European Commission

May 2021

Advanced Technologies for Industry – International Reports

Advanced technology landscape and related policies in the United States of America

This report was prepared by Kincsö Izsak from Technopolis Group and

Prof. Pierre-Alexandre Balland, Utrecht University & Artificial and Natural Intelligence Toulouse Institute (Chapter 2).

EUROPEAN COMMISSION

European Innovation Council and SMEs Executive Agency (EISMEA)

Unit I.02.2 — SMP / COSME Pillar

E-mail: EISMEA-SMP-COSME-ENQUIRIES@ec.europa.eu

Directorate General for Internal Market, Industry, Entrepreneurship and SMEs

Unit D.2 — Industrial forum, alliances, clusters

E-mail: GROW-ATI@ec.europa.eu

European Commission

B-1049 Brussels

PDF ISBN 978-92-9460-748-5 doi: 10.2826/18195 EA-03-21-310-EN-N

May 2021

Table of Contents

Section

Introduction

The objective of the international country reports is to explore the technology and policy landscape of selected non-European countries. Country performance in advanced technologies is presented based on patent, trade and investment data. This particular report is an update and extension of the US report published in 2020 (https://ati.ec.europa.eu/reports/international-reports/report-united-states-america-technological-capacities-and-key-policy) and zooms into two technology ecosystems notably into Artificial Intelligence and Nanotechnology. The reason why these fields have been selected is that they represent technologies where the US is particularly strong and important lessons can be drawn for the EU. The analysis relies on the data collected within the ATI project complemented with expert opinion.

The starting point of this analysis has been sixteen advanced technologies that are a priority for European industrial policy and that enable process, product and service innovation throughout the economy and hence foster industrial modernisation.

Advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment and include *Advanced Materials, Advanced Manufacturing, Artificial Intelligence, Augmented and Virtual Reality, Big Data, Blockchain, Cloud Technologies, Connectivity, Industrial Biotechnology, the Internet of Things, Micro and Nanoelectronics, Mobility, Nanotechnology, Photonics, Robotics and Security*. The full methodology behind the data calculations is available on the ATI website: https://ati.ec.europa.eu/reports/eu-reports/advanced-technologies-industry-methodological-report.

The report is structured as the following:

- The first section outlines the overall performance of the US in terms of technology generation (patent applications), trade and venture capital data.
- The second section dives into the field of Artificial Intelligence and the US ecosystem.
- The third section presents the US nanotechnology ecosystem.
- The last section analyses the COVID-19 impact and economic responses.

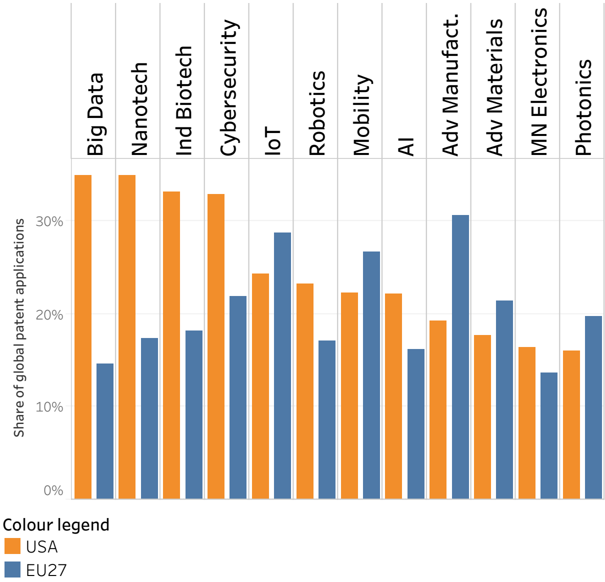
Section 1

1 Overall performance in advanced technologies

1.1 Patent applications

The US has been the world's leading nation in science and technology since the mid-1950s. An analysis of its current share of transnational patent applications helps to assess its current technological performance across twelve advanced technologies in the focus of this report. Figure 1 visualises this measure for the US in comparison with the EU27 in 2018.

Figure 1: Share in global transnational patent applications in advanced technologies (2018)[1]



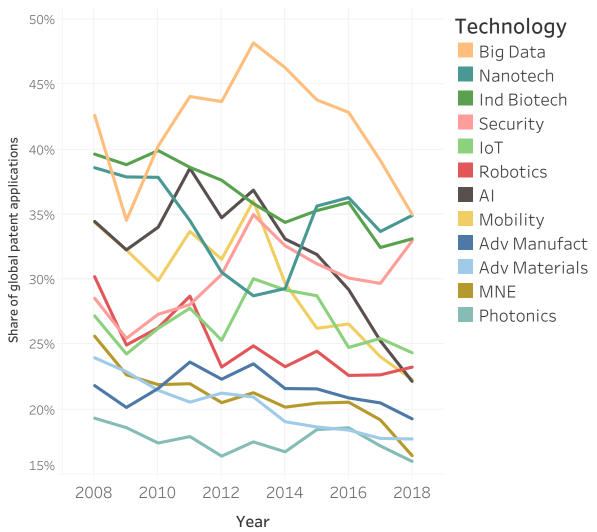
Source: Fraunhofer ISI, based on EPO PATSTAT

Compared to the EU27, the US holds higher shares of worldwide transnational patent applications in Big Data (close to 40%), Nanotechnology, Industrial Biotechnology and Cybersecurity as well as, by a lesser margin, in Artificial Intelligence, Robotics and Micro- and nanoelectronics (MNE).

The EU27 holds higher shares in Advanced Manufacturing Technology (AMT), Advanced Materials, Photonics and also technologies related to the Internet of Things (IoT) as well as IT for Mobility.

In terms of trends over the period 2008-2018, we see that the leadership of the US declined in various advanced technologies which is the result of Asian countries increasing their share and increased activity on the global patent landscape (see Figure 2). It is only the field of Cybersecurity where the US has increased its share in global patent applications over the period from 2008 to 2018.

Figure 2: Trends in the share in global transnational patent applications in the US



Source: Fraunhofer ISI, based on EPO PATSTAT

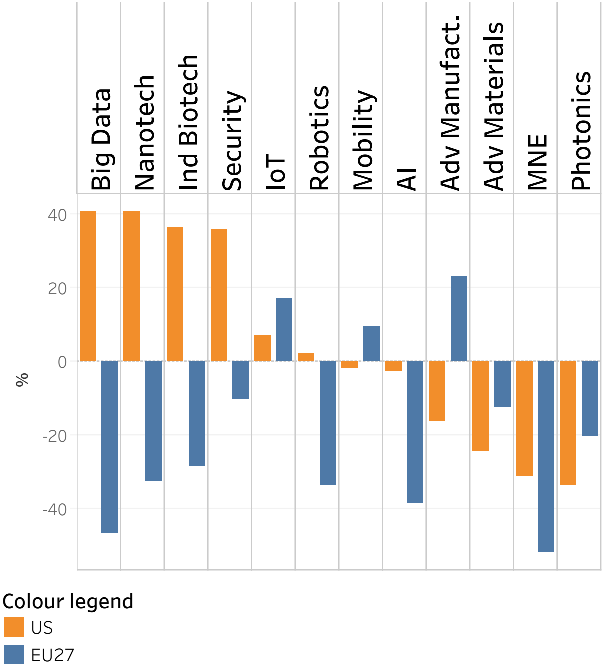
The analysis of the RPA-index[2] as visualised in Figure 3 demonstrates the US relative technological specialisation in the twelve advanced technologies in comparison with the EU27.

The US has a high relative specialisation in Big Data, Nanotechnology, Industrial Biotechnology and Security and a relatively lower specialisation in Robotics and IoT. Negative specialisation is found in Photonics, Advanced Manufacturing Technologies, Advanced Materials and Micro- and nanoelectronics, Artificial Intelligence and Mobility. Compared to 2017, the specialisation of the US both in Mobility and in Artificial Intelligence turned into negative values. In the case of Robotics, it became positively specialised.

[1] The diagrams in this report have been prepared with the software tableau.

[2] The RPA-Index illustrates the relative specialisation on a scale from -100 to +100, putting the share of a specific field in national applications in relation to the global average share.

Figure 3: Technological specialisation RPA-Index of the US and EU27 (2018)



Source: Fraunhofer ISI, based on EPO PATSTAT

1.2 International competitiveness

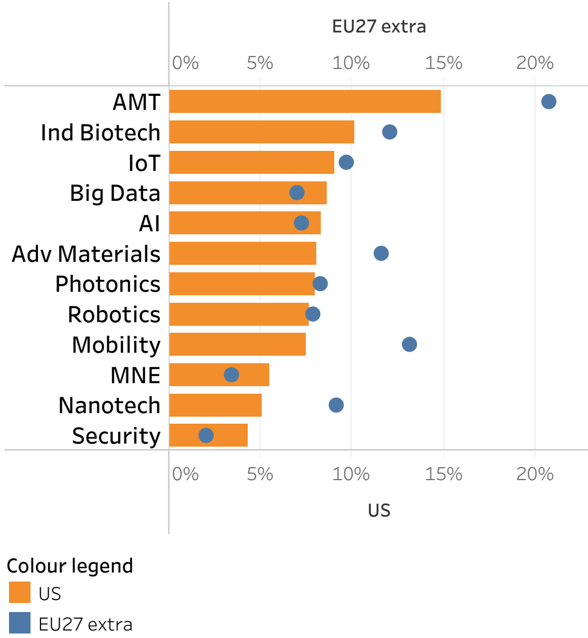
Trade measures are a common indicator of global competitiveness, as they document the attractiveness of a country's products beyond the home market. Total exports provide evidence about a country's role as a producer, and trade balance captures its sovereignty in certain areas of production.

Figure 4 visualises the US share of global technology exports in 2018 based on the analysis of UN COMTRADE data. Compared to the EU27 the US exports more products relevant for Micro- and nanoelectronics, Artificial Intelligence, Security, Big Data, IoT and Robotics. Trends over the period of 2008-2018 show that the US managed to safeguard its export share in Nanotechnology, Advanced Materials and Industrial Biotechnology but it decreased in the case of all other technologies in particular in Cybersecurity.

Figure 5 visualises the trade balance[3] in relation to the total trade volume of the US and the EU27 countries in 2018.

Besides a marked export surplus in Advanced Manufacturing Technologies and a close to an even trade balance in Micro-and nanoelectronics, the US displays a strong relative trade deficit with regard to goods relevant for all advanced technologies. Overall, however, this situation does not differ much from that of the EU, since the main exporters of advanced technology related goods are located in East Asia at least since the mid-1990s. The US trade balance in advanced technologies has been continously decreasing since 2008 except for Advanced Manufacturing Technologies.

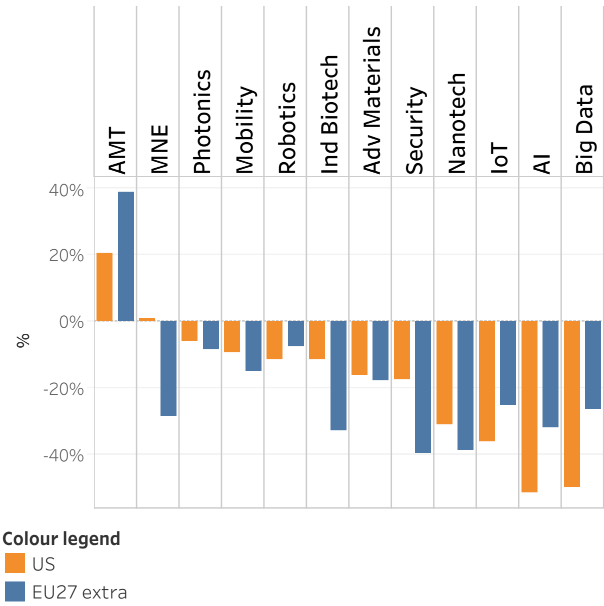
Figure 4: Export *share in world total (2018)*



Source: Fraunhofer ISI, based on UN COMTRADE

Note: "EU27-extra" refers to exports to non-EU countries, i.e. competitiveness-based exports outside the single market. The view is filtered on the US, which ranges from 4.35 to 14.85%

Figure 5: Trade balance in relation to overall trade volume (exports - imports) (2018)



Source: Fraunhofer ISI, based on UN COMTRADE

Note: "EU27-extra" refers to exports to non-EU countries, i.e. competitiveness-based exports outside the single market

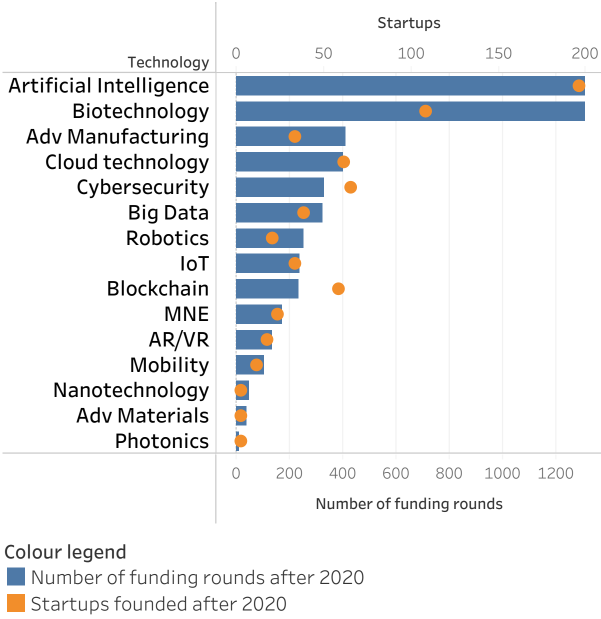
[3] Exports - Imports

1.3 Startup and scaleup activities in advanced technologies

Figure 6 analyses private and venture capital (VC) investments in advanced technologies in the US and illustrates the number of investment deals concluded in 2020 in advanced technologies and the number of startups founded in 2020 in the US based on Crunchbase[4] data.

The analysis suggests that the number of funding rounds was the highest in Artificial Intelligence and Biotechnology followed by Advanced Manufacturing and Cloud technologies. Startup creation has continued and has been especially strong in Artificial Intelligence and Industrial Biotechnology.

Figure 6: The number of funding rounds in advanced technologies and startups established in 2020 or after, US (2020)



Source: Technopolis Group calculations based on Crunchbase

[4] Private equity, venture capital investment and related innovative start-up creation have been explored based on a merged dataset available in Crunchbase and Dealroom. Crunchbase provides information on venture capital backed innovative companies.

