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Europe's Capacity to Act in the Global Tech Race

Charting a Path for Europe in Times of Major Technological Disruption

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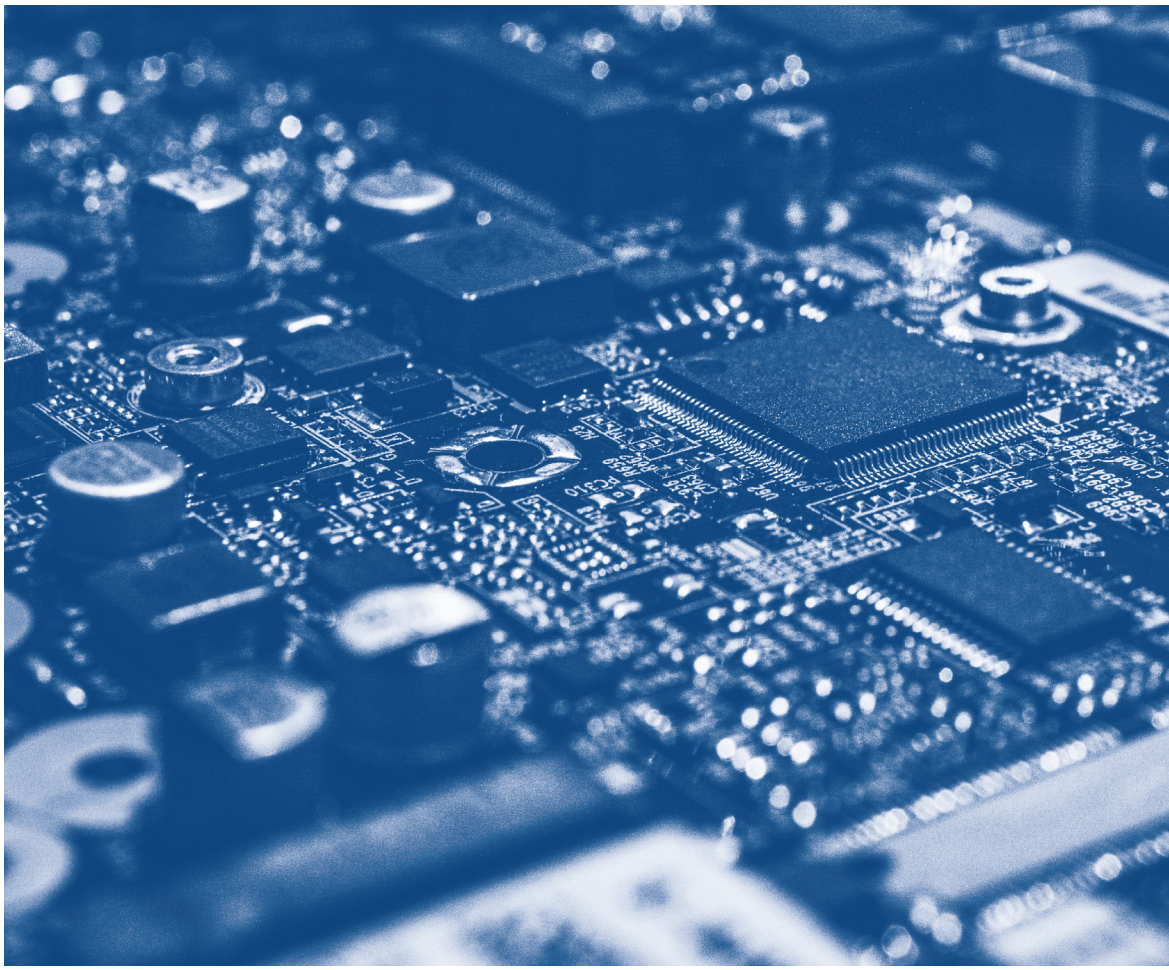

EXECUTIVE SUMMARY

In the twenty-first century, technological innovation is driving geopolitical, economic and military competition. The US and China are leading the field. The risk of an emerging global bipolar technology environment is looming; one that could force third countries to come down on the side of the US or China. Europe is lagging behind in the global tech race and faces an uphill battle in its attempts to remain competitive.

The findings in this study show that Europe has quite a way to go if it wants to become as competitive as the US or China. In particular, European stakeholders from the private and public sector as well as civil society are worried about the EU's overdependence on foreign-owned technology providers. These concerns are particularly acute in the realms where Europe does not have a strong indigenous industrial base, such as in cloud computing (76 percent express concerns), artificial intelligence (68 percent), and to a lesser extent by 5G mobile technology (54 percent).

It makes a difference whether the EU is reliant on the US or China. The majority of stakeholders surveyed say that the EU relies most on the US for key technologies including artificial intelligence (80 percent) and cloud computing (93 percent) but also blockchain, high performance computing, and the internet of things (IoT). Only in 5G and mobile networks did respondents identify a larger dependency on China (65 percent). A slim majority (54 percent) believe the EU should chart an independent path between the US and China while 46 percent believe the EU should move closer to the US.

According to the stakeholders surveyed, the EU's lack of first-mover advantage and absence of dominant home-grown tech players (such as Google, Microsoft, Amazon, and others) are the central obstacles to its capacity to act. But the EU does have levers it can use to turn the tides in its favor. When surveyed on the instruments available to Europe, stakeholders ranked the top four as: access to the EU market; global regulatory power; standard-setting; and data access and control.

There are five key technology areas that are set to define and shape the future of Europe's capacity to act. These are: artificial intelligence (AI), cloud computing, semiconductors, 5G and mobile equipment, and quantum technology. We have assessed Europe's strengths and deficits in each of these areas.

Artificial intelligence: The EU has stepped up its efforts to develop, deploy, and promote trustworthy AI. But there are three major hindrances preventing European competitiveness: Europe's inability to commercialize its AI development; the lack of venture capital investment for AI start-ups; and the tension between need for data sets to train AI models and the EU's strong data protection rules that make access to data sets difficult. The EU should further codify its values for international export. Together with its member states, the EU should also create large-scale public data pools usable for both AI research and AI application, because when the public sector leads in the adoption of AI-services, it accelerates AI take-up in other areas.

Cloud computing: Europe's gap with the US and China on cloud computing is even more striking than in the field of AI. However, the EU is aware of this. With ambitious projects such as the European Alliance for Industrial Data and Cloud and GAIA-X, Europe aims to open up its cloud market. To succeed in this, Europe will have to learn from past mistakes and focus on driving down the costs of European cloud computing while driving up its reliability. Start-ups and small and medium-sized enterprises (SMEs) active in cloud computing should be supported through interoperability rules, while rules to protect citizens' data should be enforced.

Semiconductors: Creating independent semiconductor capacity will be no easy task for the EU. And funds alone will not suffice to make European companies competitive. The task is rather to specialize in fields where the EU has incumbent strengths, such as chips for automotive, AI, and IoT devices. Instead of trying to compete directly with the US and the other world leader, Taiwan, the EU should instead focus on preserving and supporting local manufacturing capabilities as well as promoting open standards in chip design like RISC-V.

5G and mobile networks: Europe is somewhat better positioned on 5G and mobile networks compared to other areas. That partially comes down to the fact that there are no major US players in this space, but also because Europe's two leading companies – Ericsson and Nokia – have the size and scale to credibly go head-to-head with Asian

counterparts. The EU, via its innovation programs, should support intensive research in the field of 6G to maintain its strong position so that it is ready when the next development in mobile connectivity comes around. In addition, the EU and its member states should promote open standards for mobile communication networks.

Quantum computing: This technology is still in the early stages of development and its practical applications today are limited. But by 2030, it is likely to be a vital technology with projected benefit across a range of areas including communication, industry, and AI, among others. Germany and France are already pushing forward in this sector, but Europe more broadly must position itself as a frontrunner now to gain first-mover advantage and avoid falling behind, like it has in the semiconductor industry. The EU also has an opportunity to leverage its incumbent research strengths to successfully bring this technology to market. This means fostering innovation and public-private partnerships to develop the potential of quantum computing.

When it comes to the geopolitics of technology, the EU and its member states should make a priority of maintaining a globally interoperable internet and encouraging global innovation. Europeans do not always appreciate just how greatly they benefit from both of these things. To make this a reality, the EU should take the lead in the development of international coalitions with like-minded actors in standard-setting bodies and informal groupings for technology governance. And it should work out a strategy that fuels development, connectivity, and regional empowerment the Global South – a part of the world that Europe has, so far, not paid enough attention to when it comes to technology. Following the examples of the US and China, the EU must acknowledge the role that military and defense modernization can play in advancing its innovation industrial base.

If the EU wishes to assert its standards across all five technology areas, it has to take major steps to become competitive. Merely relying on regulation and leveraging access to the European market will fall short in the long term. That much is now clear. The EU needs to innovate, and if it fails in this, it will lose its capacity to act on the global stage. Furthermore, if the EU wants to be competitive it needs to complete the Digital Single Market and alter the culture behind it. Europe needs to reinvigorate its high-skilled workforce through flexible working conditions, education, and immigration, and remove blockers to the use of innovative technologies. A deeper culture of risk tolerance should be developed in which risk-taking and failing are accepted.

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INTRODUCTION

Technological leadership has become a central dimension of geopolitical power. In this development, the primary front in the emerging tech power rivalry is between the US (United States of America) and China (People's Republic of China). The European Union (EU) has fallen behind and needs to catch-up. The stakes in this race are high and will have an impact on economic competition, national security and broader values-based notions of political order. This study sheds light on Europe's approach to technological mastery.

The European Commission's President Ursula von der Leyen has made EU tech leadership a top priority of her presidency and, beginning in December 2019, she has focused on boosting the EU's role as a geopolitical actor by launching a multitude of initiatives, strategies and legislative proposals. Across European capitals, political leaders have been calling for 'digital sovereignty'. This became a rallying cry, which served as a guiding principle for the EU's digital policy during the 2020 German Presidency of the Council of the EU.

This study looks into the progress of the EU and its member states across selected technological fields and their global entanglements with other nations and technology actors. First, five trends – currently defined by the interplay between digitalization and international politics – will be examined to provide the necessary background and showcase the urgency of action needed. Second, the concept of 'capacity to act' will be outlined and positioned in the context of the EU's contemporary tech policy discourse. Third, a Stakeholder Snapshot will provide quantitative insights into how key stakeholders perceive the geopolitical dimensions of the European tech-landscape. This data includes perceptions of the EU's key dependencies and the instruments at hand for strengthening European resilience and leadership in technology. Fourth, a selection of crucial technology areas that will shape the future will be assessed. Among these are artificial intelligence, cloud computing, semiconductors, 5G and mobile connectivity, and quantum computing. Each of the sections will include a qualitative assessment of the state of play and general policy approach, while also providing specific policy recommendations. Finally, some general conclusions will be drawn on how the EU and its member states can enhance their technological competitiveness.

