccines, treatments and effective tests for the virus.

Longer-term changes may make a permanent dent in the process of globalization as we know it. The current geopolitical struggle between the USA and China, coupled with the Covid-19 pandemic, significantly raises multinational corporations' exposure to risk. This will elevate the importance of risk mitigation to the level of cost effectiveness as a consideration in determining the resilience of global value chains (Petricevic and Teece, 2019). Nevertheless, the national innovation system is dynamic and should manage to adapt to this rapidly evolving international environment.

KEY TARGETS FOR THE UNITED STATES OF AMERICA

The USA plans to:

- double government investment in research in quantum information science and artificial intelligence by 2022, compared to a 2019 baseline;
- send the next man and first woman to the Moon by 2024.

Nicholas S. Vorontas (b. 1958: Greece) holds a PhD in Economics from New York University. He is currently Professor of Economics and International Affairs at the Institute for International Science and Technology Policy and the Department of Economics at George Washington University in the USA. In parallel, he holds the São Paulo Excellence Chair in Innovation Systems, Strategy and Policy at the University of Campinas (Brazil) and is a Leading Research Fellow at the Institute for Statistical Studies and Economics of Knowledge of the Higher School of Economics in Moscow (Russian Federation).

Brennan Hoban (b. 1994: USA) holds a Bachelor of Arts in International Relations from the American University. She is currently a graduate student at the Institute for International Science and Technology Policy of George Washington University in the USA.

Connor Rabb (b. 1994: USA) holds a Bachelor of Arts in Political Science and International Relations from the University of Georgia. He is currently a graduate student at the Institute for International Science and Technology Policy of George Washington University in the USA.

REFERENCES

AAAS (2019) Historical trends in federal R&D. R&D budget and policy. American Association for the Advancement of Science. See: https://tinyurl.com/y3kgyt38

ABI Research (2019) China's AI ambition gets a reality check as the USA reclaims top spot in global AI investment. Business Wire, 30 October.

AHRQ (2018) *National Healthcare Quality and Disparities Report*: *2018*. Agency for Healthcare Research and Quality: Rockville, USA.

BEA (2019) New foreign direct investment in the United States, 2019. News release. U.S. Bureau of Economic Analysis: Maryland, USA, 1 July.

Bellafiore, R. (2019) *Amortizing Research and Development Expenses under the Tax Cuts and Jobs Act*. Fiscal Fact No. 635. Tax Foundation: Washington, DC, February.

Berger, T. and C. B. Frey (2015) Industrial renewal in the 21st century: Evidence from US cities. *Regional Studies*, 51(3): 404–413. DOI: 10.1080/00343404.2015.1100288.

Bonvillian, W. B. and P. Singer (2018) *Advanced Manufacturing: The New American Innovation Policies*. The MIT Press: Cambridge, Massachusetts, USA.

Brake, D. (2020) *A US National Strategy for 5G and Future Wireless Innovation*. Information Technology and Innovation Foundation: Washington, DC.

Breakthrough Energy (2019) *Advancing the Landscape of Clean Energy Innovation*. Report prepared by IHS Markit and Energy Futures Initiative. Breakthrough Energy: https://tinyurl.com/y6osmrgl

Castellanos, S. (2019) Executives say $1 billion for AI research isn't enough. *Wall Street Journal*, 10 September.

Clarida, R. H. (2020) U.S. economic outlook and monetary policy: remarks by Richard H. Clarids, Vice Chair, Board of Governors of the Federal Reserve System at the New York Association for Business Economics, New York, New York. Speech (transcript), May 21. Board of Governors of the Federal Reserve System: Washington, DC.

Coats, D. R. (2019) *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*. Office of the Director of National Intelligence: Washington, DC.

Cordero, C. and D. Thaw (2020) Rebooting congressional cybersecurity oversight. Center for a New American Security: Washington, DC.

Cox, J. (2020) The Fed's economic forecasts are all over the map, a sign of how uncertain these times are. *CNBC*, 12 June.

CRS (2020a) *CFIUS Reform under FIRMMA*. Congressional Research Service: Washington, DC.

— (2020b) *Federal Research and Development (R&D) Funding: FY2021*. R46341. Congressional Research Service: Washington, DC.