Section 2

2 US ecosystem in Artificial Intelligence

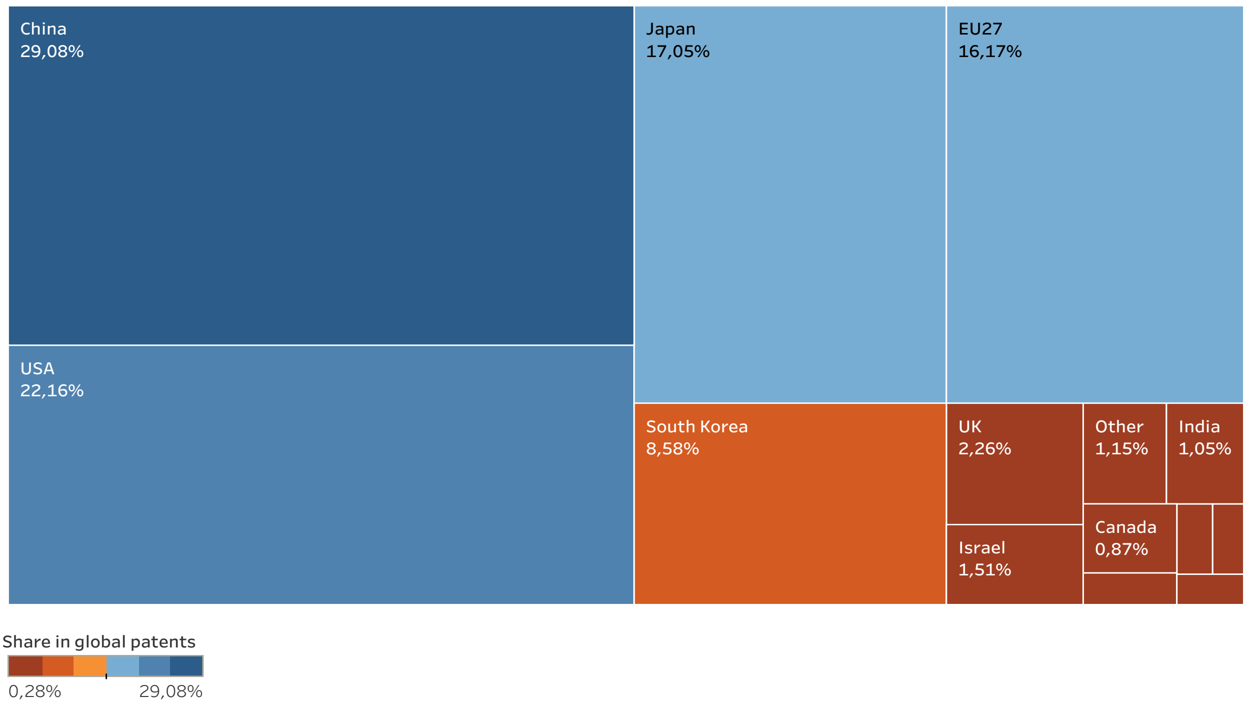
2.1 US performance in AI

The United States has led the first wave of the AI revolution. Tech giants such as Google, Amazon and Facebook, have built their corporate success by leveraging global internet data to develop the best AI recommendation systems. They are today among the most valuable companies in the world. The market capitalisation of Amazon is $1.7 tn (ca. €1.4 tn) – which represents the GDP of Spain and Portugal combined – while the market capitalisation of Google is $1.3 tn and the one of Facebook is $760 bn (ca. €620 bn). China is the only country that has grown AI giants that can compete with the US ones with Tencent, Alibaba and Baidu. Their market size and R&D investments are massive but still smaller than their US competitors.

In 2018 (the latest year when patent data are robust and available), one of every five patents filed under the Patent Cooperation Treaty (PCT)[5] or at the European Patent Office in Artificial Intelligence came from inventors living in the United States (Figure 7). This is more patents per capita than China or the EU27 countries combined.

The AI gap between the US and the EU has increased. There is still no equivalent to Google, Amazon or Facebook in Europe and there are very few European AI unicorns (examples are Klarna, an eCommerce payment solutions platform for merchants and shoppers or the Paris-based Meero that is an AI photography platform). From 2005 to 2018, the US has consistently produced more AI PCT + EPO patents than all EU27 countries combined[6]. This gap has continuously increased since the Great Recession of 2007-2009. By 2009 – which corresponds to the pre-deep learning phase (less data-driven machine learning AI) the EU27 countries produced about 30% of all PCT + EPO patents. At this date, the US patent production was about 32%. Given that the UK was still in the EU, the EU28 had an even higher share than the US with 33.6%. By 2018, the EU27 was producing only 2 patents for every 3 US patents.

Figure 7: Share in global patent applications, PCT + EPO in Artificial Intelligence

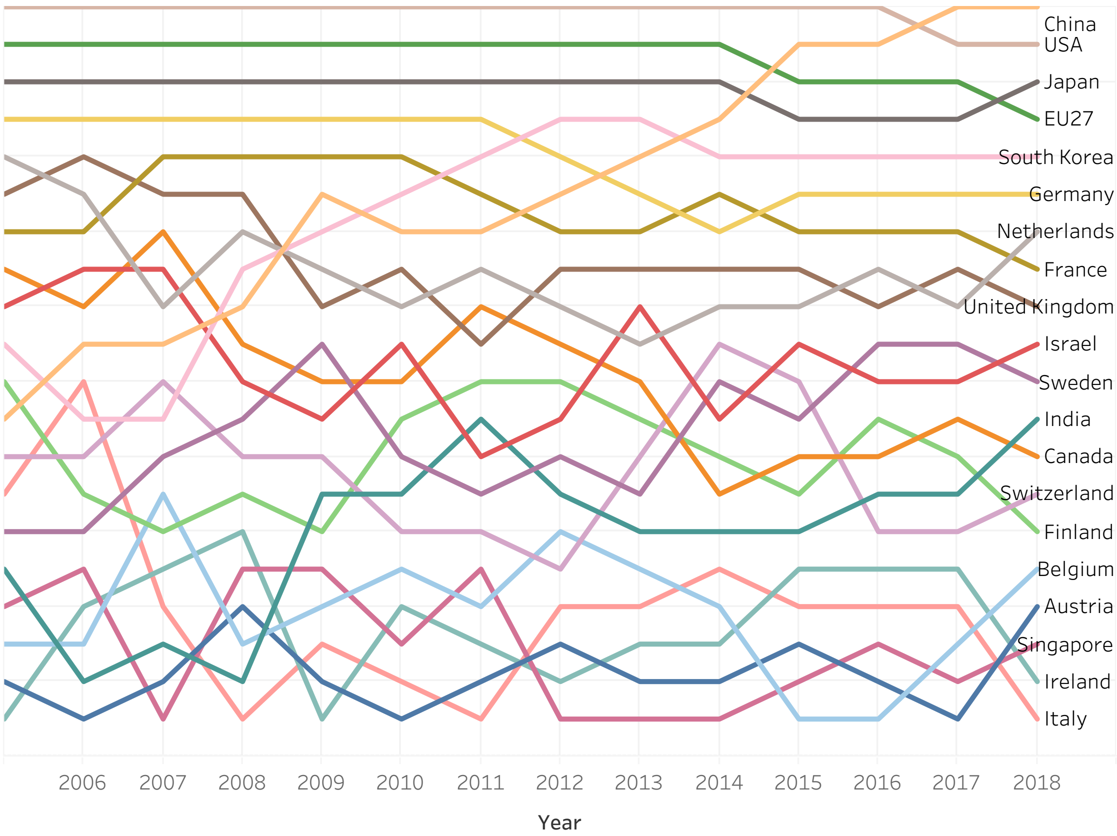


Source: Fraunhofer ISI, based on PCT and EPO PATSTAT

[5] PCT patents are international patent applications. EPO patents are European patent applications. Analysing PCT patents only leads to an even higher worldwide share of American patents.

[6] This is particularly remarkable given that (1) the EU has a larger population than the US and (2) the inclusion of EPO patents tend to overestimate the worldwide production of EU patents.

Figure 8: Patent trends in AI, ranking of top 20 countries (2005-2018)



Source: Fraunhofer ISI, based on PCT and EPO PATSTAT

The US has led the first part of the AI race, but China is quickly closing the gap.

From 2005 to 2016, the US has produced each year more AI PCT + EPO patents than any other country. Since 2017, the first position is occupied by China. China started to substantially increase its share of AI patents during the deep learning revolution in 2013 moving from 9 to 19% in 2 years.

By 2017 China was producing as many patents as the US (25%) and by 2018 China was already producing 25% more patents than the US. China has its own AI giants with Alibaba, Tencent and Baidu. Despite a lower market cap[7], many observers believe that they are already outperforming their American competitors in some segments. WeChat, for instance, has fewer users than WhatsApp but is used for a variety of tasks outside merely messaging. The largest unicorn in the AI space actually does not come from the US but from China. Through the deployment of TikTok, Bytedance leveraged the breadth and depth of Chinese internet data to reach a whopping valuation of $140 bn (ca. €115 bn). As a matter of comparison, Facebook went public in 2012 with a peak market capitalisation of over $104 bn - €85 bn (largest IPO in tech at the time) and Alibaba in January 2020 for $238 bn (ca. €190 bn).

2.2 Key players of the US AI ecosystem

A key feature of the US AI ecosystem is that it is heavily dominated by a very small number of big players. Google, Microsoft, Amazon, Apple and Facebook alone are responsible for more than one third of the overall international patent production of American organisations[8] from 2014 to 2017 period (Figure 9). Remarkably, these companies are fairly young, with Apple and Microsoft founded in the mid-'70s, Amazon and Google in the '90s, and Facebook in 2004. The Big Five are competing at an international scale with fast-growing Chinese giants Tencent, Alibaba, Baidu, Huawei and Ping An Technology.

The domination of these giants can be explained by a fundamental feature of the development and adoption of AI technologies: a winner-takes-all ecosystem arising from network effects. These big players have led the first strong wave of AI, leveraging to a large extent internet data to produce customer-

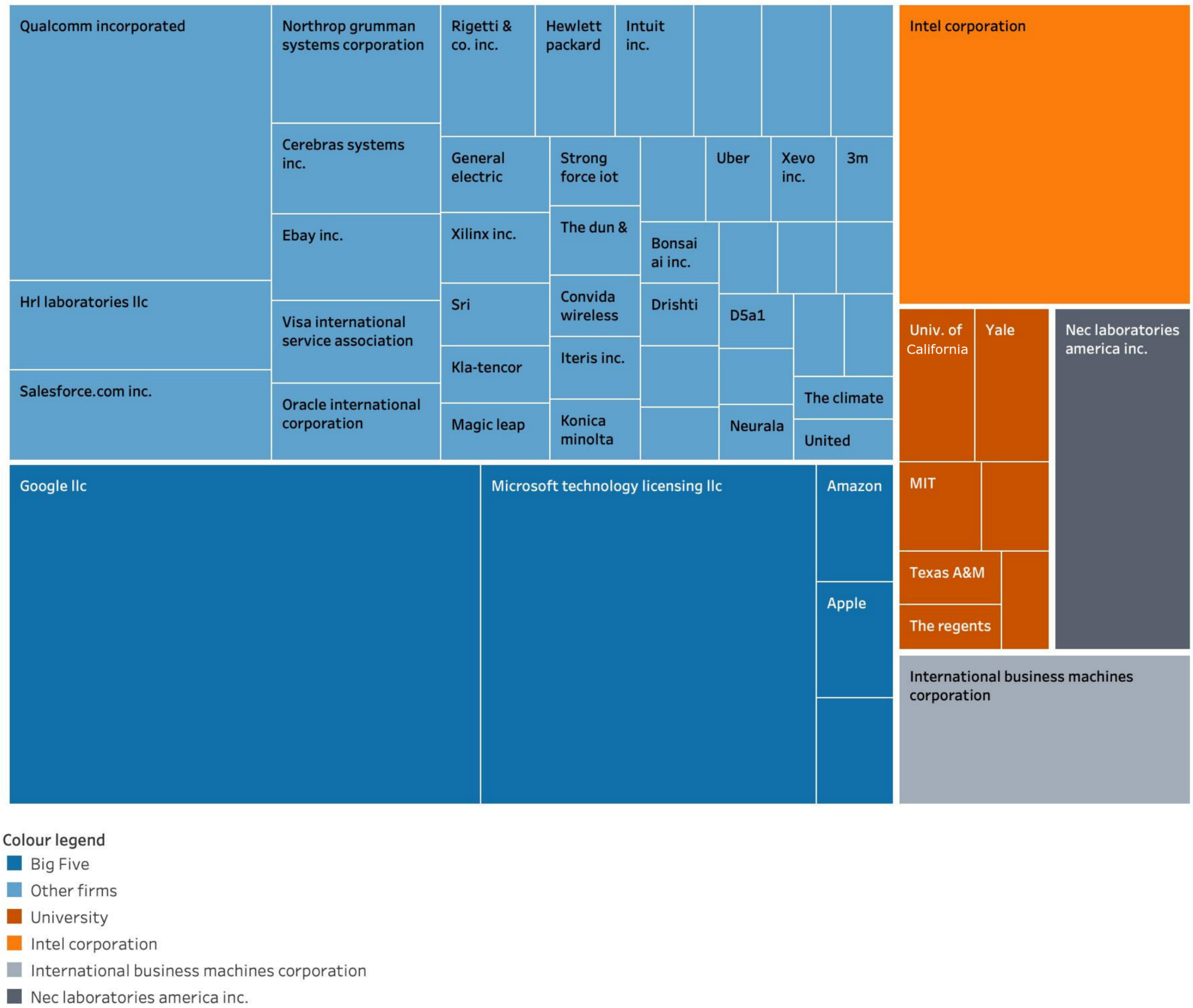
[7] "Market capitalisation or market cap refers to the total market value of a company's outstanding shares of stock". Investopedia

[8] We removed organisations that have less than 5 ICT patents during the 2014-17 period

oriented recommendation systems. The goal is to dig in an amount of data that a human cannot handle and use augmented intelligence to cater new songs, products and websites that the user might find interesting. In this perfect matching quest, the AI system that provides the best recommendations wins-it-all.

A small initial comparative advantage will compound into a monopoly in AI. Slightly better initial recommendations will attract more users. More users will lead to more data, which is the cornerstone of AI performance. More data will lead to better predictions and therefore more users, and so on until a specific segment of the AI market is entirely dominated by a single organisation. Google has a monopoly in website recommendations and Amazon in product recommendations. This is the same logic for Spotify, YouTube and Netflix; this is why the AI fields of machine learning and deep learning have been particularly shaped by the winners of the internet-AI revolution.

Figure 9: The US AI ecosystem



Source: Balland, 2021

Other big AI players include older organisations that were historically more involved in the production of hardware. These four giants are:

- Intel Corporation, the world's largest semiconductor manufacturer,
- the 100-year-old technology company IBM,
- the NEC Labs America research centre, and
- the wireless technology firm Qualcomm.

They alone account for another 27% of international patents. Outside the US, Samsung and LG from South Korea are particularly active in similar AI tech areas, together with the Japanese Sony and Hitachi.

The US is not only leading the AI race via its tech giants but also in the startup space. The big AI players are active investors that support the next AI generation. Intel Corporation invests massively in AI startups with Intel Capital - its corporate venture capital (CVC) arm. Other big AI CVC players include Google Ventures (GV), Qualcomm Ventures, Salesforce Ventures, Amazon Alexa Fund and Dell Technologies Capital. According to CBInsights[9], the US AI unicorn space (startups with a valuation over $1 bn) is worth €50 bn as of January 2021 (see Figure 10).