Key Trends Defining the Geopolitical Tech Space in 2021

Five major trends currently define the world's technological and political environment. These are the trends that motivate the EU towards action and demonstrate the urgency with which the bloc needs to act. The five trends that stand out in particular include:

1. Technology's key role in ensuring geopolitical, economic, and military competitiveness;
2. The gradual trend of US-China digital decoupling;
3. Digital authoritarianism;
4. New technological dependencies and vulnerabilities brought on by COVID-19;
5. New renaissance in tech-industrial policy.

All of these trends are interlinked with the great power rivalry between the US and China, which is increasingly defined by the race for technological leadership.

The overarching question for European policy makers is how the EU and its member states fit into this great power rivalry and how they can credibly compete for leadership and mastery in digital technologies between these two great powers.

1.1 TECHNOLOGY'S KEY ROLE IN GEOPOLITICAL COMPETITIVENESS

Technological leadership is fast becoming one of the key areas of geopolitical, economic, and military competition. The many use cases, or general-purpose character of several key technologies, is blurring the lines between previously distinct domains, such as economy and security. For example, advances in image recognition algorithms that can be used for commercial purposes, might also be used for mass surveillance or for identifying objects on a battlefield. Quantum technology that can be used for domestic manufacturing, might also be employed to detect stealth aircrafts, or to break encrypted or otherwise secure networks. Governments and companies that are able to achieve mastery of key enabling technologies and adopt them more easily, will have enormous economic and political power levers at their disposal. Actors that are unable to keep pace, will be forced to expose themselves by depending on other countries for those essential technologies.

Given the growing importance of technology for ensuring economic and military competitiveness, it should come as no surprise that the emerging great power competition between the US and China is increasingly defined by the quest for technological leadership. The Chinese Communist Party (CCP) has rolled out a range of strategic initiatives aimed at enhancing technological capabilities (see Fig. 1), while China's President Xi Jinping has made it clear that science and technology leadership are "key to military upgrading".[1]

Due to the importance of the private sector for developing cutting-edge technologies, countries need to develop and nurture a thriving innovation sector at home. Today, big tech companies in the US and China are among the world's best capitalized businesses. For context, seven of the ten largest companies in the world by market capitalization are in the tech space and out of those, five are US-based and two are from China.[2] These tech companies have become engines of growth, productivity and, most importantly, innovation. Be it IBM and Google in quantum computing; Amazon and Microsoft in cloud computing; or Baidu in machine-learning, tech companies have become the locus of cutting-edge innovation at a level previously reserved for top universities and government R&D programs.

1 Reuters Staff, "China's Xi pushes advanced technology for military", Reuters, (March 13, 2017:): https://www.reuters.com/article/us-china-parliament-defence/chinas-xi-pushes-advanced-technology-for-military-idUSKBN16K02V> (accessed November 10, 2020).

2 "The 100 largest companies in the world by market capitalization in 2020", Statista, (April 06,2021): https://www.statista.com/statistics/263264/top-companies-in-the-world-by-market-capitalization (accessed April 06, 2021).

TABLE 1: MAJOR STATE-DRIVEN TECH INITIATIVES IN CHINA

NAME	PURPOSE/OBJECTIVE	TIMEFRAME
Made in China 2025	A ten-year industrial development plan funded with approx. €252 billion will transform ten core industries into globally competitive, innovative, and digital industries. The plan was updated in 2017 with a stronger focus on self-reliance for core emerging technologies.[1]	2015–2025
Internet Plus	A subset of the Made in China 2025 plan to fully integrate conventional industries and connected services, particularly in manufacturing, finance, government, health and agriculture.	2015–2020
Digital Silk Road (DSR)	The technology and ICT infrastructure component of China's outbound Belt and Road Initiative (BRI), initially announced in 2015.[2] It aims to expand 5G networks, data centers, smart cities, satellite collaboration, and over-the-top (OTT) service providers, especially mobile payments, e-commerce, and gaming.[3] At least 16 countries have signed a memorandum of understanding on the Digital Silk Road.[4]	Since 2015
14th Five-year Plan on National Scientific and Technological Innovation	By focusing on scientific and technological self-reliance, Beijing "aims to create closer ties between academia and industry, and to improve the evaluation of the results of this collaboration."[5] However, the document lacks explicit growth targets.	2021–2025
New Generation AI Development Plan	"[B]y 2030, China's AI theories, technologies, and applications should achieve world-leading levels, making China the world's primary AI innovation center, achieving visible results in intelligent economy and intelligent society applications, and laying an important foundation for becoming a leading innovation-style nation and an economic power."[6]	Until 2030
China Standards 2035	An as yet unreleased 15-year strategy under formulation by the Standardization Administration of China to shape and export indigenous industrial and technical standards and play a larger, concerted role in international bodies like the International Standards Organization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunications Union (ITU).[7]	Until 2035

Sources:

1 The respective US-Dollar denominated amounts that were found in the literature were divided by the foreign exchange reference rate of the Euro/US-Dollar pair of 1.1888 on April 9, 2021 to display their value in Euro.

2 Robert Greene and Paul Triolo, "Will China Control the Global Internet Via its Digital Silk Road?", Carnegie Endowment For International Peace (May 08, 2020)

3 Paul Triolo et al., "The Digital Silk Road: Expanding China's Digital Footprint," Eurasia Group (April 2020)

4 Steven Feldstein, "Testimony before the U.S.-China Economic and Security Review Commission Hearing on China's Strategic Aims in Africa," May 8, 2020

5 Smriti Mallapaty, "China's five-year plan focuses on scientific self-reliance," nature, (March 11, 2021)

6 Graham Webster et al., "Full Translation: China's 'New Generation Artificial Intelligence Development Plan", New America, (August, 2017):

7 Alexander Chipman Cody, "What is the China Standards 2035 Plan and How Will it Impact Emerging Industries?", China Briefing, (July 2, 2020)

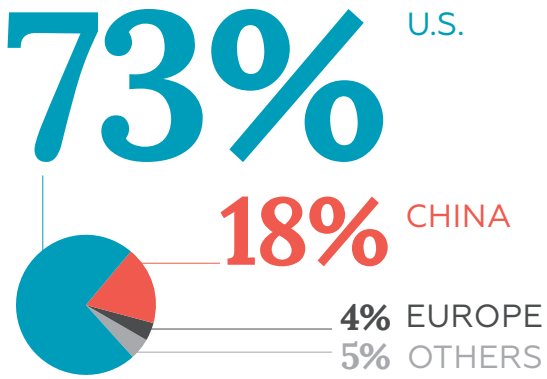
The gap between European technology companies and American and Chinese technology giants is significant. European companies count for less than 4 percent market capitalization among the world's 70 largest digital companies, compared to the US, whose companies represent 73 percent and China's, which represent 18 percent.[3] Venture capital, which is the lifeblood for new and innovative tech companies, has surged in Europe in 2019 and is up 40 percent since 2018, attracting €29 billion of capital to European tech companies.[4] But that is still considerably less than US and Chinese venture capital firms put on the table, as US based companies raised €114 billion and Chinese based firms more than €34 billion.[5] The low level of investment in indigenous European technology has created the conditions for non-European acquisitions, such as Google's purchase of UK-based AI company DeepMind.

3 The Economist, "The Brussels effect, cont", (February 20, 2020).

4 Kim Darrah, "European tech startups break records with $34bn in venture capital funding this year", Sifted, (April 06, 2021): https://sifted.eu/articles/european-tech-atomico-startups (accessed April 06, 2021).

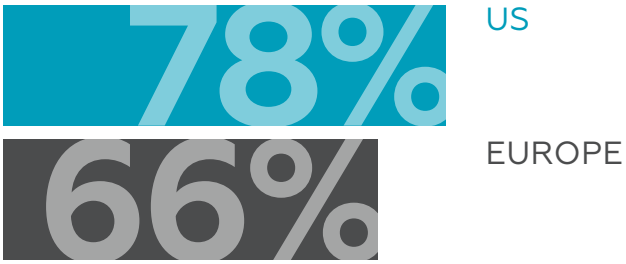
5 "Venture Pulse Q4 2019", KPMG, (January 15, 2020): https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/01/venture-pulse-q4-2019-asia.pdf (accessed April 06, 2021); Pete Settles, "Venture Capital Investment in U.S. in 2019 Hits $136.5 Billion", KPMG, (January 15, 2020): https://home.kpmg/us/en/home/media/press-releases/2020/01/venture-capital-investment-in-us-in-2019-hits-136-5-billion-second-highest-on-record-kpmg-report.html#:~:text=Venture%20Capital%20Investment%20in%20U.S.,Highest%20on%20Record%3A%20KPMG%20Report (accessed April 06, 2021).

FIGURE 1: MARKET CAPITALIZATION OF TOP 70 TECH COMPANIES



Source: "Tech regulation: The Brussels effect, continued.", The Economist (February 20, 2020).

FIGURE 2: TECHNOLOGICAL ADOPTION IN MANUFACTURING



Source: Debora Revoltella et al., "Adoption of digital technologies by firms in Europe and the US: Evidence from the EIB Investment Survey" (March 18, 2020).

1.2 THE GRADUAL TREND OF US-CHINA DIGITAL DECOUPLING

As the US and China try to outpace each other by developing and adopting new technologies, they are also in the process of cutting their reliance on each others' technologies. This is the so-called digital or technological 'decoupling'. When taken to its logical conclusion, decoupling could lead to two separate tech stacks evolving: one led by the US and one by China. Each tech stack would have its own supply chain network, innovation system, standards, and protocols. At some point the EU and its member states might have to ask whether they want to set up their own third stack. And if the answer is no, then the EU may have to decide which tech stack – and by proxy which country – to align with. Even though the emergence of two perfectly distinct systems is not realistic in the foreseeable future, the trend towards decoupling raises questions about Europe's strategic orientation.

Export controls and sanctions imposed by the US on China have also increased the extent of decoupling. For an example of how these sanctions and controls play out, we only need to look at the case of Chinese telco Huawei. Google's discovery of data security vulnerabilities when people installed Google apps or a Google OS on Huawei handsets resulted in Google blacklisting the company. Subsequently, the US government banned companies from doing business or collaborating with the company. In response, Huawei is now developing its own HarmonyOS. Furthermore, US chipmakers were forced to cut off supplies to Chinese companies, after the US government added them to the Entity List (see Table 2).

Beijing – motivated by such restrictions and its own strategic aspirations for end-to-end control – is gradually striving for digital self-reliance through investments in its own domestic tech-industries and by reducing its dependence on other suppliers. China has taken the logic of control so far as to seek other elements of digital decoupling in the field of internet governance by exploring the idea of cutting the country off from the World Wide Web and setting up "national internet sovereignty". Something that already exists in China in the form of the "Great Firewall", which significantly reduces information permeability.[6]

The US reasons for decoupling span questions of economic competitiveness and national security. The perception in Washington, shared by the Biden Administration, the former Trump Administration, and large bipartisan majorities in Congress, is that China has taken advantage of the open American market and innovation cooperation while simultaneously using the opportunity to steal intellectual property and engage in forced technology transfers, all as a means to develop China's own innovation industrial base. Washington also has concerns about the security risk posed by Chinese technologies – in particular the use of commercial products for espionage and disruption – due to the strong link between the Chinese tech industry and the CCP and military.