— (2020c) *National Institutes of Health Funding: FY1995–FY2021*. Congressional Research Service: Washington, DC.

— (2019a) *U.S.–China Investment Ties: Overview and Issues for Congress*. Congressional Research Service: Washington, DC.

— (2019b) *Drug Pricing and the Law: Pharmaceutical Pricing Disputes*. Congressional Research Service: Washington, DC.

— (2018a) *21st Century U.S. Energy Sources: A Primer*. Congressional Research Service: Washington, DC.

— (2018b) *Federal Quantum Information Science: An Overview*. Congressional Research Service: Washington, DC.

CSC (2020) *Cyberspace Solarium Commission*. Cyberspace Solarium Commission: Arlington, Virginia, USA, March.

DARPA (2018) DARPA announces $2 billion campaign to develop next wave of AI technologies. Defense Advanced Research Projects Agency, 7 September.

Deloitte (2020) United States economic forecast: 2nd quarter 2020. Deloitte Insights: New York, 15 June.

Deloitte (2019) *Future in the Balance? How Countries are Pursuing an AI Advantage.* Deloitte Center for Technology, Media & Telecommunications. Deloitte Insights: New York.

DIB (2019) *The 5G Ecosystem: Risks and Opportunities for DoD*. Defense Innovation Board: Washington, DC.

Dwyer, D. (2020) Amid pandemic, Trump administration asks Supreme Court to overturn Obamacare. *CBS News*, 26 June.

FCC (2018) *Declaratory Ruling, Report and Order, and Order: In the Matter of Restoring Internet Freedom*. FCC 17-166. Federal Communications Commission: Washington, DC.

— (2016) *The FCC's 5G FAST Plan*. Federal Communications Commission: Washington, DC.

Geller, E. (2019) Collusion aside, Mueller found abundant evidence of Russian election plot. *Politico,* 18 April.

Gibney, E. (2019) The quantum gold rush. *Nature*, *574*(7776): 22–24.

Harrison, T. (2018) Why we need a Space Force. Center for Strategic and International Studies: Washington, DC, 3 October.

Henry, C. (2020) FCC sets December C-band auction, offers up to $14.7 billion for satellite operators. *Space News,* 6 February.

Highfill, T.; Georgi, P. and D. Dubria (2019) Measuring the value of the US space economy. *Survey of Current Business: The Journal of the U.S. Bureau of Economic Analysis*, 99(12).

Hourihan, M. and D. Parkes (2016) *Federal R&D Budget Trends: A Short Summary.* American Association for the Advancement of Science: Washington, DC.

Hwang, V.; Desai, S. and R. Baird (2019) *Access to Capital for Entrepreneurs: Removing Barriers*. Ewing Marion Kauffman Foundation: Kansas City, Missouri, USA.

IEA (2019) *World Energy Investment 2019*. International Energy Agency: Paris.

IMF (2020) *World Economic Outlook 2020: Update*. International Monetary Fund: Washington, DC, June.

Kania, E. and C. John (2018) *Quantum Hegemony? China's Ambitions and the Challenge to U.S. Innovation Leadership.* Center for a New American Security: Washington, DC.

Kauffman, M.; Fairlie, R.; Morelix, A. and I. Tareque (2017) *2017 Kauffman Index of Startup Activity*. Ewing Marion Kauffman Foundation: Kansas City, Missouri, USA.

Keehan, S. P.; Cuckler, G. A.; Poisal, J. A.; Sisko, A. M. *et al.* (2020) National health expenditure projections, 2019–28: expected rebound in prices drives rising spending growth. *Health Affairs*, 39(4): 704–714.

Kennedy, J. (2019) U.S. continues to lag its competitors on tax credits for research and development. Information Technology and Innovation Foundation: Washington, DC, 13 September.

Kim, H.; Krishnan, C.; Law, J. and T. Rounsaville (2020) Covid-19 and US higher education enrolment: preparing leaders for fall. McKinsey & Company: New York, 21 May.

Kliff, S. (2018) The true story of America's sky-high prescription drug prices. *Vox*, 10 May.

Lee, K. (2019) *The Art of Economic Catch-up: Barriers, Detours and Leapfrogging in Innovation Systems*. Cambridge University Press: Cambridge, UK.