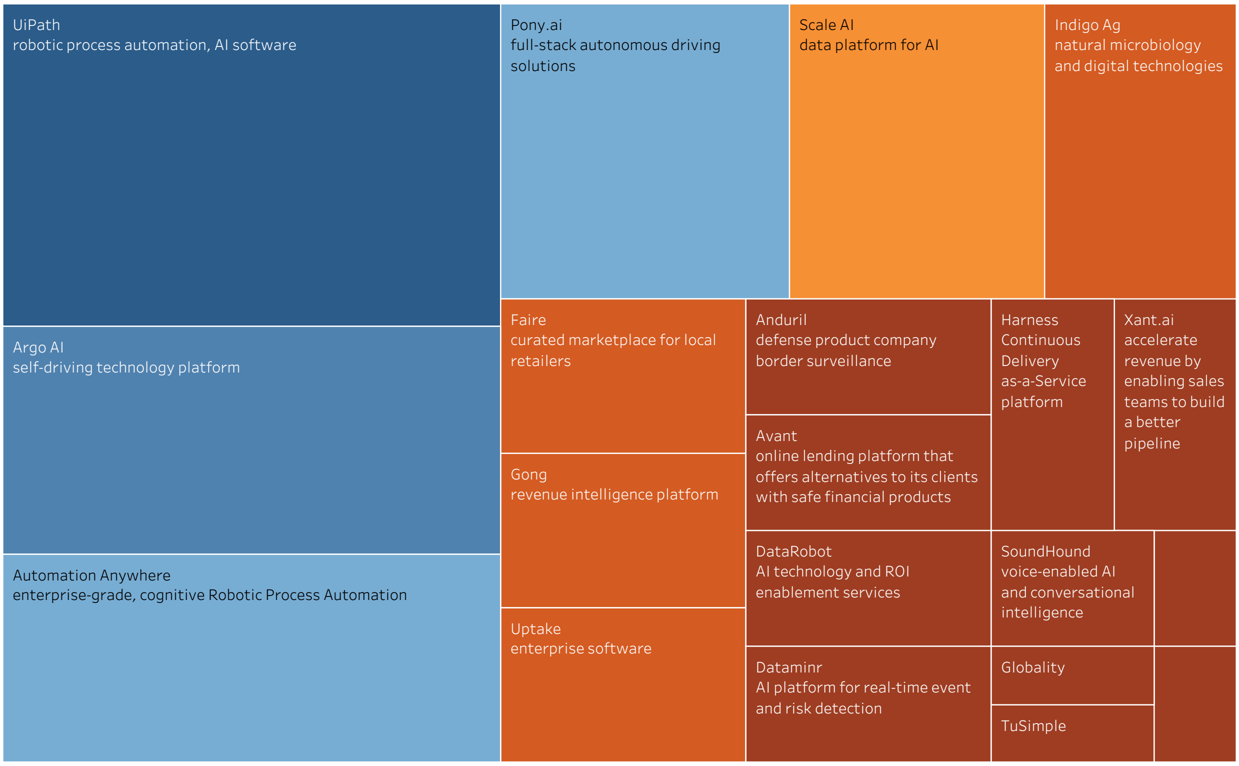
As privately owned data - not internet data but corporate data - is now increasingly being leveraged, IBM, Microsoft and Oracle appear to be very strong players, but we have also witnessed the blossoming of AI startups. Scale AI provides training data for AI applications, Uptake focused on AI solutions for enterprise data and Gong deploys AI to analyse sales conversations.

The field of computer vision is strongly shaped by Apple and Facebook, but also smaller companies such as Digimarc and Mobileye have been particularly active. Automated speech recognition is led by Google, Apple and Amazon, smaller specialised companies such as Nuance Communications and Custom Speech USA, and large telecom companies such as AT&T and Verizon. Apple, Amazon and Nuance are also central to natural language processing but IBM is one of the biggest players. Xerox is also particularly active in this field.

A key field of applications for the AI ecosystem is the rise of digital workers. UiPath, the AI startup with the largest valuation in the US ($10.2 bn - €8.4 bn as of January 2021) provides end-to-end automation platforms to eliminate repetitive manual tasks and help private companies transition towards fully automated enterprises.

UiPath was originally founded in Bucharest by two Romanian entrepreneurs, but is now based in New-York and receives a large amount of funding from American VC funds such as Accel, capitalG, Earlybrid Venture Capital and Seedcamp. The Silicon Valley-based Automation Anywhere offers similar AI technologies aiming at building digital workers and is currently valued at €5.6 bn.

Figure 10: The US AI unicorn ecosystem



Source: Crunchbase, 2021

In the startup ecosystem, we recently observed a massive deployment of resources towards organisations using AI to advance digital transition in traditional sectors. Insurance is one of the most promising fields, as evidenced by the growth of Lemonade – the AI-driven insurtech that filed an IPO mid-2020 for $3.9 bn (ca. €3.3 bn). Its Forensic Graph Network

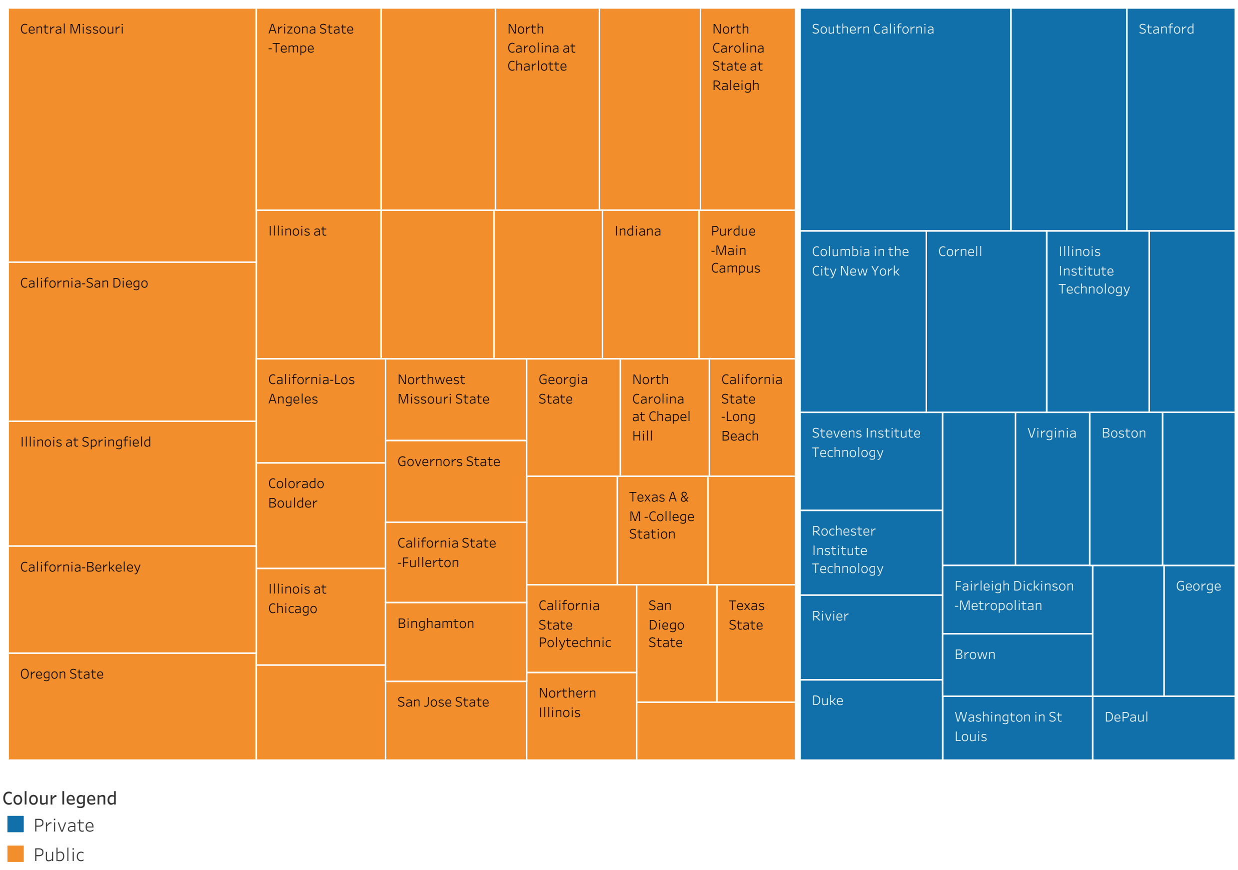
[9] https://www.cbinsights.com/research-unicorn-companies

(FGN) analyses relationships between items that may seem unrelated to prevent fraud.

Automation in banking ranges from smart chatbots, biometric authentication, money-saving applications and of course loan applications and management with companies such as Zest AI. There is also a blossoming ecosystem using machine learning and deep learning to analyse complex medical and healthcare data. The self-driving vehicles AI segment is particularly vibrant in the US. Tesla, of course, is leading the race. While its IPO was priced at about €1.4 bn the company reached €725 bn in January 2021. Other unicorns include Argo AI, Pony.ai. and Nuro.

American universities and higher education institutions fuel this ecosystem by providing a large supply of AI talent and skills. Figure 11 shows the public and private American institutions that provide 4-year or above computer science degrees in 2017. With 1430 degrees, the University of Central Missouri is the institution that awards the most computer science degrees (7%), just in front of the University of Southern California and the University of California San Diego. Carnegie Mellon University, Massachusetts Institute of Technology, Stanford University and Cornell University offer the best CS programmes for private institutions; the University of California-Berkeley and the University of Illinois-Urbana-Champaign offer the best CS programmes for public institutions.

Figure 11: Computer science degrees awarded in US universities in 2017



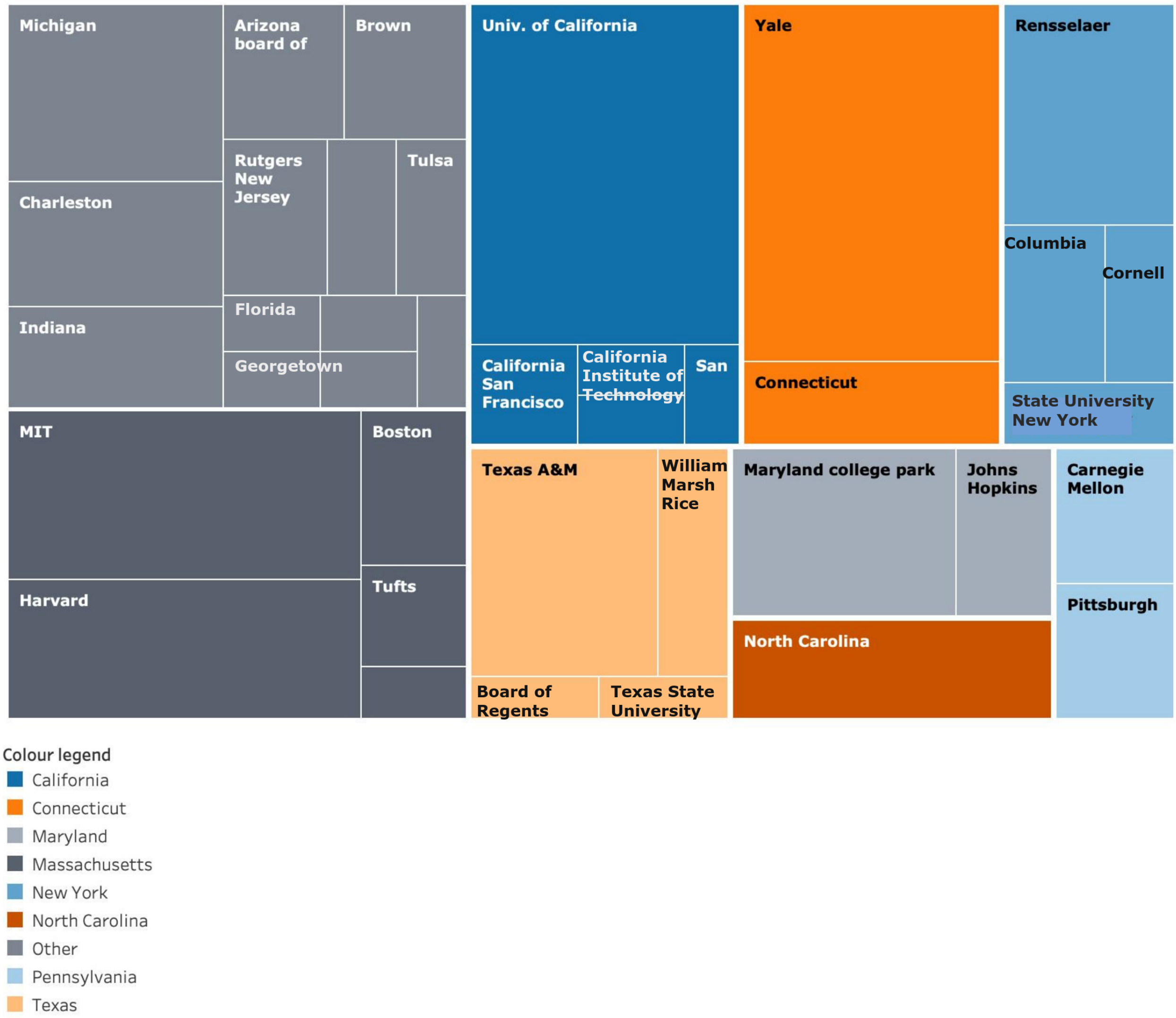
Source: Data USA & Integrated Postsecondary Education Data System (IPEDS) Completions

The tech giants and the startup AI ecosystem are strongly connected with universities and higher education institutions. University-Industry collaborations and AI spin-offs are facilitated by corporate funding of universities. The governance structure and the VC fund (E14 fund) of the MIT Media Lab and the MIT-IBM Watson AI Lab are prime examples of the corporate-academia-entrepreneurship linkages that characterises the US AI ecosystem. The birth of the AI giant Google is a story of university-industry symbiotic relationships. Google Founders, Larry Page and Sergey Brin filed a patent for the revolutionary page-rank algorithm while they were studying at Stanford. Stanford guided Page and Brin with investments and legal advice and the patent was assigned to Stanford University.

American universities are key producers of AI technologies. Figure 12 shows that the East Coast is leading the number of PCT patent applications, especially with MIT, Harvard and Boston University in Massachusetts, but patent applications are also strong in New-York, Pennsylvania and Connecticut-based institutions.

California and Texas represent a large share of AI patents – mainly with the University of California system and Texas A&M. Large endowments of top universities are key for them to stay relevant in the new AI race and allow them to implement bold AI visions. MIT recently committed $1 bn (ca. €0.8 bn) to create the Stephen A. Schwarzman College of Computing which will double MIT's academic capability in computing and Artificial Intelligence.