1.3 DIGITAL AUTHORITARIANISM

Technology is becoming a vehicle for exporting and enforcing ideologies. While technologies may have once been seen as emissaries of digital democratization, they are increasingly used to enforce digital authoritarianism

6 Beijing is considered a forerunner in this respect by establishing the so-called 'Great Firewall of China' – largest and most cultivated online censorship system – and even exporting these national notions of internet governance to other countries in the world. However, since other countries such as Russia also drives these developments, the term of 'cyberbalkanization' is also referring to this.

TABLE 2: SELECTED US GOVERNMENT ACTIONS AGAINST CHINESE TECHNOLOGIES

DATE	KEY US MARKET ACCESS ACTIONS AIMED AT CHINESE TECHNOLOGY
May 2019	Huawei and 68 non-US affiliates added to the Entity List.
June 2019	Institute of Computing Technology added to the Entity List.
August 2019	46 additional Huawei-affiliated entities added to the Entity List.
October 2019	28 Chinese companies, including world-class AI start-ups such as SenseTime, Megvii, and Yitu, added to the Entity List for their involvement in human rights violations.
November 2019	The Committee on Foreign Investment in the United States (CFIUS) launches an investigation into the TikTok (ByteDance Technology) acquisition of Musical.ly.
March 2020	Following two separate CFIUS investigations, Chinese companies are forced to divest from earlier acquisitions of the hotel management systems software company, StayNTouch, and the gay men's dating app, Grindr, citing concerns about Chinese government access to sensitive data.
May 2020	Semiconductor firms using American chipmaking equipment, intellectual property, or design software, need a special license before delivering to Huawei.
June 2020	Limited exemptions granted for certain Huawei technologies in the context of international 5G standard-setting.
August 2020	11 companies added to the Entity List based on their role in human rights abuses in Xinjiang (including forced labor, massive detention and surveillance, and involuntary biometric data collection). 38 Huawei affiliates added to the Entity List. The US withdraws exemptions and expands the foreign-produced direct product (FPDP) rule to restrict Huawei non-US affiliates access to semiconductors produced using US technology and design. The White House issues an Executive Order aimed at effectively banning the use of Tiktok and WeChat in the US.
November 2020	The White House releases an Executive Order banning US investment in Chinese companies on the so-called "Pentagon List" for ties to the Chinese military.
December 2020	77 additional multinationals added to the Entity List including Chinese semiconductor company, SMIC, and Drone Manufacturer, DJI, due to ties to the Chinese military.
January 2021	US bans transactions with Chinese electronic payment apps (Alipay, QQ Wallet, WeChat Pay). The Pentagon places nine companies on the Entity List for ties to the Chinese military including mobile phone maker Xiaomi and aerospace company Comac.
February 2021	The Biden Administration seeks a stay in litigation over US market access for Tiktok and WeChat, pending a review of US approaches to Chinese social media.
March 2021	The US Federal Communications Commission (FCC) designates Huawei, ZTE, Hytera Communications, Hangzhou Hikvision Digital Technology, and Dahua Technology as posing an "unacceptable risk" to national security.

Source: Baker McKenzie, "Sanctions & Export Controls Update": https://sanctionsnews.bakermckenzie.com/category/bis/entity-list (accessed March 1, 2021).

with "[n]ew technologies…enabl(ing) high levels of societal control at a reasonable cost."[7] The tools for effective digital authoritarianism already exist, including AI-enabled surveillance systems (e.g. facial/gait recognition technology), spyware on mobile phones, and internet censorship, to name a few.

Countries setting an example by using those technologies can inspire others. Not only like-minded autocrats, but also vulnerable democracies who could set norms for the use of invasive technologies. To see this approach in action, we need only look at China's "Great Firewall" and the example it sets. Countries such as Vietnam and Thailand have already

7 Wright and, Nicholas, "How Artificial Intelligence Will Reshape the Global Order. The Coming Competition Between Digital Authoritarianism and Liberal Democracy," Foreign Policy, 2018.

debated copying China's model. Chinese experts are also reported to have supported government censors in Sri Lanka and to have supplied surveillance or censorship equipment to Ethiopia, Iran, Malaysia, Russia, Venezuela, Zambia, and Zimbabwe, among others.[8] As technology-driven authoritarian models of governance become more apparent in fragile democracies, the concept of liberal democracy will find itself under new pressure.[9]

Since the very beginning of the COVID-19 crisis, the discussion surrounding digital authoritarianism has gained new impetus as several states – especially in Southeast Asia – have employed new technologies such as AI surveillance to detect whether citizens are wearing face-masks or not, and social tracing apps to enforce quarantine orders. Critics see the use of these technologies in aid of public health as a gateway to normalizing broader and more authoritarian uses in the future. Even in European states such as Germany, France, the United Kingdom or the US, a debate has flared up concerning the use of technologies to mitigate the spread of the COVID-19 virus and to strike the right balance between using tech for good and honoring each citizen's right to have control over their personal data.

1.4 TECHNOLOGY DEPENDENCIES AND VULNERABILITIES

The COVID-19 crisis has helped propel technology adoption forward around the world. Cloud-based services, in particular, have gained rapidly in usage and popularity. But this has revealed four key dependencies and vulnerabilities that Europe now faces::

1. **Chinese market:** The growth of the Chinese economy during the COVID-19 crisis has amplified European – particularly German – dependencies on the Chinese market for IoT and Industry 4.0 exports. In 2020, amid Chinese GDP growth and a recession in Europe and the US, China overtook the US as the EU's most important trade partner. This makes key European countries like Germany dependent on China and adds sensitive questions about economic relations to any decisions about potentially banning Chinese 5G vendors, for example.

2. **US platforms and cloud providers**: Widespread tech adoption throughout Europe during the COVID-19 crisis has intensified reliance on US web services and cloud hosting providers.

3. **Third-country supply chains:** COVID-19 revealed how brittle (tech) supply chains can be as Europe has faced bottlenecks on a range of products from semiconductors to vaccines.

4. **Cyber-security:** The COVID-19 crisis has opened up new vulnerabilities for state-backed active measures, mis-/disinformation, IP theft, and cyber-spying. One example was the hack of the European Medicines Agency, which resulted in vaccines data being leaked. New IT-based threat vectors impacting European democracy, prosperity and potential for physical harm.

Taken together, these trends show potential vulnerabilities in Europe's technological ecosystem that must be mitigated.

1.5 A NEW RENAISSANCE IN TECH-INDUSTRIAL POLICY

The growing worldwide trend toward tech industrial policy is unmistakable. In many ways, China has been a forerunner in the resurgence of this trend. China's technological development efforts have drawn greater global attention since 2015 when it launched its Made In China 2025 plan, which was updated in 2017 to put greater emphasis on creating domestic autonomy in key emerging technology areas. China's use of industrial targets and import substitution industrialization[10] to boost its indigenous technology companies, helps to incubate domestic enterprises and provide fertile ground for them to scale up. Other factors bolstering China's domestic tech sector include generous state-backed investments in the form of both subsidies and state financing, procurement structures that preference state-favored companies, forced joint ventures, and sharing of technology IP gathered through state-backed industrial espionage with copy-cat companies at home. All of these factors help to create a codependent technology ecosystem for China, in which the CCP is the undisputed senior partner.[11]

For the US in recent years, the story has been different. The US was heavily reliant on the private sector to push its technology industry forward. But now the US is also preparing more government-focused support for its innovation

8 Tarun Chhabra, "The China challenge, democracy, and U.S. grand strategy", Brookings (February 2019), pp. 5-6: https://www.brookings.edu/wp-content/uploads/2019/02/FP_20190311_us_grand_strategy_chhabra.pdf (accessed November 10, 2020).

9 Besides the direct impact of exporting technologies for undemocratic practices, China also exerts its economic and technological influence over third countries via its infrastructure projects. By deploying its own IT-Stack, the recipient countries can become structurally dependent.

10 Import Substitution Industrialization is a macroeconomic strategy of replacing imports that satisfy a domestic demand with domestically produced goods and services to support local industry while reducing dependencies on foreign enterprises.

11 Max J. Zenglein and Anna Holzmann, "Evolving Made in China 2025. China's industrial policy in the quest for global tech leadership," MERICS, (July 2019): https://merics.org/de/studie/made-china-2025 (accessed March 17, 2021).

industrial base. American tech industrial policy is driven by a sense of national mission, linked to national security and seen through the lens of the US-China great power conflict. The US is now eyeing an increase in public spending through both defense and civilian channels to maintain its leadership in key emerging technologies.[12] The Biden administration is currently putting aside €252 billion for the development of emerging technologies including AI, 5G, 6G and electric vehicles as elements of the president's Build Back Better recovery plan.[13]

Europe has also gotten serious about having a more interventionist industrial policy. In 2019, France and Germany began thinking about what a more serious approach might look like. They issued a 14-point Franco-German Manifesto on European Industrial Policy in which they laid out Europe's 2030 outlook in stark terms: "The choice is simple when it comes to industrial policy: unite our forces or allow our industrial base and capacity to gradually disappear."[14] France and Germany outlined specific focus areas, including massive industrial investment, changes to Europe's regulatory framework, and new measures to protect Europe's industrial base. This document pointed favorably to new policy developments around Important Projects of Common European Interest (IPCEI) that allow for greater state aid to be deployed and ensuring public procurement access and trade policy operates in service of strategic autonomy. Finally, it also emphasized the need for greater competitiveness of European enterprises and championed more active screening of foreign investment. Other initiatives such as the cloud and data infrastructure project GAIA-X, which was initiated by the German and French governments and designed to develop common requirements for a European data infrastructure, are heading in a similar direction.

The COVID-19 crisis and the vulnerabilities it exposed have pushed Europe to rethink EU-level industrial policy, including in key technology areas. The EU will allocate 20 percent of its Recovery and Resilience Facility (RFF) to digitalization and technology investments. Embryonic cooperation on five new IPCEIs is already underway on mobile network equipment, semiconductors, cloud and data innovations, hydrogen power, and batteries. And the European Commission has drafted its so-called "Digital Compass 2030" – an action plan for digital competitiveness – with concrete tech development targets and a monitoring process for the next nine years.[15] These efforts are complemented by multilayer initiatives at the national and regional levels. Germany, for instance, has ambitious industrial R&D plans, investing €2 billion in quantum computing, €5 billion in AI and €2 billion in 5G. Industrial policy initiatives are also taking place at the regional level, for instance in Baden-Württemberg's Cyber Valley, Europe's largest AI consortium, and Bavaria's Quantum Valley. Generally, Europe's tech industrial agenda is ambitious and heavily informed by geopolitical circumstances. Questions remain, however, as to how the EU can translate its objectives into effective action and to what extent it will enlist like-minded democracies in its efforts.