Lewis, J. A. (2020) Cyber solarium and the sunset of cybersecurity. Center for Strategic and International Studies: Washington, DC, 13 March.

Maddox, K. E. J. (2019) US health policy – 2020 and beyond. *Journal of the American Medical Association*, 321(17): 1670–1672.

Mai, T.; Cole, W.; Lantz, E.; Marcy, C. *et al.* (2016) *Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions.* NREL/TP-6A20-65571. National Renewable Energy Lab: Golden, Colorado, USA.

Martel, M. (2020) *Covid-19 Effects on High Education Campuses: From Emergency Response to Planning for Future Student Mobility*. Covid-19 Snapshot Survey Series. Institute of International Education: New York.

Metz, C. (2019) Google claims a quantum breakthrough that could change computing. *New York Times,* 23 October.

Muro, M.; Whiton, J. and R. Maxim (2019a) *Automation and Artificial Intelligence: How Machines are Affecting People and Places.* The Brookings Institution: Washington, DC.

— (2019b) *What Jobs are Affected by AI? Better-paid, Better-educated Workers Face the Most Exposure*. The Brookings Institution: Washington, DC.

National Academies of Sciences, Engineering, and Medicine (2017) *Securing Advanced Manufacturing in the United States: The Role of Manufacturing USA: Proceedings of a Workshop*. National Academies Press: Washington, DC.

Manufacturing USA (2019) Revitalizing American leadership in advanced manufacturing. National Institutes for Standards and Technology. Manufacturing USA: https://tinyurl.com/y6o6rdme

NSB (2020) *The State of US Science and Engineering 2020.* National Science Board. National Science Foundation: Arlington, Virginia, USA.

NSF (2019) *National Patterns of R&D Resource: 2016–17*. Detailed Statistical Tables. NSF 19-309. National Center for Science and Engineering Statistics, National Science Foundation: Alexandria, Virginia, USA.

NSTC (2019a) *The National Artificial Intelligence Research and Development Strategic Plan: 2019 Update*. Select Committee on Artificial Intelligence. National Science and Technology Council: Washington, DC, September.

— (2019b) *2016–2019 Progress Report: Advancing Artificial Intelligence R&D.* Artificial Intelligence Research & Development Interagency Working Group. National Science and Technology Council: Washington, DC, September.

— (2018a) *National Strategic Overview for Quantum Information Science*. National Science and Technology Council: Washington, DC, September.