Figure 12: AI patents of US universities



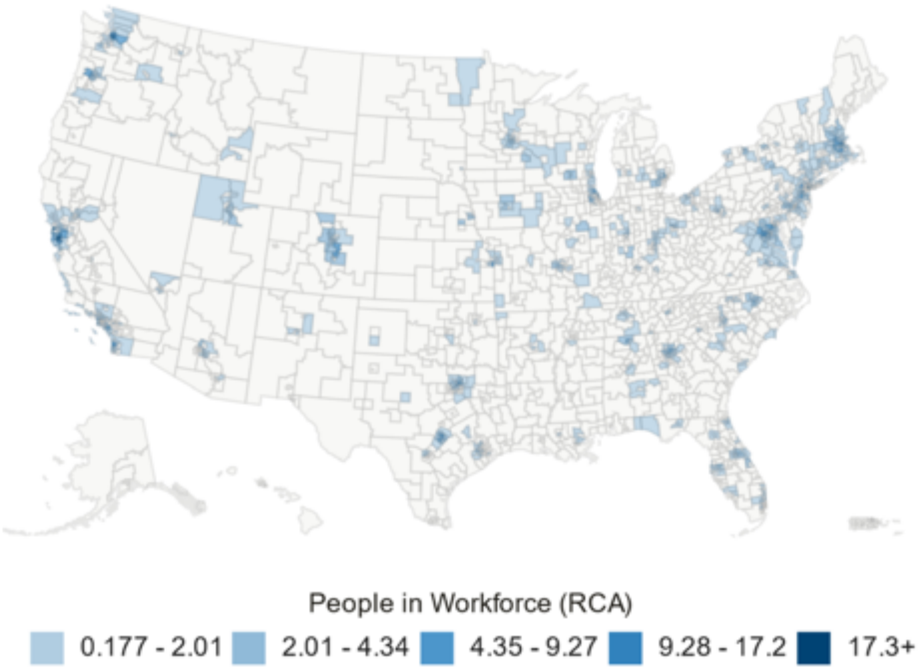
Source: Balland, 2021

The US has a workforce of 1.36 million software developers but its geography is highly concentrated (Figure 13).

The heart of the Silicon Valley: Sunnyvale & San Jose (North) is home to 15 200 software engineers, which is 1 in every 5 jobs and 22 times what one would expect based on its size. Other hotspots include parts of Seattle or Austin.

This level of concentration is higher than in European regions. It provides agglomeration economics and network effects that are beneficial to the quick scaling-up of complex technologies such as AI systems.

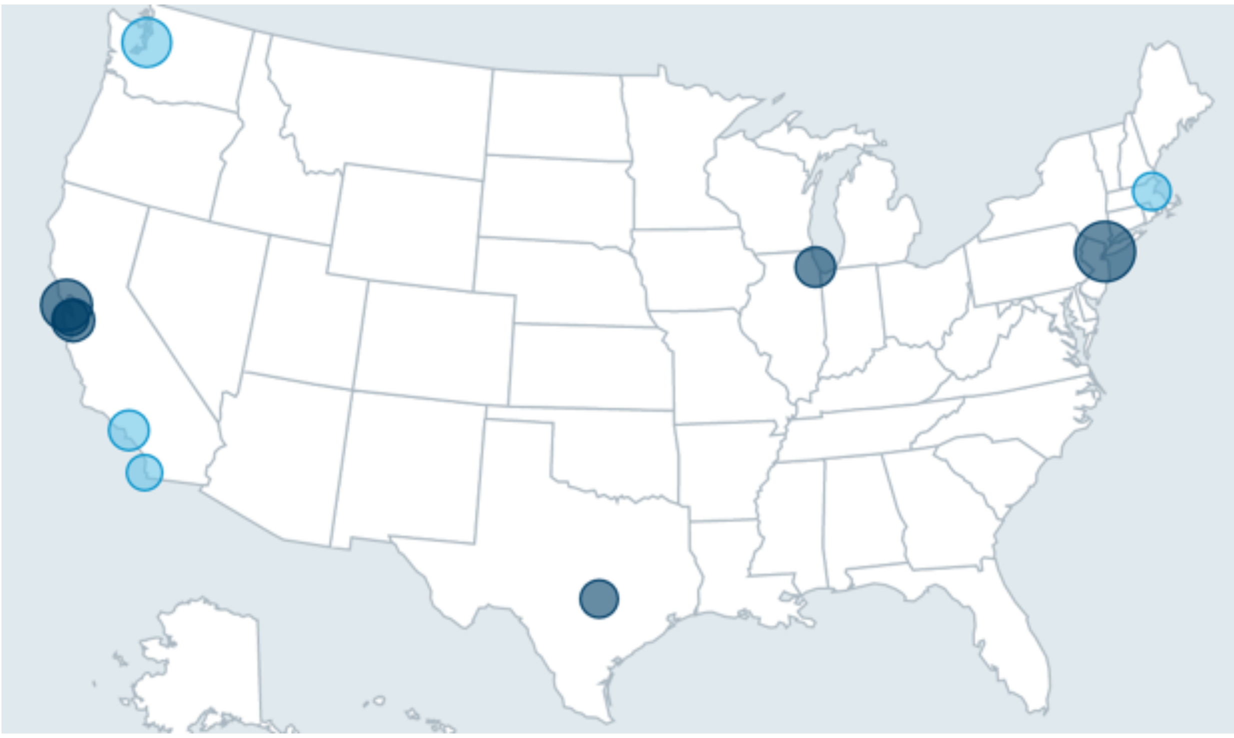
Figure 13: Spatial concentration of software developers (data visualisation from data USA)



Source: Data USA, 2021

Notes: RCA= revealed comparative advantage

Figure 14: Spatial concentration of AI professionals



Source: Technopolis Group analysis based on LinkedIn data, 2021

2.3 Drivers of the US AI ecosystem

The analysis of the AI ecosystem shows that the United States has pioneered the AI revolution and is still home to an unmatched amount of talent, skills and private capital. **The dramatic growth of the US ecosystem can mainly be explained by the extension of early advantage in computing technology and the ability to harvest global internet data**.

The AI ecosystem was, structurally, very fit for the ensuing growth of subsequent AI technology. **Using the principle of relatedness framework[10] it is clear that the US had a strong pre-existing comparative advantage in technologies that were key ingredients to the development and adoption of AI**. Figure 15 shows the degree of relatedness from a PCT patent analysis between 35 technological fields represented as a network, the technology space. The size of the nodes is given by the relative comparative advantage (RCA) of the US in these technologies in 2005-2010.

The graph clearly shows that the US has very strong capabilities in some of the core technologies relevant for AI: digital communication, computer technology, IT methods, medical technology, nanotech and control.

While the US had an RCA of 1.42 in computer technology, the EU27 only had an RCA of 0.6. The EU27 had relatively low capabilities in digital technologies and displayed a stronger command of traditional engineering sectors such as chemistry and mechanical technologies. **The United States has since doubled down on its initial comparative advantage in digital technologies and is now confirming its leadership in Artificial Intelligence.**

Figure 15: The US technological ecosystem in 2005-2010

Source: Balland, 2021

[10] Hidalgo et al., 2018; Balland et al., 2019

The initial comparative advantage of the US in digital technology did not only provide the skills, talent and technology, but also the venture capital needed for AI expansion. PayPal is the prime example of employees and founders who have used their private capital to build another layer of the ecosystem with the developments of Tesla, Inc., LinkedIn, Palantir Technologies, SpaceX, Affirm, Slide, Kiva, YouTube, Yelp and Yammer. The internet revolution created billionaires such as Elon Musk (PayPal), Marc Andreessen (Netscape) and Chamath Palihapitiya (Facebook) who all have had the capital to re-invest in AI-related projects.

These investors not only had the capital, but also the mindset to invest in 'moonshots' AI ventures. The winner-takes-all characteristic of AI ventures means that speed is essential. Early advantages compound more than in any other industry. The saying in the software business '*Ship Early, Ship Often*' is now truer than ever. Waiting for the product to be perfect before making it available to customers is a death sentence. This has strong implications for public R&D investments in AI that need to adopt a different risk management strategy. Money should be quickly allocated and risk should not be monitored at the project level but at the programme level. Having one project becoming a unicorn while 99 will fail completely is more of a success than having each project reach 'safe' milestones.

Besides the technology and venture capital, the US also had access to the key ingredient of the AI revolution: internet data. As coal powered the machines of the industrial revolution, such as the steam-engine, data now powers AI technologies. A good AI system is only as good as the data it has been trained on. Because it is a large integrated market using the English language, US AI champions had the fuel to grow at an early stage. They will soon keep building their advantage by using EU internet data. In the EU natural language processing technologies are more constrained due to cultural diversity and the need for various languages to comply with. A great example is Hungary, which launched iWiW, an online directory that allowed users to search for and connect with friends and friends of friends in 2002, 2 years before Facebook. As soon as Facebook entered the Hungarian market, iWiW died, and with it, the ability to build an AI layer on top of this database. **The fragmentation of EU AI initiatives is a key reason why the EU is lagging behind the US (and China) in AI technologies.**

As with other American innovation success stories, American AI leadership would not be complete without foreign-born talent. The US AI ecosystem is attracting talent from all over the world. As of 2018, a staggering 40% of the Silicon Valley – about 800k brains - were born outside of the United States. Yahoo!, eBay, Google and Qualcomm were all founded by immigrants. The most famous entrepreneur in the world, Elon Musk, is foreign-born. Half of the Silicon Valley startups are founded by immigrants. French-born Yann André LeCun is currently Facebook's Chief AI Scientist.

To compete with the US AI ecosystem in the coming decade, other parts of the world will need to catch-up in terms of supporting AI technologies, private or public venture capital, risk-taking mindset, depth and breadth of internet and corporate data, and high-skilled migrant policy.

2.4 Role of policy

Although the growth of the American AI ecosystem is mainly due to endogenous forces and resources, the US has recently announced a new set of strategic AI policy.

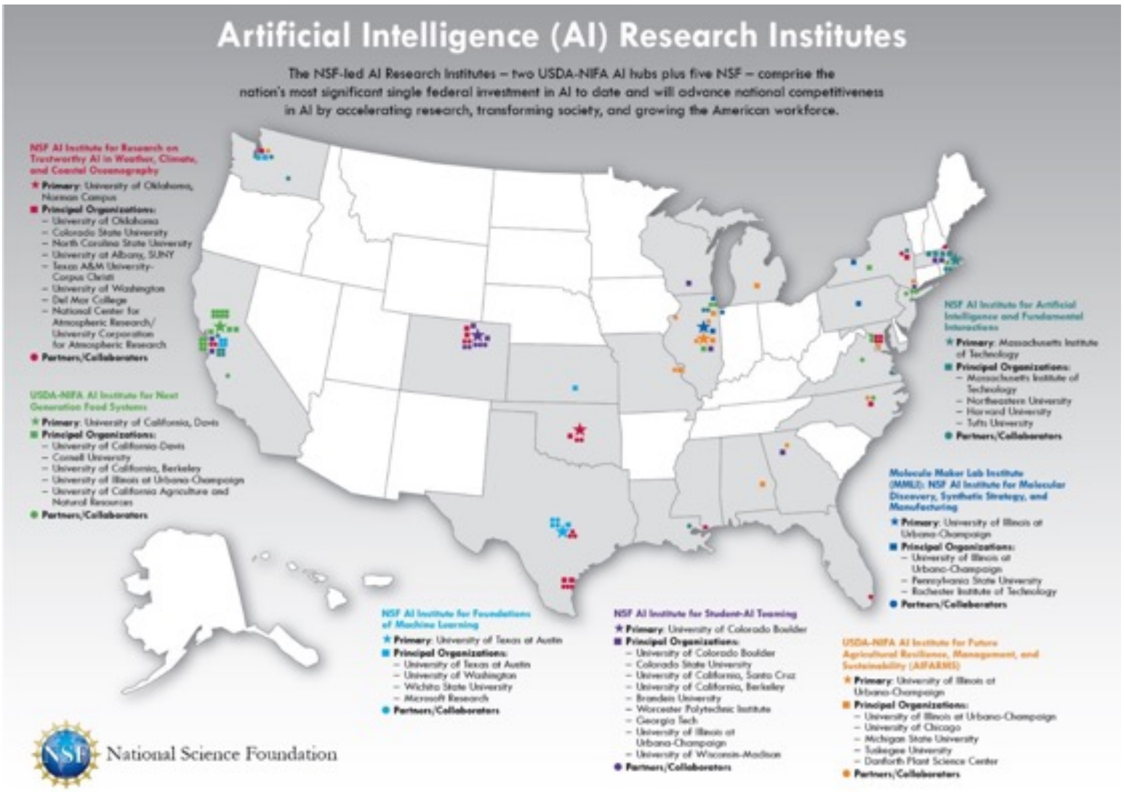
Given the pioneering AI role of American companies and universities, the AI policy of the Trump administration arrived arguably late. Other countries had started to put AI policy as an absolute top priority years before, which in this technology space represents a significant time lag. The noteworthiest plan came from China with its 2017 AI initiative, which proposed multibillion-dollar national investments to support moonshot AI projects. The late arrival of a corresponding US strategy is demonstrated by a memo sent in spring 2018 by defense secretary Jim Mattis to the White House. In this strategic memo, Mattis stated that the United States was not keeping pace with the ambitious plans of China and other countries, and that it urgently needed an ambitious national AI policy.

The White House responded in February 2019 with an Executive Order signed by President Donald J. Trump. In this Executive Order, President Trump introduced the **American Artificial Intelligence Initiative - the United States' national strategy for maintaining American leadership in AI, later codified into law as part of the National AI Initiative Act of 2020**. Among other actions, the American Artificial Intelligence focuses on four key policies and practices.

The first directive focuses on **investment in AI research and development**. The United States federal budget for the fiscal year 2021 (FY 2021) delivered on this request. AI R&D spending at the National Science Foundation is about $830 m – ca. €680 m (+70% increase over the FY 2020). The Department of Energy's Office of Science increased their AI investment by $54 m (ca. €44 m), the US Department of Agriculture by $100 m (ca. €82 m) (AI in agricultural systems programme), while the National Institutes of Health will invest $50 m (€41 m) for new research on chronic diseases using AI. The budget for

Defense AI also increased with the Defense Advanced Research Projects Agency (DARPA) adding $50 m, and the Department of Defense's Joint AI Center increasing its budget by $48 m in FY 2021. In collaboration with other Federal agencies, the National Science Foundation launched the National Artificial Intelligence (AI) Research Institutes programme.

Figure 16: AI Research Institutes



Source: NSF, 2020

Although these figures show a clear commitment to invest in AI R&D they are dwarfed by the American tech giants. According to the 2020 EU Industrial R&D Investment Scoreboard, the big 5 (Google, Microsoft, Amazon, Apple and Facebook) invested a mind-blowing €84 bn in overall R&D in 2019. Not all of this is oriented toward AI, but our technological analysis shows that it will be targeting technologies that are to a large extent related to AI.