1.6 FROM "DIGITAL SOVEREIGNTY" TO CAPACITY TO ACT

The EU must find new ways to assert itself technologically amid the fierce competition between the US and China. The push for digital or technological sovereignty or a "European third way" are buzzwords often heard thrown around. The prevalence of these buzzwords signals a deep desire and strategic need for technological autonomy. But the question of how the EU can achieve that goal remains unanswered.

The term digital sovereignty refers to the concept of self-determination and independent decision-making in the digital space.[16] Nevertheless, the term itself is used so often that it is has lost much of its meaning. Consequently, digital or technological sovereignty is sometimes mistaken for digital or technological autarky – an idea that fails to consider the level of globalization and inter-connectedness in today's supply chains, in particular regarding technologies.[17] And while sovereignty in a strict sense might make sense in the analog world, it has significant limitations in the digital space, due to the borderless nature of the internet.

12 Aaron Boyd, "White House Strategy Names 20 Emerging Technologies Crucial to National Security," Nextgov, (October 15, 2020): https://www.nextgov.com/emerging-tech/2020/10/white-house-strategy-names-20-emerging-technologies-crucial-national-security/169293 (accessed March 1, 2021).

13 Joe Biden, "THE BIDEN PLAN TO ENSURE THE FUTURE IS "MADE IN ALL OF AMERICA" BY ALL OF AMERICA'S WORKERS": https://joebiden.com/made-in-america (accessed March 1, 2021).

14 BMWi and Ministère de l'Économie et des Finances, "A Franco-German Manifesto for a European industrial policy fit for the 21st Century", (February 2, 2019): https://www.bmwi.de/Redaktion/DE/Downloads/F/franco-german-manifesto-for-a-european-industrial-policy.pdf?__blob=publicationFile&v=2 (accessed March 1, 2021).

15 Debora Revoltella et al., "Adoption of digital technologies by firms in Europe and the US: Evidence from the EIB Investment Survey", (March 18, 2020): https://voxeu.org/article/adoption-digital-technologies-firms-europe-and-us (accessed April 21, 2021).

16 Isabel Skierka, „Öffentliche Anhörung zum Thema IT-Sicherheit von Hard- und Software als Voraussetzung für digitale Souveränität" ["Public hearing on IT security of hardware and software as a prerequisite for digital sovereignty"], (December 10, 2019): https://www.bundestag.de/resource/blob/672536/b2b63aeeaffe54e40f8c62571cc628c4/Stellungnahme-Skierka-data.pdf (accessed November 10, 2020); Adam Satariano, Matina Stevis-Gridneff, "Big Tech's Toughest Opponent Says She's Just Getting Started", New York Times, (November 19, 2019): https://www.nytimes.com/2019/11/19/technology/tech-regulator-europe.html (accessed November 10, 2020).

17 BITKOM, "Digitale Souveränität" (2015): https://www.bitkom.org/sites/default/files/file/import/BITKOM-Position-Digitale-Souveraenitaet1.pdf (accessed March 01, 2021).

The call for a "European third way" brings with it other misconceptions.[18] One interpretation concerns the EU's distinct regulatory and ethical emphasis on developing technologies. In this way, EU tech would focus on Europe's human-centred or value-oriented approach with regard to technology to differentiate it from the US, which is considered more "hands-off" and profit maximizing, and China, which is state-driven and oriented toward social control. Another view builds on the concept of a third European tech stack or sealed-off supply chain that eliminates third-party dependencies. Those notions have recently been brought forward in light of the US-Chinese trend towards decoupling and the danger of the EU having to align with one great power or the other in these uncertain times.

Both interpretations have their limitations. The human-centered approach is based on the EU's regulatory power but neglects the industrial and capabilities side. The idea of a European IT stack can be reduced to just describing a push for technological import substitution industrialization (ISI) or even autarky.

Against this backdrop, the following study puts forward the concept of the EU's "capacity to act in the technological realm" – at least as an interpretation of "digital sovereignty" - in order to describe the EU's prospects and opportunities in the digital age.

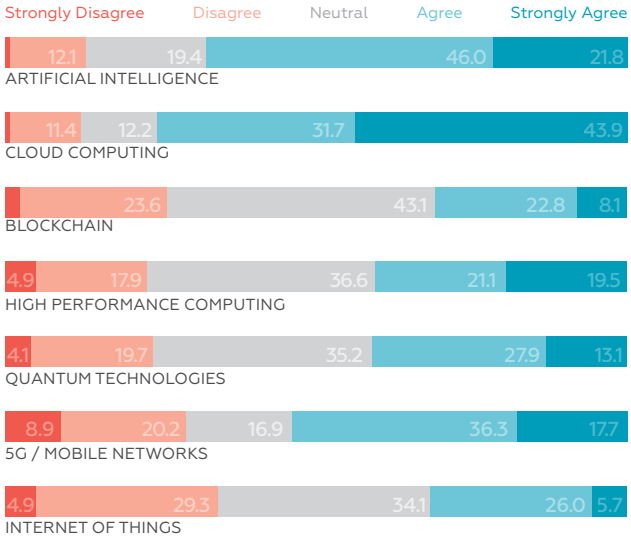
18 Melissa Heikila, Steven Overly, "China wants to dominate AI. The US and Europe need each other to tame it.", (March 02, 2021): https://www.politico.eu/article/china-wants-to-dominate-ai-the-us-and-europe-need-each-other-to-tame-it/> (accessed April 06, 2021).

Stakeholder Snapshot

2.1 A 2021 SNAPSHOT OF STAKEHOLDER PERCEPTIONS ABOUT EUROPE'S CAPACITY TO ACT IN THE GLOBAL TECH RACE

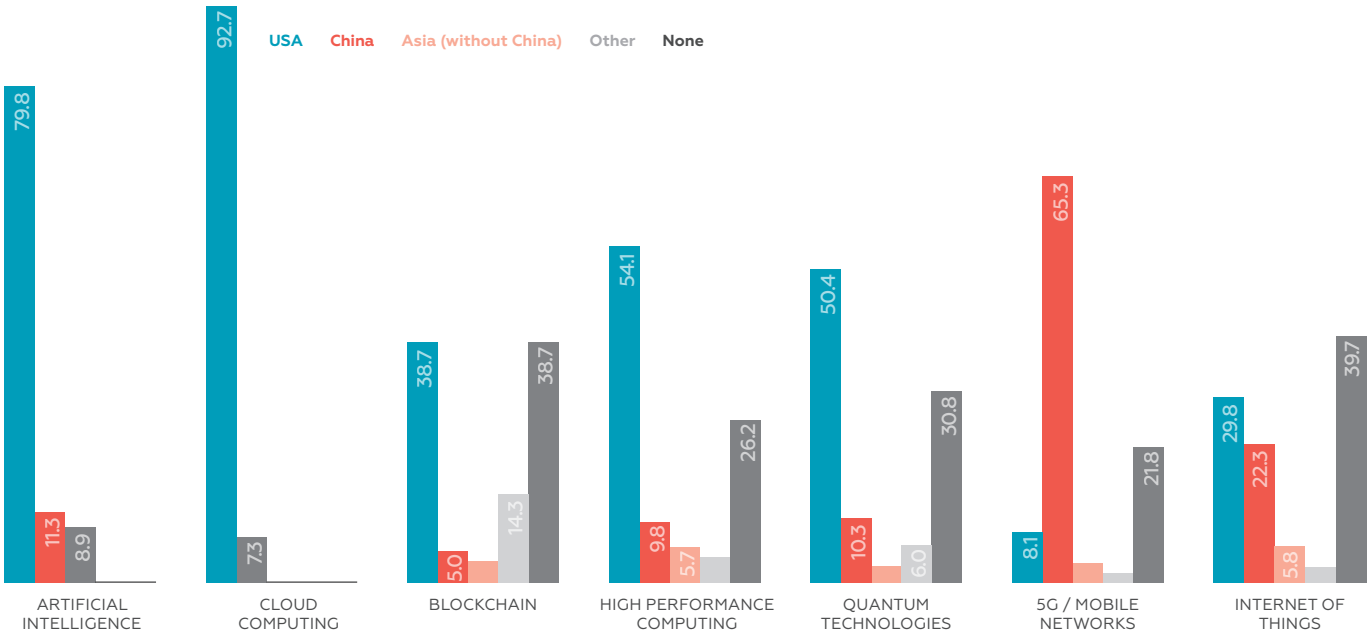
To gauge perceptions of Europe's access to and control of key technologies, over 2,500 key experts working on European technology and digital policy in government, industry, think tanks, academia, parliaments, and civil society were asked to participate in a survey, key results of which are presented here. The selection of potential participants was based on expertise in the European tech landscape and familiarity with the issues at hand. One hundred and twenty-six people participated. Respondents hailed primarily from Europe, with stakeholders from Berlin and Brussels heavily represented. The survey was conducted between January 12 and February 5, 2021 and all responses were fully anonymous.

FIGURE 3: I BELIEVE THE EUROPEAN UNION IS TOO DEPENDENT ON EXTERNAL ACTORS IN THE FIELD OF:
(FIGURES IN %)



Source: DGAP Stakeholder Survey 2021

FIGURE 4: ON WHICH ACTOR DO YOU THINK THE EU IS MOST DEPENDENT ON FOR EACH TECHNOLOGY AREA?
(FIGURES IN %)



Source: DGAP Stakeholder Survey 2021

2.2 TAKING STOCK OF EUROPE'S TECHNOLOGY DEPENDENCIES

The survey first attempted to establish a topography of Europe's perceived dependencies across seven technology areas mentioned in the EU's 2020 Digital Strategy.[19] Three trends stood out:

1. The perception among participants that the EU's dependencies are most pronounced in cloud computing (76 percent "agree" or "strongly agree") and artificial intelligence (68 percent), followed to a lesser extent 5G mobile technology (54 percent).

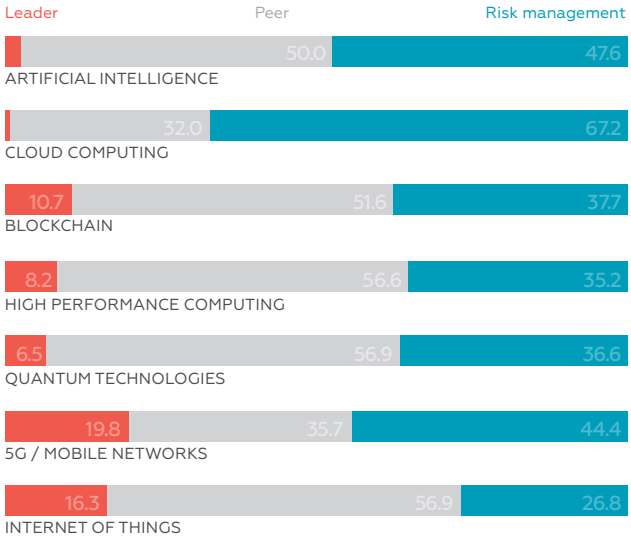
2. Stakeholders remain largely neutral on the question of over-dependencies in blockchain technology, high performance computing, and quantum technologies. Each of the three have been less present in Europe's political discourse around the geopolitics of technology, although that is slowly changing.