— (2018b) *Strategy for American Leadership in Advanced Manufacturing*. Subcommittee on Advanced Manufacturing, Committee on Technology. National Science and Technology Council: Washington, DC, September.
— (2016) *The National Artificial Intelligence Research and Development Strategic Plan*. National Science and Technology Council: Washington, DC, October.
Office of the United States Trade Representative (2020) *The People's Republic of China: U.S.–China trade facts*. Executive Office of the President. See: https://tinyurl.com/hjot3sf
OMB (2020) *A Budget for America's Future: Analytical Perspectives.* Budget of the U.S. government: fiscal year 2021. U.S. Government Publishing Office: Washington, DC.
— (2019) *A Budget for a Better America*. Budget of the U.S. government: fiscal year 2020. U.S. Government Publishing Office: Washington, DC.
Petricevic, O. and D. J. Teece (2019) The structural reshaping of globalization: Implications for strategic sectors, profiting from innovation, and the multinational enterprise. *Journal of International Business Studies*, 50(9): 1487–1512. DOI: https://doi.org/10.1057/s41267-019-00269-x
Pickl, M. J. (2019) The renewable energy strategies of oil majors – from oil to energy? *Energy Strategy Reviews*, 26(100370). DOI: https://doi.org/10.1016/j.esr.2019.100370
PitchBook (2020) *Venture Monitor: Q2 2020*. PitchBook Data, Inc.: Seattle, USA.
Pompeo, M. R. (2019) On the U.S. withdrawal from the Paris Agreement. Press Statement. U.S. Department of State, 4 November.
Popovich, N.; Albeck-Ripka, L. and K. Pierre-Louis (2020) The Trump Administration is reversing 100 environmental rules: here's the full list. *The New York Times*, 20 May.
Porter, J. (2019) Google confirms 'quantum supremacy' breakthrough. *The Verge,* 23 October.
Poushter, Jacob and Christine Huang (2019) Climate change still seen as top global threat, but cyberattacks rising concern. Pew Research Center's Global Attitudes Project. Blog, February.
PwC (2020) *PwC/CB Insights MoneyTree Report*. Investments by region: Q1 1995 – Q2 2020. PricewaterhouseCoopers: London.
Ramaswamy, S.; Manyika, J.; Pinkus, G.; George, K. *et al.* (2017) *Making it in America: Revitalizing US Manufacturing*. McKinsey Global Institute: Washington, DC.
Space Capital (2020) *Space Investment Quarterly: Q4 2019*. Space Capital: New York.
Stewart, S. and Stacy Springs (2015) United States of America. In: *UNESCO Science Report: towards 2030*. UNESCO: Paris.
TEConomy and BIO (2020) *The Bioscience Economy: Propelling Life-saving Treatments, Supporting State & Local Communities*. TEConomy and Biotechnology Innovation Organization: Columbus, Ohio and Washington, DC, USA.
The Economist (2020a) *Big Tech's $2trn Bull Run*. The Economist: London, 21 February.
— (2020b) *Technology Quarterly: Personalised Medicine*. *The Economist*: London, 14 March.
— (2020c) Covid-19's blow to world trade is a heavy one. Briefing. *The Economist,* 16 May.
— (2019) *The Next 50 Years in Space*. The Economist*:* London, 20 July.
The White House (2020a) Memorandum for the Heads of Executive Departments and Agencies. Office of Management and Budget. The White House, 20 January.
— (2020)b *National Strategy to Secure 5G of the United States of America*. The White House: Washington, DC.
— (2019) Text of Space Policy Directive-4: establishment of the United States Space Force. Presidential Memorandum. The White House, 19 February.
— (2018) President Donald J. Trump is unveiling an America First National Space Strategy. Fact sheet. The White House, 23 March.
Thomas, W. (2019) National quantum Initiative signed into law. FYI: Science Policy News from American Institute of Physics*,* 4 January.
Thompson, Tabitha (2017) Statement about SpaceX Private Moon Venture Announcement. Press statement, 28 February.
Travagnin, M. (2019) *Patent Analysis of Selected Quantum Technologies.* JRC Technical Report. Joint Research Centre, European Commission. Publications Office of the European Union: Luxembourg. ISBN: 978-92-79-98120-3.
U.S. Census Bureau (2020) Trade in goods with China. Database. United States Census Bureau: https://www.census.gov/foreign-trade/balance/c5700.html
Whitsel, L.; Wilbanks, J.; Huffman, M. D. and J. L. Hall (2019) The role of government in precision medicine, precision public health and the intersection with healthy living. *Progress in Cardiovascular Diseases*, 62(1): 50–54.
WIPO (2019) *WIPO Technology Trends 2019: Artificial Intelligence*. World Intellectual Property Organization: Geneva.