The second fundamental policy of this AI initiative is to prepare the American workforce for an AI-dominated world. The goal is to make sure that both the current and the next generation are capable of taking full advantage of the opportunities of AI. All federal agencies have therefore been asked to prioritise AI-related apprenticeship and job training programmes. This is also connected to the ambition to develop new methods for AI-human collaborations.

The third key strategy is to increase trust in AI technologies to accelerate their adoption and ensure that the US sets AI technical standards. It seems that AI regulation is largely described as a tool to accelerate American AI leadership and that this regulation should not hamper and constrain the effective and timely development of AI. This led to the development of a national AI regulatory policy – the US AI regulatory principles - that aims at promoting AI based on American values. The 2019' executive order also specifically directed the National Institute of Standards and Technology (NIST) to create "*a plan for Federal engagement in the development of technical standards and related tools in support of reliable, robust, and trustworthy systems that use AI technologies*". This led the NIST to develop a plan for Federal engagement in developing technical standards and related tools by summer 2019.

The fourth critical policy is related to providing access to high-quality cyberinfrastructure and data. This policy aims at making a large variety of AI training and testing datasets accessible and developing open-source software libraries and toolkits. The Federal Data Strategy was established in 2019 with the goal of "leveraging data as a strategic asset."

The American AI policy goes beyond the mere investment in AI R&D and national

regulations; it is defensive and geopolitical by nature. The 2019 Executive Order explicitly stated the importance and urgency to protect *"our critical AI technologies from acquisition by strategic competitors and adversarial nations."*

On July 7, 2020, US Secretary of State Mike Pompeo announced that the government was considering banning Beijing-based TikTok, the largest AI unicorn in the world. Pompeo raised the concern that TikTok was sharing data with Chinese authorities. A few days later, President Trump announced a decision ordering TikTok's parent company (ByteDance) to divest ownership and advised Microsoft to acquire a large share of TikTok's American operations.

The ban of Chinese AI in the US directly or indirectly echoes China's internet censorship that has been in place since 1996. China's Internet censorship was historically based on ideological considerations but turned in practice to result in a protectionist economic policy that would plant the seeds to the growth of the AI ecosystem. Chinese internet data has been, in practice, saved, to be harvested by Chinese AI instead of foreign-AI. Restricting the use of American internet data to foreign AI companies would have strong implications in terms of global AI leadership in the future.

The next AI policy for the US is not yet clearly outlined. The inauguration of Joe Biden as the 46th president of the United States took place on January 20, 2021, starting a series of Executive Orders to address the most pressing issues of fighting the coronavirus pandemic and reversing a series of President Trump policies on climate change and international relations. Despite these pressing tasks, the new administration has already made some announcements focusing on AI leadership. While introducing the Executive Order on Strengthening American Manufacturing, President Joe Biden made the statement that "We'll also make historic investments in research and development — hundreds of billions of dollars — to sharpen America's innovative edge in markets where global leadership is up for grabs — markets like battery technology, Artificial Intelligence, biotechnology, clean energy."

2.5 Lessons for Europe

Europe needs an integrated and ambitious AI strategy. AI leadership and sovereignty is critical given that AI can help to tackle climate change and other grand challenges. AI can radically transform almost every industry, automate blue and white-collar jobs, and has strong military and geopolitical considerations as analysed in detail in the ATI technology watch report on AI[11]. The growing gap with the US and now with China is worrisome. AI technologies have strong network effects that compound over time and lead to winner-takes-all algorithms. The longer the EU waits, the harder it will be to catch up. Because scale matters so much for AI development, AI strategy needs to go beyond the Member States level towards a unified EU AI strategy. France, Germany or Estonia do not stand a chance in the global AI race – but Europe as a whole does.

Overall public R&D spending needs to increase significantly. The US could build its technological advantage on pre-existing digital technologies and internet VC money. Because the same amount of private wealth was not created in Europe, there is now more than ever a case for massive public investment. Aiming for moonshots projects also requires the EU to adopt a different risk management strategy. The metrics for success is not that none of the project fails, but that the portfolio of projects leads to the very best AI systems at a global scale. For maximum efficiency, this investment should be place-based. AI eco-systems are extremely concentrated in Europe. It is important to map them and identify the ones that have the most potential to grow different AI segments: deep learning, machine learning, computer vision, all building on slightly different capabilities.

Europe needs to retain and attract top AI talent. The EU has a critical mass of AI talent but there is a net loss of the most talented ones benefiting the US ecosystem. In AI more than in other traditional sectors, attracting the best talent, such as Yann LeCun, Yoshua Bengio or Geoffrey Hinton, makes a bigger impact on technological development than having thousands of proficient AI engineers. The US migration policy has not been pro-migrant lately, and China is still not able to attract foreign talent at a massive scale. There is a small window of opportunity for Europe to send a welcome message and adopt a smart visa policy for AI workers. With the increasing amount of remote-work options, Europe can also double down on the quality of life it can offer. European cities have the advantage to be cities where people want to live.

European data should be used in priority by European AI companies. This is probably the biggest challenge but also the policy action with the highest leverage to close the gap with the US and China. As Kai-Fu Lee likes to say: *"AI is usually more improved by more data than better AI engineers*." China's Internet censorship led to the creation of a separate internet world that allowed Tencent, Baidu, Alibaba and TikTok to grow without competing too early with American giants. This is a key lesson for Europe as EU internet data is still very free to be harvested. EU

[11]https://ati.ec.europa.eu/reports/technology-watch/technology-focus-artificial-intelligence

data regulations should be developed to increase the usage of EU data by EU companies. That means that new data regulations should at the very least not hurt the small EU companies with complex and restrictive regulations. The amount of regulation may well be proportional to the size of the tech giants, but we could also imagine some form of data tariff in some cases.

To influence the impact of AI on society, the EU needs to lead the global race. If we act fast, the technological gap with the US and China can still close. Member States will need to unite their efforts under a common EU AI strategy, coordinate historically high R&D investments, adopt a high-skilled migrant policy and ensure that EU data powers EU AI ventures.

Section 3

3 US ecosystem in Nanotechnology

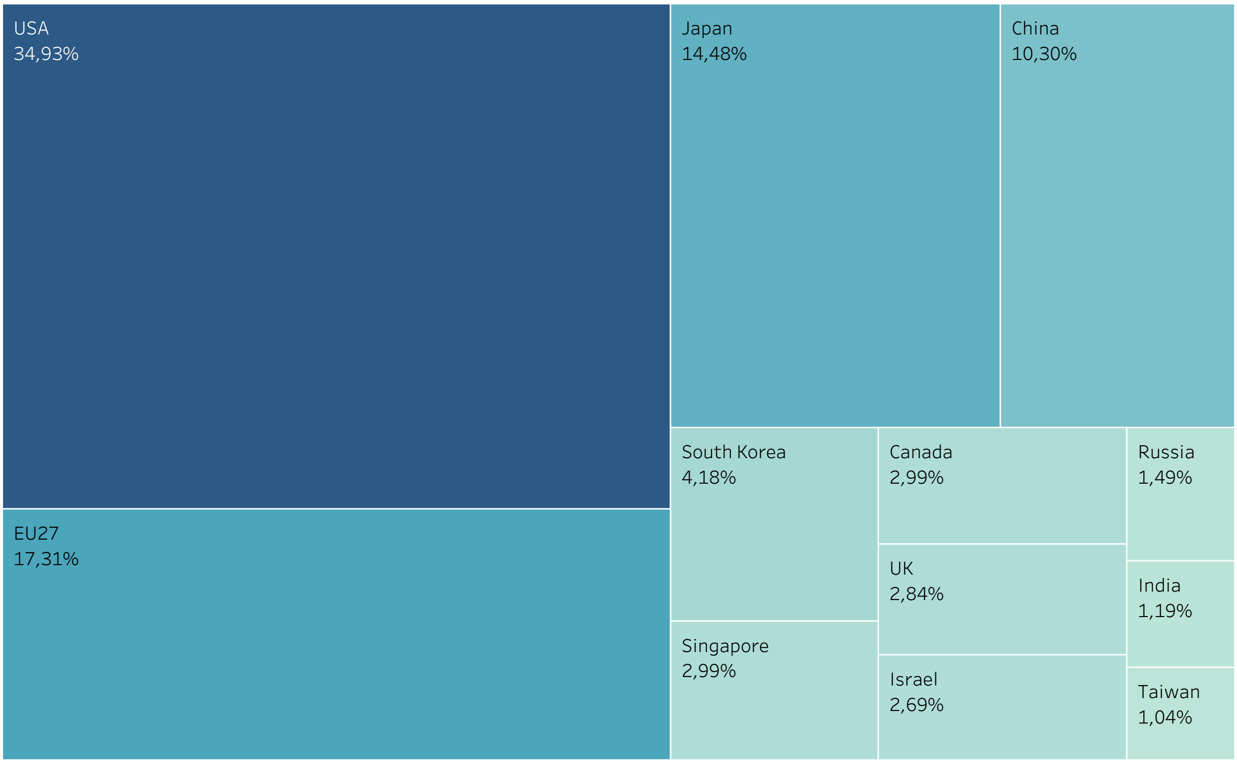
3.1 US leadership in nanotechnology

Nanotechnology is in the strategic focus of the United States government, in the field of which it is a global leader both in terms of transnational patent applications and publications. The US National Academy of Sciences describes nanotechnology as the "*ability to manipulate and characterise matter at the level of single atoms and small groups of atoms*."[12]

In 2018, the US accounted for 34.93% of the global patent applications, followed by the EU27 with a share of 17.31% and Japan (14.48%) as indicated in Figure 17. The US has kept this leading position since 2006 as Figure 17 also demonstrates. The patent data shows a balanced composition of companies and universities. US authors have also had the highest share of corporate nanotechnology publications[13] in the period 2000-2019.

Nanomanufacturing is enabling the transformation of various other industries including defense, medicine, transportation, energy, environmental science, telecommunications or electronics. It is also contributing to the performance of the most sophisticated computing and data storage technologies, which is a very important field in the times of a data-driven economy. Nanotechnology is multidisciplinary and many research happens at the intersections of scientific disciplines such as biology, chemistry, materials science and physics to enable new discoveries[14]. Key application areas where US research institutes and companies are active include 1) advanced nano-engineered materials 2) electronics and IT applications – nano-scale sensors 3) healthcare, pharmaceuticals and medical devices – nanomedicine and nanodevices 4) energy – nanoparticles in solar cells 5) transport 6) environmental remediation[15].

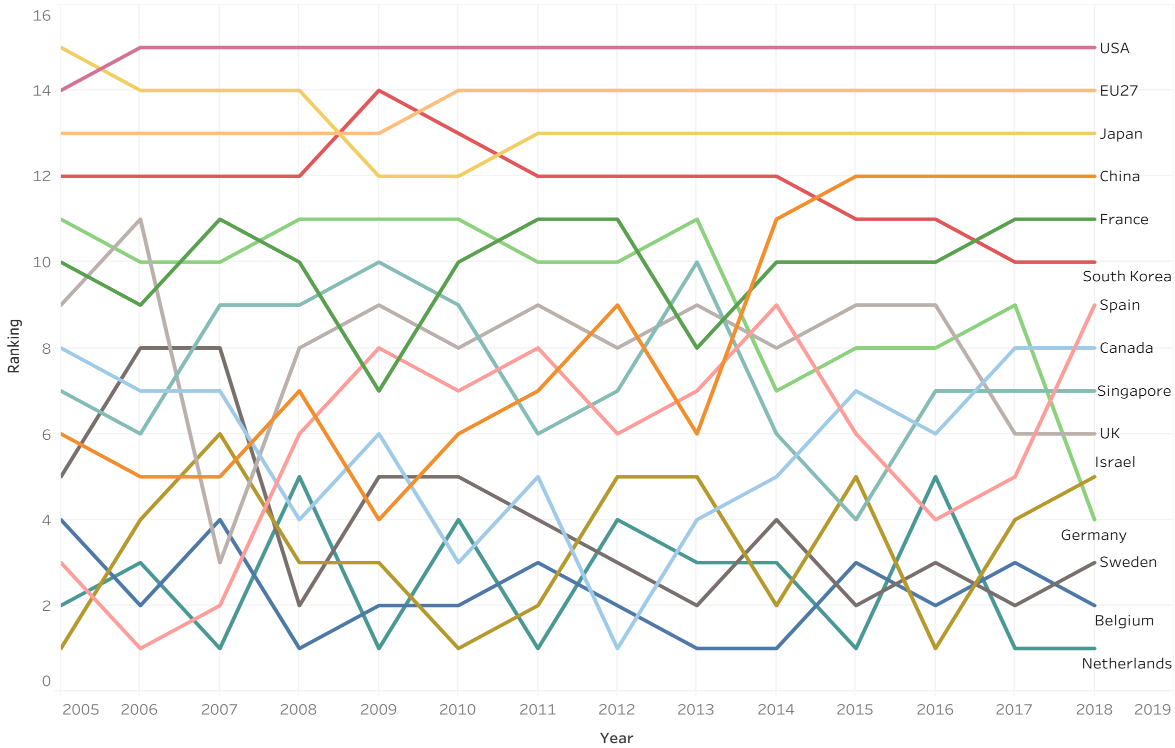
Figure 17: Share in global patent applications, PCT + EPO in nanotechnology (2018 – latest available data)



Source: Fraunhofer ISI calculations

[12] https://www.govinfo.gov/content/pkg/CHRG-109hhrg21950/html/CHRG-109hhrg21950.htm
[13] Jan Youtie, 2020
[14] National Nanotechnology Initiative Strategic Plan, 2016
[15] https://www.nano.gov/you/nanotechnology-benefits

Figure 18: Share in global patent applications, PCT + EPO in nanotechnology, (2018 – latest available data)



Source: Fraunhofer ISI calculations

3.2 Key players of the US nanotechnology ecosystem

Key players of the US nanotechnology ecosystem include first of all an extensive infrastructure of research and technology centres, large companies, startups and public agencies.

Research and technology centres

The **US National Nanotechnology Initiative (NNI)** has put in place an infrastructure of more than 100 interdisciplinary research and education centres and user facilities across the United States. These centres provide specialised equipment and trained staff.

The supported world-class physical user facilities are the following:

- National Science Foundation - National Nanotechnology Coordinated Infrastructure[16]
- Department of Energy's Nanoscale Science Research Centres[17]
- NIST Center for Nanoscale Science and Technology[18]
- National Cancer Institute Nanotechnology Characterisation Laboratory[19]

The NNCI sites (Figure 19) provide researchers from academia, small and large companies, and government with access to university user facilities with leading-edge fabrication and characterisation tools, instrumentation and expertise within all disciplines of nanoscale science, engineering and technology.

Another public agency, the **Food and Drug Administration (FDA)** plays an important role in fostering and also regulating nanotechnology developments. The Federal Drug Administration strategy for strengthening nanotechnology-related research relies on a robust framework that coordinates regulatory science activities across all FDA product centers.