3. Participants demonstrated the greatest confidence in Europe's IoT performance. But even here, approximately one third of respondents either agreed or strongly agreed that Europe is too reliant on external actors.

When drilling down into the EU technology dependencies, the survey showed that the EU is perceived to depend most on the US compared to any other state, including China. This is particularly true in cloud computing (93 percent see the EU as dependent on the US) and artificial intelligence (80 percent). On blockchain, high performance computing (HPC) and IoT, the US was seen as the primary source of dependence. Only in 5G and mobile networks did respondents identify a larger dependency on China (65 percent).

Respondents were asked to provide a baseline assessment of these seven emerging technology areas according to the same three-tiered framework that was used for assessing US technological standing in the October 2020 White House National Strategy for Emerging and Critical Techogies.[20] Respondents could rate the EU as a "technology leader" in which independent, world-leader capabilities should be achieved; a "technology peer" where capabilities are linked to interdependence; or "risk management", where dependencies on external actors could lead to strategic and geo-economic vulnerabilities.

FIGURE 5: HOW WOULD YOU RATE THE EUROPEAN UNION'S OVERALL POSITION IN THE FOLLOWING CRITICAL TECHNOLOGIES? (FIGURES IN %)



Source: DGAP Stakeholder Survey 2021

For most technologies, a plurality of respondents perceived the EU as a "technology peer" when assessed against other technology powers. This reflects some degree of confidence in Europe's innovation industrial base. In cloud computing (67 percent) and 5G/mobile networks (44.4 percent) more respondents saw the EU in the "risk management category". But a significant number also perceived Europe to be in a "risk management" position on other technology areas, including artificial intelligence, blockchain, HPC, and even IoT – a finding that indicates an acute awareness of the risky position the EU is in. Europe is not seen as a leader in any critical technology area, although 5G/mobile network equipment (20 percent) and IoT (16 percent) had the highest level of respondents classify Europe as a technology leader. These results indicate a level of precariousness in the EU's 2021 baseline position in key technology areas.

2.3 EUROPE'S STANDING IN THE FIVE ENABLING TECHNOLOGY AREAS

When starting to focus on how the EU should prioritize, the survey narrows focuses on the five key enabling technology areas identified as significant for Europe's innovation industrial base and capacity to act independently: artifi-

19 European Commission, Technology that works for people, https://ec.europa.eu/digital-single-market/en/content/technology-works-people (accessed 10 April, 2021).

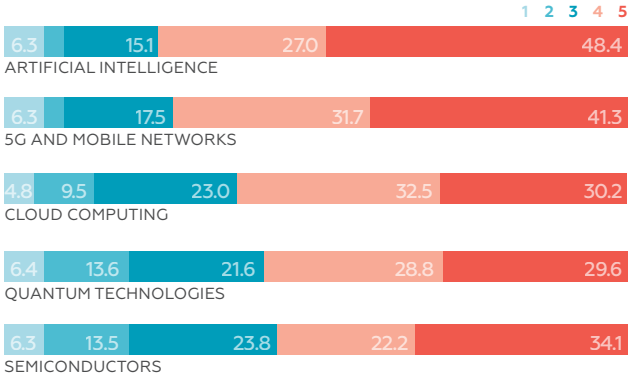
20 White House National Strategy for Critical and Emerging Technologies, (October 15, 2020): https://nps.edu/documents/115559645/121916825/2020+Dist+A+EOPOTUS+National+Strategy+for+ Critical+%26+Emerging+Tech+Oct+2020.pdf/1543be15-a2ae-3629-7a45-aabdecaedb84?t=1602805142602 (accessed April 11, 2021)

cial intelligence, cloud computing, 5G and mobile network equipment, and quantum technologies. In all these areas, the sense of exposure is great. A majority of respondents assess all five as important for Europe's capacity to act, with artificial intelligence (75 percent rate it as important or very important) and 5G and mobile networks (73 percent as important or very important), as particularly acute. The enormity of the challenge of addressing the EU's dependencies is also daunting, particularly in the areas of artificial intelligence (56.8 percent rate it as difficult or very difficult), cloud computing, semiconductors, and quantum technology (each rated difficult or very difficult by 49 percent of participants).

In 2021, the United States is seen by stakeholders as the global leader in four of the five technologies. In AI, 60 percent of respondents named the US as the global leader; in semiconductors, 43.5 percent; in quantum technologies, 57.7 percent; and in cloud computing, an overwhelming 95 percent perceived the US as the dominant country. Only in 5G and mobile networks was China perceived as the global leader by 72.5 percent of respondents.

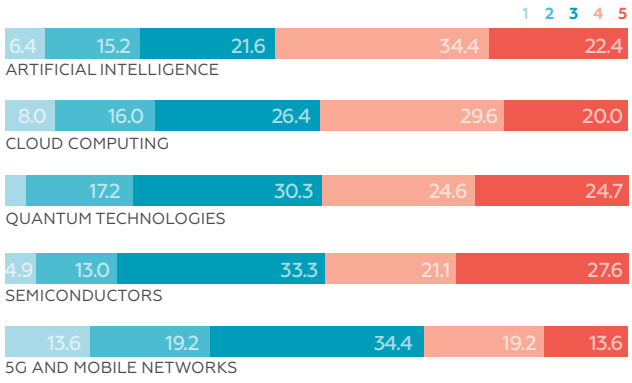
The picture shifts markedly eastward when asked to assess key technologies in 2030. In two of the five key technology areas, participants expect China to overtake the US: in artificial intelligence (55 percent) and semiconductors (47 percent). China is expected to continue its leadership in 5G and mobile network equipment although its leadership is expected to shrink to 63.8 percent from 2021 to 2030. The US is expected to maintain technological leadership in cloud computing (66.9 percent agree or strongly agree) and quantum technologies (63 percent agree or strongly agree) in 2030. Europe is not expected to become a global leader in any of the five key technology areas, although the percentage of those expecting greater European tech leadership increases across all five technologies between 2021 and 2030.

FIGURE 6: HOW WOULD YOU RATE THE FOLLOWING CRITICAL TECHNOLOGY AREAS BY DEGREE OF IMPORTANCE FOR THE EUROPEAN UNION'S INNOVATION INDUSTRIAL BASE AND CAPACITY TO ACT INDEPENDENTLY?
FROM LEAST (1) TO MOST IMPORTANT (5); FIGURES IN %



Source: DGAP Stakeholder Survey 2021

FIGURE 7: HOW WOULD YOU RATE THE FOLLOWING CRITICAL TECHNOLOGY AREAS BY DEGREE OF DIFFICULTY FOR THE EUROPEAN UNION'S INNOVATION INDUSTRIAL BASE AND CAPACITY TO ACT INDEPENDENTLY?
FROM LEAST (1) TO MOST DIFFICULT (5); FIGURES IN %



Source: DGAP Stakeholder Survey 2021

TABLE 3: WHICH POWER (WORLDWIDE) IS THE LEADER IN EACH OF THE TECHNOLOGICAL AREAS? (2021 & 2030)*

United States China Europe	2021	2030	2021	2030	2021	2030
Artificial Intelligence	60.4 %	37.0 %	31.3 %	55.0 %	3.7 %	6.8 %
Cloud Computing	95.0 %	66.9 %	3.0 %	26.6 %	1.0 %	5.5 %
Semiconductors	43.5 %	29.4 %	24.1 %	47.0 %	6.4 %	11.7 %
Quantum Technologies	57.7 %	48.5 %	20.6 %	33.0 %	9.5 %	16.8 %
5G and Mobile Network Equipment	4.8 %	8.5 %	72.6 %	63.8 %	17.7 %	24.7 %

*Some totals do not add up to 100% due to an 'other' category where various different countries may have been considered leaders. Such as Taiwan, for example, on semiconductors.

Source: DGAP Stakeholder Survey 2021

2.4 MAPPING EUROPEAN STRATEGIES AND OBSTACLES

When asked about how the EU should position itself amid a US-China tech confrontation, stakeholders are almost evenly split. A slim majority (54 percent) believe the EU should chart an independent path between the two, while 46 percent believe the EU should move closer to the US (see Fig. 6). This reflects very live debates in European capitals about how to shape industrial policy and market access vis-à-vis the US given the already existing dependencies. None of the respondents felt Europe should move closer to China.

The survey also gauged expert views across 12 potential obstacles to Europe's capacity to act in the digital technology space (see Fig. 10). On each issue, respondents were asked to rate each obstacle on a scale of importance between one (least important) and five (most important) as a hindrance to Europe's technological leadership in a global context. They were then asked to rate the same obstacles by the degree of difficulty for Europe to overcome them.

Two broad findings stand out in this data:

1. Respondents perceive a generally noticeable positive correlation between difficulty and importance across issues. This is consistent with some of the challenges recognized for generations, like availability of venture capital investment and commercialization of research.

2. By far, respondents saw Europe's lack of first mover advantage and absence of dominant incumbent tech players as a central obstacle to its capacity to act. Respondents were able to prioritize across obstacles with some areas where the EU has shown strength – like basic R&D and public-private partnerships – which are perceived less difficult and less important to Europe's quest for digital sovereignty.

This is not meant to be a comprehensive list of policy and economic conditions informing Europe's digital competitiveness landscape. Important issues were left out. Issues like levels of connectivity and the incomplete digital single market clearly also play important roles in shaping Europe's position in the world. But this composite snapshot captures many of the key potential barriers addressed by policy makers and analysts when assessing Europe's standing in global tech leadership.

2.5 EUROPE'S GLOBAL OBJECTIVES AND INSTRUMENTS ON TECH POLICY

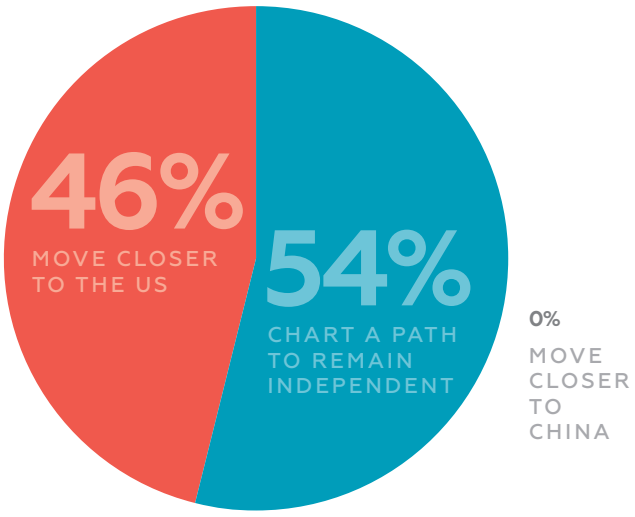
On Europe's global objectives (see Fig.11), two issues stand out and clearly reflect the policy priorities on emerging technology in Brussels and many capitals across the EU.