ENDNOTES

1 The present report not only covers UNESCO member states. The USA's withdrawal from UNESCO came into effect on 31 December 2018.
2 See: https://coronavirus.jhu.edu/data/mortality
3 See: https://climate.law.columbia.edu/Silencing-Science-Tracker
4 US Bureau of Labor Statistics press release of 6 November 2020
5 For example, the combined trade deficit in goods and services with China was US$ 378.6 billion in 2018, whereas the deficit in goods alone reached US$ 419.2 billion. These deficits compare with a US surplus of US$ 33.4 billion in goods and services and US$ 31.0 billion in goods with China's special administrative region of Hong Kong. Although a significant share of the trade imbalance is attributable to American multinational corporations, reliable data are difficult to come by. Such numbers largely explain the eagerness of successive US administrations to address the huge trade imbalances with China (Office of the United States Trade Representative, 2020). For more details of bilateral trade balances, see US Census Bureau (2020).
6 The stock of US FDI in China amounted to US$ 116.5 billion in 2018 (up 8.3% from 2017), whereas Chinese FDI stock in the USA amounted to US$ 60.2 billion (up 3.7% from 2017), accounting for 1.4% of total FDI stock in the USA, up from 0.05% in 2002 (CRS, 2019a).
7 Congress may opt to agree with none, part or all of the president's request and may express different priorities through the appropriations process (CRS, 2020b).
8 The ratio between the Federal Research Tax Credit and Qualified Research Spending by business has declined since 2000.
9 See the Census Bureau, US Department of Commerce: www.census.gov/econ/bfs/index.html
10 The legislative branch in the USA is comprised of the House of Representatives and the Senate, collectively referred to as Congress.
11 An executive order is a directive from the president to the relevant federal agencies to act in a given area but it does not constitute an actionable strategy in itself. In issuing an executive order, the president does not create a new law or appropriate funds from the US Department of the Treasury, these steps being the purview of Congress.
12 See: https://www.whitehouse.gov/ai/
13 The other founding members of the Global Partnership on Artificial Intelligence are Australia, Canada, the European Union, France, Germany, India, Italy, Japan, Rep. Korea, Mexico, New Zealand, Singapore, Slovenia and the UK. The GPAI Secretariat is hosted by the OECD in Paris, France. UNESCO will be tabling an international instrument on the ethics of AI for adoption by 192 member states in November 2021.
14 A carrier is a wireless service provider that supplies mobile phones with cellular connectivity. There are now three major carriers in the USA, following the merger of T-Mobile and Sprint.
15 The other two categories at the Department of Energy are national security and science.
16 Other agencies conducting energy science research include the Department of Defense, the Department of Transportation and the Department of Agriculture.
17 The USA spent US$ 1 229 per capita on pharmaceuticals in 2018, well ahead of Switzerland's US$ 894, the next biggest spender among OECD countries. See: https://data.oecd.org/healthres/pharmaceutical-spending.htm
18 See: California *et al*., Petitioners v. Texas *et al*., case no. 19-10011.
19 In Australia, for instance, this body is the Pharmaceutical Benefits Advisory Committee (Kliff, 2018). It is estimated that American citizens pay twice as much as Australians for the same drugs.
20 For a discussion of biosimilars in the USA, see Stewart and Springs, 2015.
21 Multiagency research programmes with a statutory basis include the Networking and Information Technology Research and Development Program (est. 1991), the National Nanotechnology Initiative (est. 2001) and the US Global Change Research Program (est. 1990), which studies climate change.
22 See: https://databrowser.researchallofus.org/
23 Foreign-born workers employed in science and engineering occupations are a self-selected group, as related studies are conducted within US institutions of higher education.

UNESCO SCIENCE REPORT

The race against time for smarter development

It is striking how development priorities have aligned over the past five years. Countries of all income levels are prioritizing their transition to digital and 'green' economies, in parallel. This dual transition reflects a double imperative. On the one hand, the clock is ticking for countries to reach their Sustainable Development Goals by 2030. On the other, countries are convinced that their future economic competitiveness will depend upon how quickly they transition to digital societies. The UNESCO Science Report's subtitle, 'the race against time for smarter development', is an allusion to these twin priorities.

This seventh edition of the report monitors the development path that countries have been following over the past five years from the perspective of science governance. It documents the rapid societal transformation under way, which offers new opportunities for social and economic experimentation but also risks exacerbating social inequalities, unless safeguards are put in place.

The report concludes that countries will need to invest more in research and innovation, if they are to succeed in their dual digital and green transition. More than 30 countries have already raised their research spending since 2014, in line with their commitment to the Sustainable Development Goals. Despite this progress, eight out of ten countries still devote less than 1% of GDP to research, perpetuating their dependence on foreign technologies.

Since the private sector will need to drive much of this dual green and digital transition, governments have been striving to make it easier for the private sector to innovate through novel policy instruments such as digital innovation hubs where companies can 'test before they invest' in digital technologies. Some governments are also seeking to improve the status of researchers through pay rises and other means. The global researcher population has surged since 2014.

The Covid-19 pandemic has energized knowledge production systems. This dynamic builds on the trend towards greater international scientific collaboration, which bodes well for tackling this and other global challenges such as climate change and biodiversity loss. However, sustainability science is not yet mainstream in academic publishing, according to a new UNESCO study, even though countries are investing more than before in green technologies.

With financial support from

FONDATION IPSEN

unesco

9 789231 004506