Figure 19: Locations of the 16 NNCI Sites

Source: NNCI Coordinating Office Annual Report, 2020

[16] https://www.nnci.net/
[17] https://nsrcportal.sandia.gov/
[18] https://www.nist.gov/cnst
[19] https://ncl.cancer.gov/

One of the success stories of the NNI is the **Albany NanoTech Complex** at SUNY Albany that demonstrates how public initiatives can transform a stagnating region into a prosperous economic area. Albany is one of the biggest investments in public-private applied research institutions by the local government. The complex was established by the state government in cooperation with firms such as IBM, Advanced Micro Devices, Applied Materials and Tokyo Electron.

The capital region was formerly described as 'rustbelt' and has been written off as a declining manufacturing area condemned to failure. Nevertheless, the negative trends were offset by a focus on high-tech industries such as chip-making and nanotechnology helping Albany to become the brainbelt it is today. Their success is also thanks to their proximity to major cities like Boston and New York City and a thriving educational system[20].

The rise of the nanotech-cluster in the capital region has been tightly linked to the cooperation with IBM. The company played a crucial role in the successful development of cutting-edge technology for commercial wafer, semiconductors and their large-scale production. The New York nanocluster is heavily dependent upon semiconductors, which is a volatile technology and frequently destabilised by new technological innovations or government interventions.[21]

Large companies

The top 20 applicants of patents in the field of nanotechnology consist of eleven companies[22]. The top players registering patents in the United States Patent and Trademark Office in the field of nanotechnology includes IBM.[23] This US-based multinational technology company is a leading provider of computer hardware, middleware and software, which also offers hosting and consulting services in the areas ranging from mainframe computers to nanotechnology. Intel Corporation is the second largest private player in nanotechnology. It is a multinational technology company manufacturing computer hardware including motherboard chipsets, microprocessors, modems, mobile phones, central processing units and integrated graphics processing units.

Other corporations that had most scientific publications in nanotechnology include the following[24]:

- Texas Instruments
- Applied Materials
- Corning
- Seagate technologies
- Samsung
- Dupont
- Global foundries
- Agilent Technologies

According to the analysis of LinkedIn data, registered professionals with nanotechnology skills have been employed most beyond the list above also in companies such as the following:

- Apple,
- Thermo Fisher Scientific,
- 3M,
- Dow,
- Micron Technology,
- ASML,
- KLA,
- Western Digital,
- Google,
- Northrop Grumman.

VC investment and startups

The venture capital sector plays a key role in transferring technological knowledge from research centres to industry and supporting the market uptake of nanotechnology. Many venture capitalists claim that nanotech is one of the great advanced technology waves that will revolutionise most industries. Several venture capital-backed nanotechnology startups have spun out of breakthroughs in universities.

One of the largest private equity investment in the period went to Sila Nanotechnologies founded in 2011 that is a provider and manufacturer of revolutionary car batteries.

Another VC backed company is Nanotech Industrial Solutions which is the manufacturer of nano-sized particles of 'Inorganic Fullerene-like Tungsten Disulfide IFWS2'. Nanotech Industrial Solutions has raised a total of €79 m in funding over 3 rounds. Their latest funding was raised in 2019 from a private equity round. Their recent investors are the London-based EMV Capital and the German Evonik Venture Capital.

PredaSAR is an emerging nanosatellite data provider that develops satellite constellations. Peak Nano Optics has developed a so-called nanolayer gradient refractive index technology which allows for the design and manufacture of lenses with greater electro-optical performance. Their solutions enable medical and commercial sectors to create desired spherical refractive index distributions within the lens.

---

[20] https://www.albany.com/nanotech/from-manufacturing-to-nanotech/

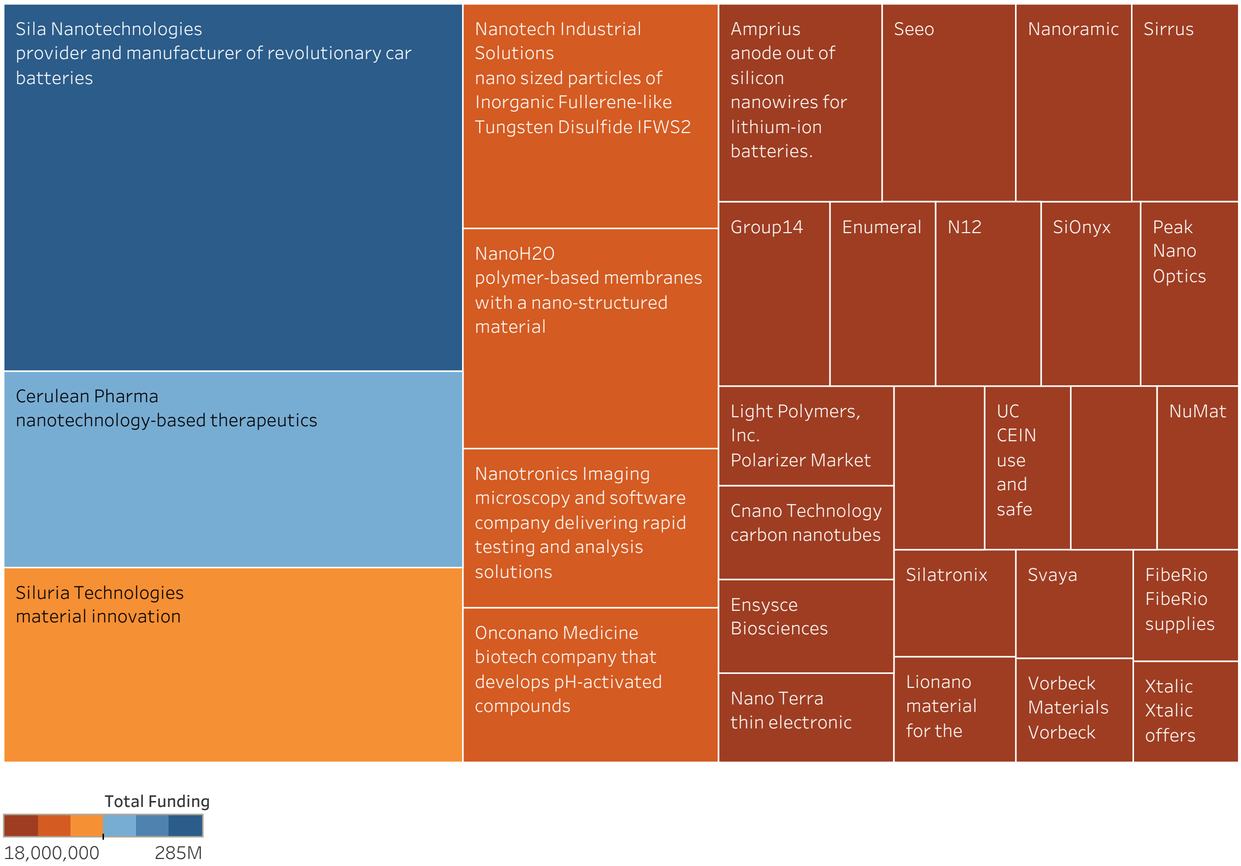
[21] Wessner and Howell 2018.

[22] Wu et al. 2019, p. 10..

[23] Wu et al. 2019, p. 12.

[24] Yan Youtie, presentation at NSE grantee conference

Figure 20: Nanotechnology startups (founded after 2005) with the highest total venture capital and private equity investment in the US (total funding amount in euro)



Source: Technopolis Group, based on Crunchbase, 2021

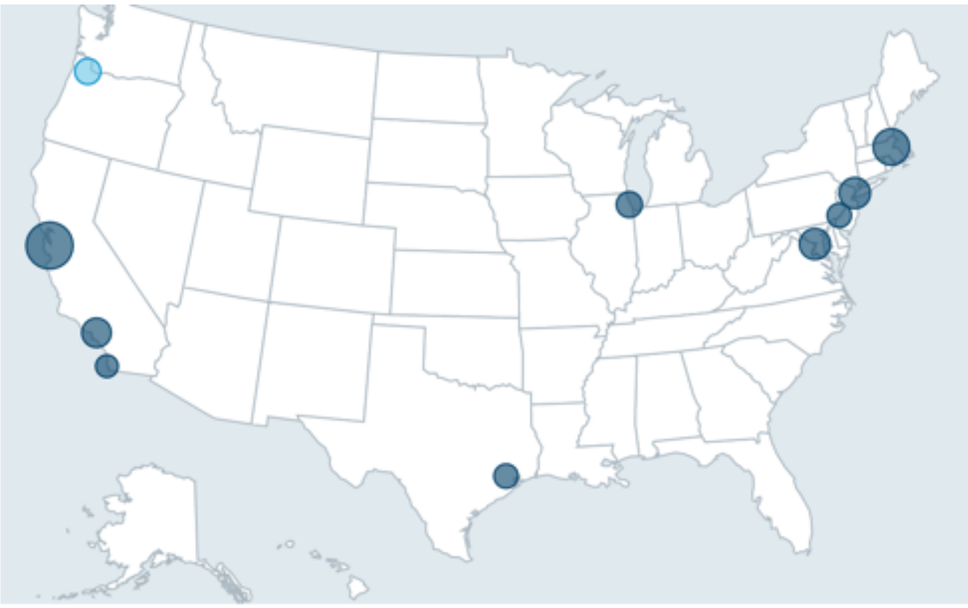
Success in nanotechnology research, development and commercialisation requires a skilled workforce. The NNI has dedicated a lot of effort to strengthen education and outreach through programmes such as the Nanoscale Informal Science Education Network (NISE Net), a network of museums and other institutions.

Most nanotech talent is nurtured at institutes and universities such as the Massachusetts Institute of Technology (located close to Albany), University of California - Berkeley, Stanford, University of Illinois, Cornell, Pen State and Georgia Institute of Technology.

Nanotechnology professionals concentrate in specific states such as San Francisco Bay area, Boston, New York, Washington and Portland (see below analysis based on LinkedIn data).

These professionals are also very much linked to specific sectors and industries. In 2020, most nanotechnology skilled professionals have been employed in the higher education and research sectors followed by industries such as semiconductors, biotechnology, chemicals, defense and space and medical devices.

Figure 21: Distribution of nanotechnology skilled professionals in the US



Source: Technopolis Group analysis based on LinkedIn data, 2021

3.3 Role for policy

Nanotechnology has been a US political priority for more than 20 years. President Bill Clinton launched the **National Nanotechnology Initiative (NNI)** in 2000 with the objective to support the growth of the nanotechnology industry in the US. The goals of the NNI have been to

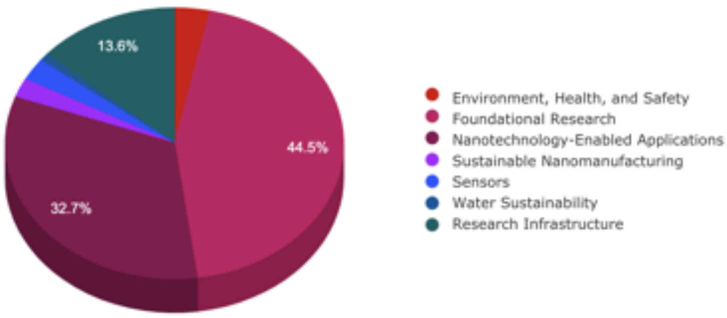
- strengthen the national security innovation base,
- transform health care,
- modernise America's infrastructure, advance manufacturing,
- educate a future-focused workforce, and
- lead to job growth and economic prosperity.[25]

Investments were made in basic research, early-stage applied research and technology transfer. Since the introduction of the initiative, the cumulative budget of the NNI has been around €25.8 bn. In 2020, the budget was €1.31 bn and represented a continued investment in basic research, early-stage applied research and technology transfer efforts that are leading to the breakthroughs of the future. In 2021, all nanotech agencies combined are proposing to spend a total of ca. €1.4 bn.

The current Programme Component Areas (PCAs) include the following (see Figure 22):

- Nanotechnology Signature Initiatives and Grand Challenges
    - Sustainable Nanomanufacturing: Creating the Industries of the Future
    - Nanoelectronics for 2020 and Beyond
    - Nanotechnology Knowledge Infrastructure
    - Nanotechnology for Sensors and Sensors for Nanotechnology:
    - Improving and Protecting Health, Safety and the Environment
    - Water Sustainability through Nanotechnology: Nanoscale Solutions for a Global-Scale Challenge
    - Nanotechnology-Inspired Grand Challenge for Future Computing
- Foundational Research
- Nanotechnology-Enabled Applications, Devices, and Systems
- Research Infrastructure and Instrumentation
- Environment, Health and Safety

Figure 22: Key investment areas of the NNI in 2021



Source: Nano.gov Nanodashboard 2021, https://www.nano.gov/nanodashboard

[25] Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Council

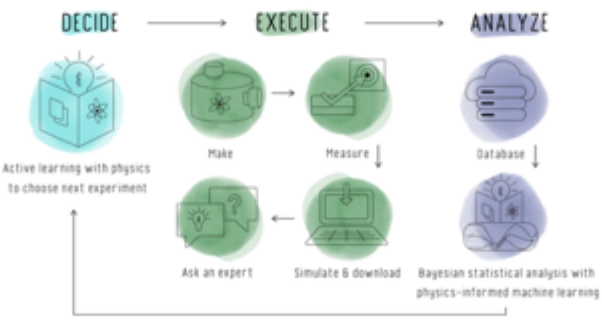
Within the NNI several agencies focus on nano-manufacturing such as the **Nanomanufacturing and Small Business Innovation Research** (SBIR) programmes. They aim at transferring newly developed nanotechnologies into products for both commercial and public use.

Another programme of the NIST called NanoFab provides researchers with rapid access to state-of-the-art, commercial nanoscale measurement and fabrication tools and methods, along with associated technical expertise, at economical hourly rates. It is well equipped to process and characterise a wide range of nanoscale materials, structures and devices.

The new directions of the NNI planned for 2021 include the following:

- nanotechnology for using Artificial Intelligence (AI) for nanomaterial and nano-system design and enabling AI systems,
- sustainable nanotechnology for micro and nano particles,
- brain-like computing and advancing human-technology frontier, including highly energy efficient systems and intelligent cognitive assistants.
- nanobiomanufacturing, including nanobiomotors and cell technology.
- NSF-Wide Investments food-energy-water processes, such as nanofiltration at end-users.
- nanomodular materials and systems by design, including quantum structures and three-dimensional nanoscale materials.
- emerging aspects of nanoelectronics, photonics, use of Artificial Intelligence for smart materials and systems, and neuroscience.
- convergence of nanotechnology with other emerging science and engineering fields.

Figure 23:NIST CAMEO logic



Source: NIST, 2020

The link between nanotechnology and AI is particularly noteworthy. As one of the latest developments, NIST created an AI algorithm called CAMEO in 2020 that discovered a potentially useful new material without requiring additional training from scientists. The AI system can help reduce the amount of trial-and-error time scientists spend in the lab, while maximising productivity and efficiency in their research[26].