The first is pushing for greater competitiveness in emerging technology areas, which is by far seen as the most important priority and also something that is relatively difficult to achieve. Europe's efforts in this area – spanning the digital single market, regulation to open new spaces for technology competition, and industrial policy – remain at the center of the European Commission's digital agenda.

Second, is the use of emerging technologies to improve sustainability and lower carbon emissions. Climate and tech competitiveness are followed by a cluster of global objectives, including cyber-stability, digital rights, global digital rules, and an open global Internet. All areas are seen as moderately difficult to achieve.

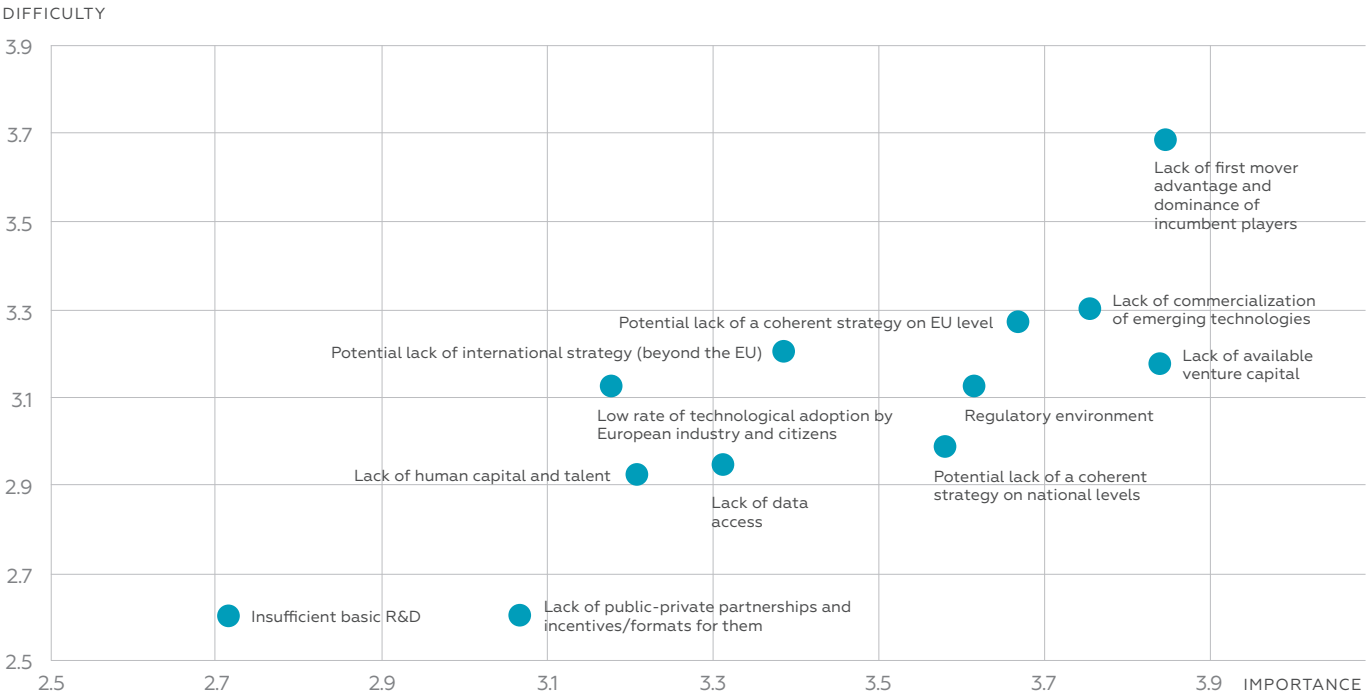
Discovering how to employ emerging technologies in military contexts is seen as both the most difficult potential objective and the second least important. New efforts to build stronger connective tissue between NATO and the EU on emerging technology might raise the profile of this cause. But currently it remains a relatively low priority. More strikingly, the role of tech access and adoption in the Global South is perceived as both the least difficult and least important objective for the EU. This could reflect the more inward-looking nature of EU member states but could also

FIGURE 8: HOW SHOULD THE EU POSITION ITSELF IN THE US-CHINA TECH CONFRONTATION?



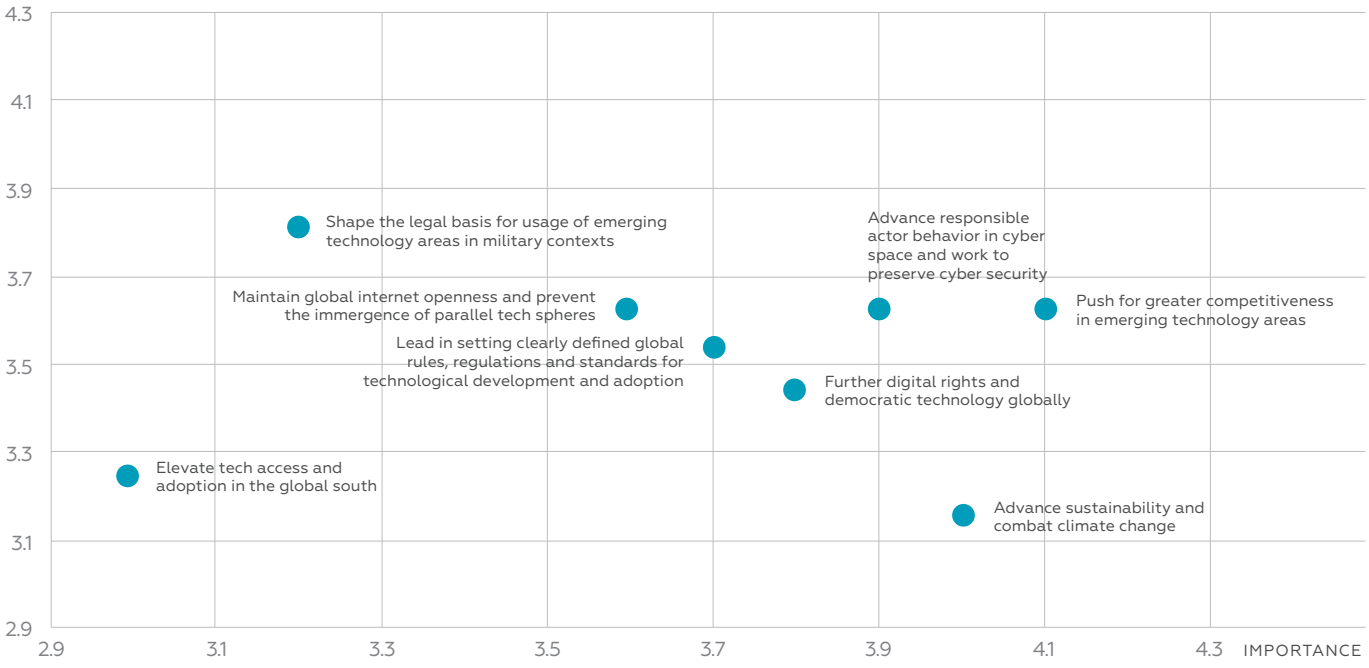
Source: DGAP Stakeholder Survey 2021

FIGURE 9: HOW WOULD YOU RATE THE FOLLOWING OBSTACLES TO EUROPE'S ABILITY TO ACT IN THE DIGITAL REALM?
(RATING SCALE: 1-5)



Source: DGAP Stakeholder Survey 2021

FIGURE 10: HOW WOULD YOU RATE THE FOLLOWING OBJECTIVES TO EUROPE'S ABILITY TO ACT IN THE DIGITAL REALM?
(RATING SCALE: 1-5)



Source: DGAP Stakeholder Survey 2021

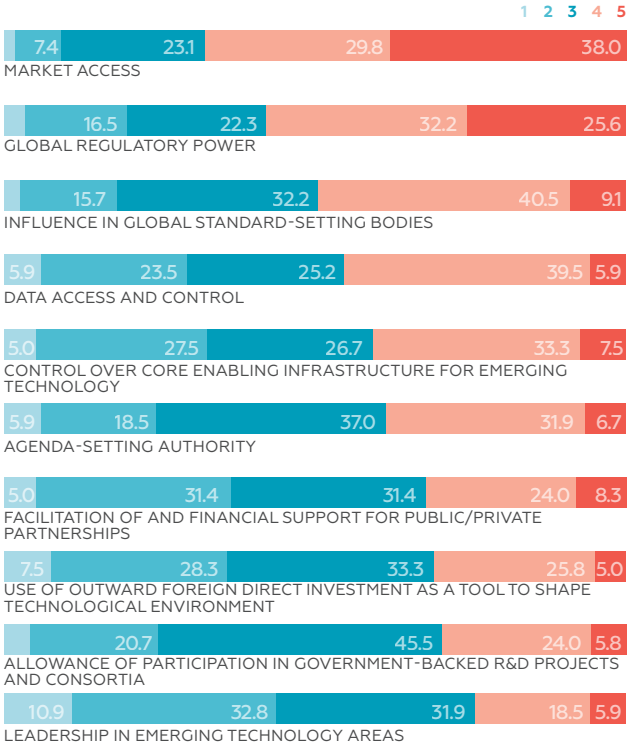
emerge as a blind spot if policy does not take into account the linkages between tech adoption in developing countries and other objectives like competitiveness, the ability to make global rules, and the shaping of digital rights.

The EU has a few useful tools at hand that can help advance its global tech objectives. The first is the EU's regulatory framework. Market access and Europe's ability to use its regulatory weight to pull people around to its own values feature prominently in stakeholders' minds, with significant numbers identifying these regulatory tools as very effective. The ability of the EU to influence global standard-setting – likely the result of the preponderant influence of Europe's leading standard-setting bodies including the European Committee for Standardization (CEN) and the Committee for Electrotechnical Standardization (CENELEC)- and the development of frameworks like the General Data Protection Regulation (GDPR) – turn countries around the world to the EU's way of doing things.

Interestingly, European outbound foreign direct investment (FDI) is seen as a less effective instrument in the EU's quest to achieve its global technology objectives. Given the role of US FDI as an instrument of American tech leadership and rising awareness of Chinese FDI, such as Tencent acquisitions in the European mobile gaming industry and AliCloud's data center acquisitions, it's interesting to see that this tool is not perceived as particularly effective for the EU to advance its global interests. The situation is similar in the case of public-private partnerships. Perception of European innovation leadership in emerging technology areas is by far seen as the EU's least effective potential instrument.

The data also reveals clear trends around how participants feel tech policy should be managed between the EU and national levels. On the EU level, overwhelming majorities saw four key policy drivers: industrial policy, regulatory policy, strategic vision, and international cooperation. Of those, a majority ranks "regulatory policy" as most important (77 percent rated it as important or very important). This is unsurprising given the EU's high-profile role in digital regulation and its ambitious regulatory agenda around the Digital Services Act, the Digital Markets Act, data governance, cloud rules, and cybersecurity. Respondents also attach a great deal of importance to the EU's role in shaping a coherent strategic vision for tech policy (70 percent rated as important or very important). However, in this area, the role of member states is also rated highly, although slightly less than the EU, suggesting recognition of a desire or need for multilevel coordination, where both the EU and individual member states have a role to play.

FIGURE 11: PLEASE RATE THE FOLLOWING INSTRUMENTS THAT THE EU POSSESSES TO ADVANCE ITS OBJECTIVES FOR TECHNOLOGY IN GLOBAL AFFAIRS IN TERMS OF EFFECTIVENESS
(FROM LEAST (1) TO MOST EFFECTIVE (5); FIGURES IN %)

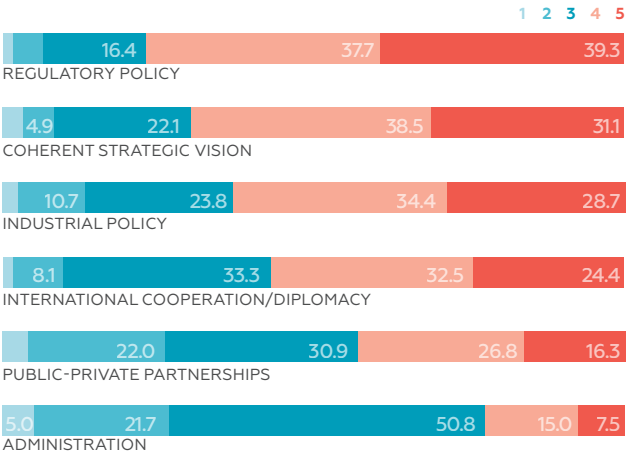


Source: DGAP Stakeholder Survey 2021

At the member state level (Fig. 13, the aggregate response places the greatest importance on each member state's ability to shape an effective industrial policy (60 percent rated it as important or very important). This is not to say that the EU should not play a role in industrial policy. According to the stakeholder response, both EU and member-state roles in industrial policy are important. The member state role is also seen as slightly more important in establishing public-private partnerships.

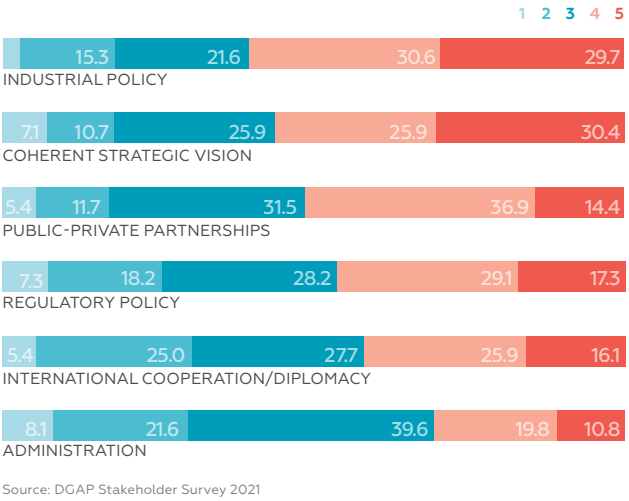
Interestingly, a significant number of participants saw the EU's role in fostering international cooperation as more important than that of individual member states. We could attribute this coordinating power across 27 member states is better suited to shaping Europe's technological capacity to act in a global context in a coherent way. Some participants felt that the EU should take the lead on this, with 30 percent saying that the member states are of little or no importance in international digital cooperation.

FIGURE 12: PLEASE RATE THE IMPORTANCE OF EACH POLICY FIELD TO SHAPE THE CAPACITY TO ACT AT THE EU LEVEL:
(FROM LEAST (1) TO MOST IMPORTANT (5); FIGURES IN %)



Source: DGAP Stakeholder Survey 2021

FIGURE 13: PLEASE RATE THE IMPORTANCE OF EACH POLICY FIELD TO SHAPE THE CAPACITY TO ACT AT THE LEVEL OF INDIVIDUAL EU MEMBER STATES:
(FROM LEAST (1) TO MOST IMPORTANT (5); FIGURES IN %)



Source: DGAP Stakeholder Survey 2021

Assessing Capacity to Act in 5 Key Enabling Technology Areas

The Stakeholder Snapshot makes Europe's exposure acutely apparent. It also points to some of the instruments the EU has and obstacles it faces in its quest for peer and leadership status in key technology areas. This section takes a deeper look at each of the five technology areas to provide an overview of the field, analysis of current policy approaches, and practical recommendations for how the EU can push forward in each area. The five technology areas are consistent with those mentioned above: AI, cloud computing, semiconductors, 5G and mobile equipment, and quantum technology.

The content in this section is based on reviews of key literature and primary source material, interviews with relevant actors, and quantitative inputs from the stakeholder survey. The stakeholders in the survey also provided additional analysis and policy recommendations, and the survey results inform the recommendations we have made for each technology area. For each technology we look into the state of play and current policy approach to ground our recommendations.

Here's what is meant by those terms:
The **State of Play** covers the industrial and technological capabilities in current global value chains. But also includes how able actors are to innovate in each specific technology area by looking at indicators such as the number of relevant patents, technology-specific export portions or production statistics, market share, or the number of relevant start-ups in each technology area[21].

The **Current Policy Approach** looks at whether the EU and its member states have specific visions and targets regarding a specific technology and how detailed these are. It builds upon institutional instruments – the tools the EU has at its disposal – and puts them into political context.

These sections also look at the extent to which there is policy coherence among member states or between the EU and individual member states.

The five new key enabling technology areas analyzed in this study were selected based on their dual-use or even general-purpose nature and whether they influence economic and military competitiveness. These technologies have also been chosen because they have become areas of geopolitical contention, which will be showcased in the next chapters.

While this study deals with each technology separately, it's important to understand that these technologies in fact depend on each other and are often inter-related. For instance, AI systems can only become more effective as there are advances in the semiconductor industry, just as the increase in computation power and the huge and steady accumulation of data provide the necessary ingredients for more complex systems. The same interrelationship, for instance, can be drawn between cloud and edge infrastructures and advances that may be triggered by 5G technology. Therefore, even though these technologies are grouped, the mutual conditionality between them is important to keep in mind[22].

Increasing Europe's capacity to act in the tech space is a long-term task. It will not be achieved in a mere year or two and it will involve, coordinating industrial commitments, securing access to skills and investments across the bloc, and formulating supportive policies at the member state level. Through the Digital Compass, the EU has just begun the process of overviewing competencies and responsibilities concerning new enabling technology areas on the EU level.[23] This exercise helps us to identify strengths and vulnerabilities in the digital and technological realm and to explore which measures we need to maintain or enhance to improve the EU's capacity to act. Against this backdrop, foreign policy decision-makers can determine in which key enabling technology areas capacity building is most urgently needed and can have the greatest impact.

21 Jakob Edler et. al, "Technologiesouveränität. Von der Förderung zum Konzept," Fraunhofer Institut (Juli 2020).

22 Furthermore, the debate concerning 'digital sovereignty' or capacity to act also encompasses questions of cybersecurity and resilience of digital infrastructures. Currently, several initiatives on EU level are in the making or already published, which aim at tackling these issues, including the NIS Directive Review, the establishment of a Joint Cyber Unit, and the Cyber Security Strategy issued in December 2020. Aspects of cybersecurity are reflected in the study, however, but not in their entirety.

23 Isabel Skierka, "Öffentliche Anhörung zum Thema IT-Sicherheit von Hard- und Software als Voraussetzung für digitale Souveränität" ["Public hearing on IT security of hardware and software as a prerequisite for digital sovereignty"], (December 10, 2019): https://www.bundestag.de/resource/blob/672536/b2b63aeeaffe54e40f8c62571cc628c4/Stellungnahme-Skierka-data.pdf (accessed November 10, 2020). See also Falk Steiner and Viktoria Grzymek, "Digital Sovereignty in the EU", European Public Goods, Bertelsmann Stiftung (Juli 2020), p.7: "There have been no convincing empirical studies on Europe's actual dependencies to date."

3.1 ARTIFICIAL INTELLIGENCE

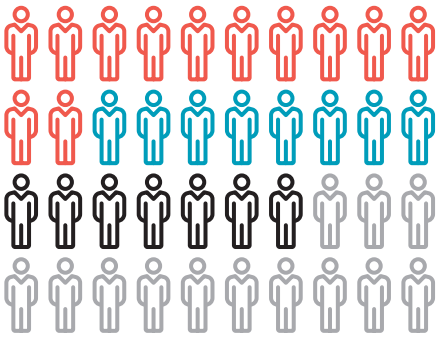
State of Play

Artificial intelligence (AI) is on track to penetrate all areas of life by enabling new forms of medical screening and patient treatment; self-driving vehicles; easier, more natural man-machine interfaces; more efficient logistics; better farming techniques and crop yields; and faster decision-making in everything from insurance, to banking, policing, and even national security. According to one study, global GDP will be 14 percent higher in 2030 due to efficiencies from using AI. This amount of GDP in absolute terms is more than the current GDP of China and India combined.[24]

The transformational potential of AI has put heavy pressure on the EU, whose competitive industries – once defined by engineering precision – are increasingly defined by integrated systems powered by AI and data. As the Stakeholder Snapshot shows, there is a perception that two "AI superpowers" – the US and China – are battling it out for superiority in the AI space and leaving the EU behind.[25] But Europe is still in the game. It has an academic research base on par with both the US and China – reflected in the comparatively high number of AI research and conference papers. According to the Global AI Talent Tracker, 29 percent of the top-tier AI researchers currently come from China, 20 percent are from the US and 18 percent are from Europe.[26] That puts Europe only a small way behind the US. Europe has strengths in IoT and industrial data-based AI applications due to its globally respected manufacturing base as well as new research hubs like Baden-Württemberg's Cyber Valley or the strong AI start-up scenes in cities such as Stockholm and Paris. However, there are three key sticking points that hinder Europe's ambitions to catch-up in the global AI race.

The first of those sticking points is Europe's inability to commercialize its AI developments. This is especially problematic because the private sector largely drives AI research demand and investment.[27] Europe trails behind the US and China in its number of registered AI-related patents. Only two European companies (Siemens and Philips) are among the global top ten AI patent-holding companies.[28] The EU has some clout in specific fields like patents for autonomous vehicles[29] but its broader inability to move from basic research to applied use cases capitalized by European industry is a central gap in European AI competitiveness. It has also left Europe without the kind of attractive commercial research ecosystems that exist in places like the US and Canada, which have drawn top European talent across the Atlantic.[30]

FIGURE 14: DISTRIBUTION OF TOP-TIER AI RESEARCHERS



Source: "The Global AI Talent Tracker", MacroPolo (March 14, 2021)

FIGURE 15: DISTRIBUTION OF AI PAPERS

Source: Daniel Castro et. al, "Who Is Winning the AI Race: China, the EU or the United States?", Center for Data Innovation (August 19, 2019)

24 PwC, "Sizing the prize. What's the real value of AI for your business and how can you capitalise?," (2017), p.3: https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf (accessed November 10, 2020).