Nanotechnology policy is also regulated by the US Food and Drug Administration (FDA) that requires a relatively lengthy approval procedure and series of regulations that must be respected before any products are available for public use. Nanoparticles and nanomaterials can raise health and safety concerns and hence require regulation. The FDA developed an increased amount of procedures that pharmaceutical or other industries must meet before commercialising a nanomedicine or use of nanomaterial.

3.4 Drivers of the US ecosystem

The US nanotechnology research and technology ecosystems have been first and foremost **catalysed by strategic government policies** notably the previously presented NNI with a history of more than 20 years. The NNI has been successful in setting up a network of world-class facilities for academic nanoscience research and it was instrumental to establish US leadership in the field of nanotechnology. The Albany NanoTech Complex has been a similar effort at state level enabled by coordinated public interventions[27].

Besides public policy, partnerships with the private sector (in particular with the US semiconductor industry) played an important role in helping nanotechnology investments yield economic benefits and enter the marketplace. Collaborative research programmes such as STARnet supported by the Semiconductor Research Corporation (SRC), have had an important role in maintaining US competitiveness. Cooperation with key agencies such as the Defense Advanced Research Projects Agency (one of the participating NNI agencies) have also helped commercialisation efforts. In the case of Albany, the state of New York had a strong commitment to invest in a university research infrastructure that aimed at attracting private investment[28].

The coupling of nanotechnology research and specific application fields such as semiconductors has been a key driver behind the developments. Large initial investments were made in the field of microelectronics and focused

[26] https://www.nist.gov/news-events/news/2020/11/nist-ai-system-discovers-new-material

[27] National Research Council 2013. Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century. Washington, DC: The National Academies Press. https://doi.org/10.17226/18364. Chapter: 7 The New York Nanotechnology Initiative

[28] National Research Council 2013. Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century. Washington, DC: The National Academies Press. https://doi.org/10.17226/18364. Chapter: 7 The New York Nanotechnology Initiative

on a developed market. These initial steps permitted Albany to leverage its success into more nascent technology areas such as biomedicine and energy as the next key application areas.

Progress has been reached through impactful initiatives such as the so-called **Nanotechnology Signature Initiatives** (NSIs) designed to target technological areas of national importance as already highlighted above.

Successful examples include the NSIs on water sustainability and environmental nanosensors to detect heavy metal contamination. The efforts of integrating environmental, health and safety considerations into commercialised products has been also acknowledged as having a positive impact and generating acceptance of nanotechnologies by the public[29].

3.5 Lessons for Europe

The model of the US NNI nanotechnology networks has inspired many other countries including the EU and several Members States. The NNI physical and cyber-physical infrastructure has been a key enabler for nanotechnology R&D. The Quadrennial Review conducted in 2020 found that **easy access to core facilities has enabled startup companies to a large extent to develop prototypes and test new applications.**

Although the NNI has been considered as a highly successful interagency coordination effort, its recent reviews identified various concerns related to commercialisation and education.

The Quadrennial Review concluded that the return on NNI investment in terms of commercial adoption has not reached its potential and "*several other countries and regions have evolved their central nanotechnology R&D efforts to incorporate a strong emphasis on commercial translation, yielding lab-to-market pathways that are accelerated relative to those in the United States*". To foster commercialisation, the **Nanotechnology Entrepreneurship Network (NEN)** has been organised in 2020, providing a forum for sharing best practices for advancing nanotechnology commercialisation and the lessons learned along the technology development pathway. Traditionally, the US prefers market-inspired commercialisation activity in most business sectors, strongly preferring that to government-supported commercialisation activity. Nevertheless, in the future it will need to engage in stronger public-private partnerships.

Another cause for concern is the stagnating number of US nanotechnology students and researchers that are necessary to ensure long-term growth in this field. The review found that the number of STEM (science, technology, engineering, and mathematics) graduates was not increasing rapidly enough in the US and called for stronger actions. This demonstrates the importance and **need for an overarching strategy for student recruitment and support to attract technology talent** also internationally.

The example of the US NNI also reveals that advances in nanotechnology are closely intertwined with other technologies and application areas such as gene-editing, additive manufacturing, Artificial Intelligence, spacecraft or quantum computing. The interdisciplinary nature of nanotechnology should be reflected in **policies that shall be designed in a way to enable the nanotechnology ecosystem to reach out/tap into other digital and technological ecosystems.** To this end, rethinking technological linkages and better targeting the various application areas of nanotechnology will be a key.

Last but not least, the long-term success of nanotechnology will depend on its environmental and health related safety. As nanotechnology is not only enabling useful innovations but it can create novel and more complex threats, there is a need for a greater understanding of its actual impact. More **proactive policy frameworks will be needed in order to stimulate responsible nanotechnology** and safe research and commercialisation.

[29] A Quadrennial Review of the National Nanotechnology Initiative: Nanoscience, Applications, and Commercialisation

Section 4

4 COVID-19: Impact, Response and Recovery

4.1 COVID-19 impact on the US economy

The COVID-19 pandemic has had a devastating effect on the US economy as everywhere else in the world. GDP collapsed and the drop was more than three times higher than the loss experienced after the Second World War. The economy recovered in the third quarter of 2020. According to the forecast released at the Federal Open Market Committee (FOMC)[30] in January 2021, US GDP growth has contracted by 3.5% overall in 2020.

According to the FOMC, the pace of the recovery in economic activity and employment has moderated early 2021. Weaker demand and declines in oil prices have been holding down consumer price inflation. GDP is estimated to rebound up to a 4.2% growth rate in 2021, and slow to 3.2% in 2022 and 2.4% in 2023.

Unemployment spiked to its highest rate hitting 14.7% in April 2020, it remained in the double digits until August and it dropped to 6.7% in December 2020[31]. This is still nearly double where it was before the pandemic. According to Moody's Analytics, around 5 million US jobs are lost for ever, forcing the unemployed in industries such as restaurants and bars to find work in other sectors.

The immediate impact of Covid-19 on the stock market has been also catastrophic as in February and March 2020 major stock indexes dropped by almost 40%. The stock market, however, quickly recovered as the economy started to bounce back. The stock indexes have increased again to high levels.

Small businesses in various sectors are still struggling. A survey conducted at the end of 2020 in the US found that only 34% of small business owners said that their operations are profitable. According to the US Institute for Supply Management[32], severe supply chain disruptions were experienced and 15% of respondents reported severe supply chain issues in May 2020 in North America. In addition, there have been shortages of raw materials and final products. In terms of the supply chain, analysts in the US expected companies to move towards a mode of production that moves further away from China in order to continue serving local markets but to diversify and find alternative channels for materials and inputs.

Not just supply chains but also market demand has been shattered as consumers have less disposable income to spend[33]. The pandemic also devastated demand for vehicles. According to Statista (2021), the US automotive industry experienced a 38% year-on-year drop in demand in 2020[34].

The recession has ruined US industries especially those that involve face-to-face contact such as hospitality, tourism and retail. In terms of stock valuation, all industries have become more volatile than they were in the pre-Covid environment. Industries that have experienced the most volatility include petroleum and natural gas, apparel, restaurants and transportation[35]. The sectors with the least volatility in the current environment are those that have been least disrupted by social distancing measures such as food production and healthcare.

The manufacturing industry has been also hit hard and many companies could see a significant decrease in their revenues[36]. The manufacturing sectors most impacted include: printing and publishing, industrial machinery and equipment, fabricated metal products, apparel and textile. When combined, these industries represent over half a million businesses across the United States, with over 17% of them expected to experience a severe negative impact from the pandemic.

4.2 Impact on advanced technologies

The supply chain disruption and the demand side shocks caused by the COVID-19 pandemic have affected tech companies too. As a consequence of sluggish demand for various products, advertisers had to cut their spending. As it is well known, companies such as Facebook, Youtube, Google depend very much on these marketing revenues and make money by selling advertising space. Especially in the beginning of the pandemic, supply chain disruptions created issues for tech firms producing consumer high-tech products such as smartphones. For instance, Apple relies on supply from Chinese factories and had to face major problems.

[30] https://www.federalreserve.gov/newsevents/pressreleases/monetary20210127a.htm
[31] Bureau of Labour Statistics, report released on January 8, 2021
[32] https://www.ismworld.org/
[33] Score, 2020
[34] https://www.statista.com/topics/1721/us-automotive-industry/
[35] Brooklyn College Research, 2020
[36] Creditsafe, 2020

While the pandemic has reduced overall demand for many consumer products, it has favoured those activities that depend on data and information. Technology-intensive services witnessed a growth in particular those that offer technical or digital solutions for a remote organisation of work and production. Digital business models also proliferated with more businesses shifting their operations online.

US 'Big Tech' firms as winners of the pandemic

Most improvement in stock markets has been driven by a handful of tech stocks such as Facebook, Apple, Amazon, Alphabet and Microsoft (the so-called 'FAAAM' stocks). Amazon's earnings doubled compared to 2019 and it created 400 000 new jobs in 2020, nearly doubling its workforce in response to the pandemic. Both Facebook and Apple witnessed double-digit earnings jumps. Facebook also announced plans to hire 10 000 additional workers in April 2020. Netflix reported a revenue of ca. €5 bn in 2020 although experienced downward trends in the last quarter of 2020.

Cloud services have been one of the winners of the pandemic as demand for moving to the cloud has increased sharply. Working from home depends mainly on cloud computing applications that help employees to efficiently accomplish their tasks. According to a recent survey from Flexera on the 'State of Tech Spend in 2021'[37], firms used more often Microsoft Azure and its software-as-service offerings as well as Amazon Web Services. Google Cloud Platform has also gained interest for big data and analytics workloads. Amazon's Web Service has been one of the best operational arms as it accounted for 55% of the company's operating profit already back in 2018. Hybrid cloud and traditional data center vendors such as IBM, Dell Technologies, Hewlett-Packard Enterprise and VMware have been successful as well during the pandemic.

Semiconductors supply chain under pressure

Semiconductors is a critical industry for the US. The traditionally complex semiconductor supply chains have been hit hard during the pandemic both in the US and globally as proved by a recent survey in which 63% of the respondents reported supply chain related shortages[38]. Semiconductors are, however, of strategic importance in particular in a world moving more and more towards increased connectivity, smart cities and smart factories.

In the last quarter of 2020, a semiconductor microchip shortage has burdened the industry and caused further disruptions in other parts of the value chain such as in automotive production. At the beginning of the pandemic, demand for semiconductors fell and deliveries slowed down. Nevertheless, demand for electronic components grew sharply again when the situation got better, and interest surged in consumer electronics products and telecommunications solutions.

The microchip shortage has had a negative impact on the automotive semiconductors and has disrupted the automotive production in the US.

In order to reinforce American supply chains, the Biden administration has put forward measures to increase the ability of the US to manufacture semiconductors at home[39]. As a result of this, Intel has announced to spend ca. €15 bn to build two new chip factories.

Impact on technology budgets

As companies had to focus their resources on being able to reorganise and continue their operations, R&D funding for advanced technology initiatives and other projects has become scarcer. The immediate focus was first on survival, which became the number one priority for most emerging technology investments.

Despite of these trends, businesses of all types invested more in necessary digital technologies. As a recent McKinsey survey in the US found: "*about the impact of the crisis on a range of measures, funding for digital initiatives has increased more than anything else*." There has been a sharp increase in the share of North American consumers who interact digitally, rising by over 58%.

Companies spent the equivalent of around $15 bn (ca. €12 bn) extra a week on technology to enable safe and secure home working during the pandemic as a survey conducted in 2020 by Harvey Nash/KPMG CIO[40] revealed. This was one of the biggest surges in technology investment in history – with the world's IT leaders spending more than their annual budget rise in just three months.

4.3 Economic response and countervailing policies

Fiscal measures

As an economic response to the pandemic massive monetary and fiscal interventions have been put in place in the US to protect households and businesses. The Federal Reserve (Fed) stepped in

[37] Flexera, 2020
[38] KPMG and Global Semiconductor Alliance survey ('The impact of COVID-19 on the semiconductor industry')
[39] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/
[40] https://home.kpmg/content/dam/kpmg/xx/pdf/2020/09/harvey-nash-and-kpmg-cio-survey-2020-infographic.pdf

with a broad array of actions to limit the economic damage from the pandemic.

Several stimulus bills have been passed. The first was launched in March 2020 with a budget of $2.3 tn (ca. €1.9 tn) called the **Coronavirus Aid, Relief, and Economic Security Act** (CARES). The CARES Act meant a major individual and business assistance and economic stimulus, the largest package addressing COVID-19. Money was allocated directly to state and local governments based on population. The Trump administration signed another **$900 bn (ca. €740 bn) stimulus package** in December 2020. The stimulus legislation included $330 bn (ca. €270 bn) in small business loans and $69 bn (ca. €56 bn) for vaccine development and deployment. After the presidential elections, President Joe Biden has put forward a **new $1.9 tn** (ca. €1.5 tn) bill. His administration is pushing to accelerate the pace of vaccinations to control the spread of COVID-19 and allow the economy to open faster.

More concretely, the Fed's stimulus measures have included **interest rate cuts, loans and asset purchases, and regulation changes**. The Fed has reintroduced both old facilities used during the global financial crisis and created new ones to support the flow of credit.

Despite the injection of money into the system, inflation has dropped to almost zero–well below the Fed's ideal 2% rate–signalling deflationary pressure on the economy.

The Fed kept its benchmark interest rate at a record low near zero and stressed that it would keep pursuing its low-rate policies until a recovery is underway. At its January meeting, the Federal Open Markets Committee (FOMC) left rates unchanged.

Multiple facilities have been established to support the flow of credit to businesses:

- The *Payroll Protection Programme* provided up to $10 m (ca €8.2 m) in federally backed loans to qualified small businesses to assist with payroll costs and other operating expenses such as mortgage payments and rent. It served as a lifeline for many businesses.
- *Money Market Mutual Fund Liquidity Facility* (MMLF) made loans available to eligible financial institutions secured by high-quality assets purchased by the financial institution from money market mutual funds.
- Through the *Primary Dealer Credit Facility* (PDCF), a programme revived from the global financial crisis, the Fed offered low interest rate (currently 0.25%) loans up to 90 days to 24 large financial institutions known as primary dealers.
- The *Primary Market Corporate Credit Facility* (PMCCF) is a new bond and loan issuance. This facility is open to investment grade companies and will provide bridge financing of four years. Borrowers may elect to defer interest and principal payments during the first six months of the loan, extendable at the Federal Reserve's discretion, in order to have additional cash on hand that can be used to pay employees and suppliers.
- *Main Street Lending Programme* aimed to ensure credit flows to small and mid-sized businesses with the purchase of up to $600 bn in loans.

Assisting technological transformation during the pandemic

Since March 2020, several actions have been implemented to **support the shift to digital business operation**. The Federal Communications Commission has granted 'Special Temporary Authority'[41] to numerous providers of both fixed and mobile wireless services in all parts of the country to access additional spectrum to augment their capacity. It also has temporarily waived certain technical rules to enable service providers to meet increased customer demand for broadband during the coronavirus pandemic. These actions help consumers participate in telehealth, distance learning and telework, and simply remain connected while practicing recommended social distancing[42]. The United States granted operators temporary access to spectrum in the 5.9 GHz band to meet increased rural broadband demand following the COVID-19 crisis.

Leveraging the 'Manufacturing USA' institutes as a COVID response

The US Department of Commerce's National Institute of Standards and Technology (NIST) put in place an action called '**Manufacturing USA National Emergency Assistance Programme**'[43] in 2020 as part of the CARES act.

The rationale behind this measure is that the community of world-leading manufacturers is well positioned to leverage existing manufacturing efforts to fight the negative consequences of COVID-19.

NIST has opened a funding opportunity for rapid, high-impact projects. Funding has been awarded

[41] https://www.fcc.gov/research-reports/guides/wtb-special-temporary-authority-and-waiver-request-filing-guide
[42] OECD, 2020
[43] https://www.nist.gov/news-events/news/2020/03/nist-funding-manufacturing-institutes-support-pandemic-response

to eligible 'Manufacturing USA' institutes to implement COVID related projects. These can include for instance medical or nonmedical countermeasures, production of critical materials, equipment and supplies; additional production facilities, technology road-mapping for pandemic response and recovery, leveraging institute capabilities to strengthen state and community resilience.

Manufacturing USA's network includes more than 2 000 R&D institutions, 369 large manufacturers, 800 small manufacturers and nearly every top-ranked research and engineering university in the US[44]. Each institute focuses on a particular advanced manufacturing technology such as industrial biotechnology, 3D printing or advanced functional fabrics.

One of the Manufacturing USA institutes, the Advanced Regenerative Manufacturing Institute (ARMI) has launched the **National Technology Roadmap for Pandemic Response and Recovery in March 2021**. This has been the first pandemic roadmap driven by the manufacturing sector. The roadmap promotes taking steps in the fields of intentional regulatory and deployment frameworks, optimised predictive capabilities, stronger data infrastructure and better manufacturing and supply chain networks[45].

4.4 Technology policy highlights during the pandemic

The United States does not have an overall, coordinated innovation policy and instead follows the notion of leaving innovation to the market. The US approach has been to let new industries and competitors emerge unhindered by product-specific regulations[46]. Having said that, policy interventions have been reinforced for many years in particular as a response to the threat of Asian competitors. Most recently, technology policy has been characterised by the trade and investment disagreements with China. After a range of programmes launched under the Obama administration, Trump launched various technology competitiveness bills to respond to the Chinese technology challenge. These sanctions have been recently followed up by the Biden administration putting technological leadership in the centre of its strategy.

Attack on Chinese tech

The US government has imposed further sanctions on Chinese tech firms in 2020 to restrict Chinese access to US technology. It has also stressed that US-headquartered multinational companies are encouraged to shift their production elsewhere than China and preferably back home. China responded with counter-sanctions in early 2021. These measures are forcing companies and industries to rethink their dependencies and the organisation of their supply chains.

The **Foreign Investment Risk Review Modernisation Act Regulations** took effect on 13 February 2020. The act makes it much more difficult for Chinese telecommunication companies to access US technology and for Chinese social media companies to operate in the US. In September 2020, the White House banned Huawei Technologies from buying chips made with US technology. Huawei stockpiled chips ahead of the restriction[47]. Washington has also imposed stringent export controls on Chinese **semiconductor companies, banning the sale of American semiconductor chips** and other integral parts on the basis of national security concerns. The congress enacted a legislation calling for federal incentives for domestic chip manufacturing and investments in semiconductor research to meet the growing demand[48]. Recent legislative proposals around the semiconductor industry, increased R&D funding, support of

Biden's proactive measures for critical technologies

In the American Jobs Plan, a $180 bn (ca. €150 bn) investment is planned with the aim to advancing "***US leadership in critical technologies and upgrade America's research infrastructure***."

Substantial investments are expected in particular in Artificial Intelligence, synthetic Biotechnology, Semiconductors and Cybersecurity. In this respect, the Biden approach is also very much proactive.

A technology directorate is expected to be set up under the National Science and Technology Foundation to spend $50 bn to fund research in 10 key areas including Artificial Intelligence, Cybersecurity, Semiconductors, Robotics, Materials sciences, advanced communications technologies, biotechnology, genomics, and synthetic biology, advanced energy, quantum computing.

Source: https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/

[44] Manufacturing USA Annual Report, 2020
[45] https://www.armiusa.org/pandemicroadmap
[46] MIT Sloan, January 2021
[47] Reuters, 2021
[48] https://www.semiconductors.org/semiconductor-shortage-highlights-need-to-strengthen-u-s-chip-manufacturing-research/

technology hubs have the objective to safeguard technological supremacy[49].

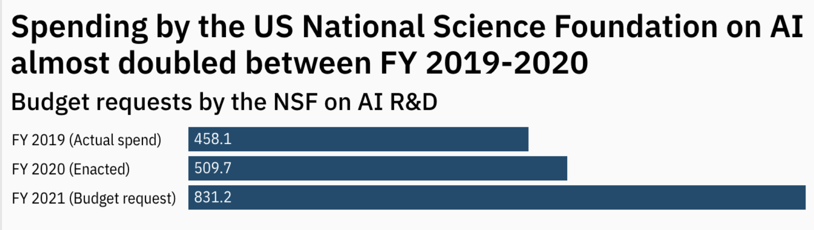
5G is another key industry with a strategic priority for the US[50]. 5G technology and its associated networks are critical for the factories of the future, smart cities and smart mobility. Besides the sanctions against Huawei, the US government provided national telecommunication stakeholders with $1 bn funding. A bill issued in March 2020 established a mechanism to prevent communications equipment or services that pose a national security risk from entering US networks. It has also put in place the 'Secure and Trusted Communications Networks Reimbursement Programme' to supply small communications providers with funds to offset the cost of removing prohibited equipment or services from their networks and replacing it with more secure communications equipment or services[51].

Export controls of emerging technologies have been further strengthened in 2020. The Export Control Reform Act[52] was introduced originally in 2018 to protect certain new technologies for security and defence. Controls took effect on six specific technologies in 2020 including the following:

- hybrid additive manufacturing and computer numerically controlled tools
- computational lithography software designed for the fabrication of extreme ultraviolet masks
- technology for finishing wafers for 5 nm production
- digital forensics tools that circumvent authentication or authorisation controls on a computer (or communications device) and extract raw data
- software for monitoring and analysis of communications and metadata acquired from a telecommunications service provider via a handover interface and
- sub-orbital craft[53].

Nevertheless, beyond these defensive measures, the Biden administration is also acting more strategic (than the Trump administration) in terms of **exploring potential technological alliances** for instance with Japan (in the area of Artificial Intelligence and Robotics) but also with the EU.

National Science Foundation AI spending



Source: TechMonitor, 2021

Protecting Critical Technologies

As already highlighted above, the development of critical technologies is a key cornerstone of the Biden strategy. In March 2021, President Biden has called for an investment of $50 bn (€40 bn) in the National Science Foundation. Technologies such as Semiconductors, Artificial Intelligence, Biotechnology and Cybersecurity are especially highlighted and supported.

The funding of the **Networking and Information Technology Research and Development (NITRD)[54]** Programme has been also reinforced. The NITDR is the Nation's primary source of federally funded work on advanced information technologies in computing, networking, and software. The programme provides research and development foundations for ensuring technological leadership.

The plan also includes $40 bn (ca. €32 bn) allocated for **upgrading research infrastructure in laboratories[55]** across the country, including computing capabilities, networks, facilities. The creation of a new **national lab focused on climate** is also foreseen.

Biden's plan contains a $100 bn (ca. €80 bn) broadband investment plan with **Cybersecurity spending** among others to protect the energy grid. The Departement of Energy[56] kicked off a so-called '100-Day Plan' in April 2021 to address cybersecurity risks to the US electric system.

Advancing Commercialisation of Digital Products from Federal Laboratories

Emphasis is also strongly put on commercialisation. The National Academies of Sciences, Engineering, and Medicine has been tasked to set up an ad-hoc committee that will investigate the impact of technology protection in specific science and technology domains on

[49] Atkinson, 2020
[50] https://www.invesco.com/invest-china/en/institutional/insights/as-covid-19-spreads-global-technology-sector-decouples.html
[51] https://www.congress.gov/bill/116th-congress/house-bill/4998
[52] https://www.congress.gov/bill/115th-congress/house-bill/5040
[53] Gibbson Dunn, 2021
[54] https://www.nitrd.gov/
[55] https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/
[56] https://www.energy.gov/articles/biden-administration-takes-bold-action-protect-electricity-operations-increasing-cyber-0

national security. In addition, the committee will consider market or institutional challenges and appropriate policy changes related to production and commercialisation.

Recent US administrations put the transfer of federally funded technologies high on the agenda through Lab-to-Market initiatives. The National Academies of Sciences, Engineering, and Medicine convened a committee of experts in 2020 to investigate the use and ownership of digital products and the current state of commercialisation developed at the federal labs[57]. The committee concluded that federally produced digital products should be freely available, however, the committee recognised that there may be cases in which the granting of exclusive rights to a firm is necessary to promote additional investment in innovation to facilitate commercialisation.

Reinforcing STEM education

STEM education is one of the agreed priorities of the US government. In December 2020, the Office of Science and Technology Policy at the White House issued the Progress Report on the Implementation of The Federal Stem Education Strategic Plan. This progress report describes ongoing efforts and implementation practices across the Federal Government.

The US Department of Education announced in November 2020 that during 2020, it invested ca. €470 m to support high-quality STEM education, including computer science, for students through its discretionary and research grants.

Regulating tech firms at home

The Biden administration is expected to launch reforms of the antitrust law with the objective to better regulate the biggest US tech companies. These actions have come even more to the forefront after the violence at the US Capitol that was fuelled by disinformation spreading on social media platforms like Facebook and Twitter and raised concerns about some of the large tech firms.

A recent congressional report[58] has discussed the negative influence and monopoly of tech firms such as Google, Apple, Amazon and Facebook and lays out a roadmap to curb their power through new regulation. Google and Facebook are already facing multiple lawsuits from federal and state law enforcement as well as regulatory agencies.

New proposals would make changes to Section 230, which shields social media companies from liability for content published by users of their platforms. In February 2021 the first steps were taken when Senator Mark Warner from Virginia introduced to the Senate the 'Safeguarding Against Fraud, Exploitation, Threats, Extremism and Consumer Harms Act'. The bill wishes to change the protections that social media companies have under Section 230 of the Communications Decency Act. The potential changes include:

- Holding platforms accountable for ads and other paid content that scams vulnerable consumers.
- Letting victims seek out legal action when the platform is used to cause harm.
- Upholding civil rights protections.
- Making sure platforms do not interfere with cyberstalking laws and can be held accountable by victims of targeted harassment and abuse.

57 https://www.nap.edu/catalog/26006/advancing-commercialization-of-digital-products-from-federal-laboratories

58 https://judiciary.house.gov/news/documentsingle.aspx?DocumentID=3429

Bibliography

Atkinson R. (2020). Understanding the U.S. National Innovation System, 2020 available at: https://itif.org/publications/2020/11/02/understanding-us-national-innovation-system-2020#:~:text=The%20United%20States%20has%20no,challenge%20of%20addressing%20this%20problem.

Creditsafe (2020). The State of the Manufacturing Industry Q3: A COVID-19 Impact Study

Deloitte (2020). COVID-19 outlook for the US technology industry, available at: https://www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/covid-19-outlook-on-technology-industry.html

Gibbson Dunn (2021). 2020 Year-end sanctions and export controls update

Hidalgo et al. Balland et al. (2019). The principles of relatedness, Springer

National Academies of Sciences, Engineering, and Medicine. 2020. A Quadrennial Review of the National Nanotechnology Initiative: Nanoscience, Applications, and Commercialization. Washington, DC: The National Academies Press. https://doi.org/10.17226/25729.

National Academies of Sciences, Engineering, and Medicine 2021. Advancing Commercialization of Digital Products from Federal Laboratories. Washington, DC: The National Academies Press. https://doi.org/10.17226/26006.

OECD (2020). Policy options to support digitalisation of business models during Covid-19, ANNEX

Roco, M.C. (2011). The long view of nanotechnology development: the National Nanotechnology Initiative at 10 years. J Nanopart Res 13, 427–445 https://doi.org/10.1007/s11051-010-0192-z

Score (2020). The megaphone of main street: fall 2020 presented by The Impact of COVID-19

US (2020). Nanotechnology—Over a Decade of Progress and Innovation A REPORT BY THE U.S. FOOD AND DRUG ADMINISTRATION, Issued July 2020

Whitehouse (2021). National-Strategy-for-the-COVID-19-Response-and-Pandemic-Preparedness, available at: https://www.whitehouse.gov/wp-content/uploads/2021/01/National-Strategy-for-the-COVID-19-Response-and-Pandemic-Preparedness.pdf

Winstead (2020). The Applications and Implications of Nanotechnology, American University Washington available at: https://www.american.edu/sis/centers/security-technology/the-applications-and-implications-of-nanotechnology.cfm

Internet sources:

https://www.cazenovecapital.com/uk/wealth-management/insights/strategy-and-economics/covid-19-why-the-tech-giants-have-emerged-as-winners/

https://www.congress.gov/bill/116th-congress/house-bill/4998

https://www.cnbc.com/2021/04/29/biden-100-days-china-tech-battle-sees-sanctions-remain-alliances-made.html

https://www.investopedia.com/congress-agrees-on-second-stimulus-here-s-what-s-in-it-and-what-s-not-5093226

https://www.investopedia.com/coronavirus-aid-relief-and-economic-security-cares-act-4800707

https://www.invesco.com/invest-china/en/institutional/insights/as-covid-19-spreads-global-technology-sector-decouples.html

https://www.gibsondunn.com/2020-year-end-sanctions-and-export-controls-update/

https://www.congress.gov/bill/116th-congress/house-bill/133/text?format=txt https://www.congress.gov/bill/115th-congress/house-bill/5040

https://www.reuters.com/article/us-autos-tech-chips-focus-idUSKBN29K0GA

https://www.texaspowerfulsmart.com/nanotech-companies/venture-investment-in-nanotechnology.html

About the 'Advanced Technologies for Industry' Project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies are needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. The project provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies, including enabling conditions such as skills, investment and entrepreneurship
- Analytical reports, such as on technology trends, sector-based insights and products
- Analyses of policy measures and policy tools related to the uptake of advanced technologies
- Analysis of technology trends in competing economies, such as in the US, China and Japan
- Access to technology centres and innovation hubs across EU countries

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project has been undertaken on behalf of the European Commission – the Directorate General for Internal Market, Industry, Entrepreneurship, and SMEs and the European Innovation Council and SME Executive Agency (EISMEA) – by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult, and NESTA.

EA-03-21-310-EN-N

Publications Office
of the European Union