25 Carly Minsky, "One former Google exec says there's no hope for Europe's artificial intelligence sector", Sifted, (December 14, 2018): https://sifted.eu/articles/interview-google-kaifu-lee-ai-artificial-intelligence (accessed November 10, 2020). Raymond Perrault et. Al, "The AI Index 2019 Annual Report", Stanford University Human-Centered AI Institute (December 2019): https://hai.stanford.edu/sites/default/files/ai_index_2019_report.pdf (accessed April 21, 2021).

26 Raymond Perrault et. Al, "The AI Index 2019 Annual Report", Stanford University Human-Centered AI Institute (December 2019): https://hai.stanford.edu/sites/g/files/sbiybj10986/f/ai_index_2019_report.pdf (accessed November 10, 2020).

27 Gleb Chuvpilo, "Who's Ahead in AI Research in 2020? Insights from the International Conference on Machine Learning (ICML 2020)", Medium, July 14, 2020: https://medium.com/@chuvpilo/whos-ahead-in-ai-research-in-2020-2009da5cd799 (accessed November 10, 2020).

28 Zachary Arnold et. al, "Identifying AI-Related Companies: A Conceptual Outline and Proof of Concept", Center for Security and Emerging Technology (July, 2020): https://cset.georgetown.edu/research/identifying-ai-related-companies (accessed November 10, 2020).

29 Ulrike Franke, "Harnessing Artificial Intelligence," European Council on Foreign Relations (June 2019), pp. 4-5: https://www.ecfr.eu/page/-/3_Harnessing_artificial_intelligence.pdf (accessed November 10, 2020).

30 Minsky, "One former Google exec says there's no hope for Europe's artificial intelligence sector," (see note 31).

The second sticking point is lack of access to venture capital and limited prospects for scaling-up. In 2018, Europe (UK included) was second only to the US in terms of the number of AI start-ups, accounting for 22 percent of the overall number of AI startups on the global market.[31] However, only six of those EU-based start-ups are among the world's top 100.[32] The COVID-19 crisis has created an influx of capital into Europe's AI start-up scene as investors and governments ploughed money into specific areas like AI health applications. However, it remains to be seen whether this capital will continue to be deployed for future funding rounds or to build a broader AI tech start-up scene in Europe.

Finally, there is the question of data usage. Data is key to AI systems, since algorithms need to be trained how to operate by consuming and learning from data sets. The size and quality of data sets on which an AI application has been trained therefore directly impact its real-world utility.[33] The EU's strong data protection regulation, which makes it a global leader in some settings, makes it difficult to obtain personal data sets from which AI applications can be trained. Whereas in China extensive data sets of faces and population movements, can be developed with very few restrictions and be actively pursued by the government, itself.[34]

European lawmakers need to find ways to harness data for AI while preserving its strong track record and reputation on data protection. The EU is now taking its first steps in this direction by implementing a flexible pilot for open access to research data in the Horizon Europe program. As part of that program, efforts are underway to create clear guidelines for anonymization that would allow Europe to take advantage of the continent's high-quality pools of health data.[35] However, leveraging these strengths against the backdrop of the EU's diminishing competitiveness in AI will prove a major mid-term challenge, especially given that reforms could take years to materialize.

Current Policy Approach

During the European Commission's Jean-Claude Juncker years (2014-2019), the EU began to sketch out a strategic framework for its approach to AI[36] that included investing €20 billion per year in AI from 2020 onwards.[37] A High-Level Group on Artificial Intelligence (AI HLEG) was also launched, consisting of representatives from politics, industry, the research community, and civil society who together laid out seven guiding principles for ethical and trustworthy AI.[38]

When Ursula Von der Leyen became European Commission president, she set the EU's sights on delivering a regulatory proposal on "trustworthy AI".[39] The term basically refers to the notion that AI will be used under the conditions of strong data protection and limit the application of AI for rightful purposes according to the European values of democracy and human dignity. The EU's February 2020 AI White Paper provides some guiding principles and some practical measures towards achieving the "twin objectives" of simulating indigenous European AI innovation and addressing potential AI-associated risks.[40] The paper sets out the need for stricter regulation on the question of whether an AI system is deemed "high risk" based on assessment of a technology's use and sector. In the first "use" criteria, examples include recruitment processes or remote biometric identification. The second criterion includes sectors characterized by a high-risk density.[41] As of writing this report, the European Commission is working to integrate this risk classification system into a legislative proposal for AI that will likely set the tone for global discourse on AI regulations and standards.

31 Axelle Lemaire et al., "Artificial Intelligence – A Strategy for European Startups: Recommendations for Policymakers," Roland Berger and Asgard – Human Venture Capital (2018), p.7: https://asgard.vc/wp-content/uploads/2018/05/Artificial-Intelligence-Strategy-for-Europe-2018.pdf (accessed March 17, 2021).

32 "AI 100: The Artificial Intelligence Startups Redefining Industries," CBINSIGHTS (March 3, 2020): https://www.cbinsights.com/research/artificial-intelligence-top-startups (accessed March 1, 2021).

33 Thomas C. Redman, "If Your Data Is Bad, Your Machine Learning Tools Are Useless," Harvard Business Review, (April 02, 2018): https://hbr.org/2018/04/if-your-data-is-bad-your-machine-learning-tools-are-useless (accessed March 01, 2021).

34 EPRS, "The impact of the General Data Protection Regulation (GDPR) on artificial intelligence," (June 2020): https://www.europarl.europa.eu/thinktank/de/document.html?reference=EPRS_STU(2020)641530 (accessed October 21, 2020).

35 Daniel Castro, Michael McLaughlin and Eline Chivot, "Who Is Winning the AI Race: China, the EU or the United States?," Center For Data Innovation (August 19, 2019): https://www.datainnovation.org/2019/08/who-is-winning-the-ai-race-china-the-eu-or-the-united-states (accessed March 01, 2021).

36 The former document sets out a triad of general objectives, namely 1) stimulating the industrial capabilities, 2) preparing the member states for socio-economic changes as well as 3) ensuring an appropriate ethical and legal framework.

37 The 'Coordinated Plan' also states "the ambition is for Europe to become the world-leading region for developing and deploying cutting-edge, ethical and secure AI, promoting a human-centric approach in the global context." European Commission, "Coordinated Plan on Artificial Intelligence," (December 7, 2018): https://ec.europa.eu/digital-single-market/en/news/coordinated-plan-artificial-intelligence (accessed March 01, 2021).

38 European Commission, "High-Level Expert Group on Artificial Intelligence,", (November 18, 2020): https://ec.europa.eu/digital-single-market/en/high-level-expert-group-artificial-intelligence (accessed March 01, 2021).

39 In her speech in the European Parliament, she even promised that in her first 100 days, she "will put forward legislation for a coordinated European approach on the human and ethical implications of artificial intelligence." Access Partnership, "Europe Sets Sights on AI Regulation Within 100 Days," September 16, 2019: https://www.accesspartnership.com/europe-sets-sights-on-ai-regulation-within-100-days (accessed March 01, 2021).

40 European Commission, "On Artificial Intelligence-a european approach to excellence and trust", (February 19, 2020): https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf (accessed April 07, 2021).

41 Interestingly, in a previous leaked version of the white paper in January 2020, a potential time-limited ban of facial recognition technology on public spaces was put up for discussion. At the end, however, the final document abstains from a complete ban and envisages rather severe requirements.

The European Commission has also recognized the importance of data for developing AI technologies. The EU's Data Strategy has the stated aim of creating a single EU market for data, particularly in non-personal, industrial data areas.[42] The strategy outlines the goals for a Data Act with incentives for business-to-government and business-to-business data sharing, including potential legal obligations for sharing data in certain cases. The aim is to create nine sector-specific "Common European Data Spaces", in which different stakeholders pool their data to develop new applications for AI. This act is at the heart of EU's attempt to get data economies of scale that can help it develop its competitive edge when faced with the massive incumbent advantages held by American and Chinese tech.[43] In essence, the EU wants to combine its strong industrial base with digitalization. However, a key challenge will be to persuade the private and the public sector to share data. Here, incentives and the promise of data protection (e.g. via data anonymization) will likely have to form a part of the upcoming Data Act.

The COVID-19 crisis has acted as an impetus for increased innovation, adoption, and financing of AI.[44] The European Commission remains committed to its aim of attracting over €20 billion in investments into European AI by leveraging existing funding programs like the Digital Europe Program, Horizon Europe, and the European Structural and Investment Funds. The European Commission Next Generation EU fund also includes €150 billion for technology R&D and digitization. France's 2018 AI for Humanity Strategy included a pledge of €1.5 billion by 2022, including €700 million for research. Based on its 2018 AI strategy, Germany approved a €3 billion investment in AI capabilities until 2025. It then increased the amount to €5 billion as part of its COVID-19 stimulus package. Many of these efforts are driven by large core member states – France and Germany in particular. As such, these policies exist on the national level and could be duplicated by other member states across the EU.

Despite a recognition that AI mastery pits Europe in direct competition with the United States and China, the EU's approach does not adequately address some of the underlying geopolitical tensions. For example, the growing trend of digital authoritarianism and dual-use potential of AI systems remains largely unaddressed. Another area in which the EU's White Paper on AI falls short is in addressing the competing interests between AI and data protection. There is no AI without data, and in the EU, available data is severely limited by GDPR. In sum, the European Commission has to address more strategically how it wants to keep up in the AI race while not compromising on data protection.

Recommendations

Europe needs to catch up to the US and China in the commercialization of its AI technologies and access to data sources. Research capabilities and talent in this area are strong but the EU has fallen far behind in translating its indigenous strengths into commercialized advantages that could strengthen Europe's innovation industrial base. To do so, Europe should:

1. **Leverage AI norms, standards, and regulation to codify European values:** The EU should work on its legal and ethical AI framework and take the issue of AI regulation, norms, and standards beyond its own continent. In order to fulfil its global AI ambitions, the EU should engage with like-minded states to solidify its global vision of how AI should be used. The EU should pursue the development of AI principles, norms and standardize multiple formats and organizations – the Council of Europe, OECD, G20, UNESCO, ITU and standard setting bodies[45] – to promote its "human-centered AI" approach internationally as a direct counter-narrative to authoritarian AI, which is now on the rise through enhanced COVID-19 driven surveillance and China's increasingly strident efforts to export AI-powered facial/voice recognition technologies and predictive analytics in its partner countries. This should include some mention of the geopolitical dimension in the upcoming European Commission's new AI legislative proposal.

2. **Create large-scale public data pools usable for both AI research and AI application:** Many AI systems need data sets to be trained. And the higher quality the data is and the more of it that exists, the more effective and accurate AI applications can be. The benefits of this are most obvious for sectors like health care, where the use of AI can already save lives today. But data availability can help spur AI innovation in many areas. At a minimum, data sets involving personal data need to be anonymized in accordance with GDPR. But further guidance will also be needed to interpret vague regulations to ensure

42 European Commission, "A European strategy for data", (February 19, 2020): https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1582551099377&uri=CELEX:52020DC0066 (accessed April 07, 2021).

43 Those thematic data spaces include, among others, industrial (manufacturing), mobility, health and agriculture.

44 Guntram Wolff, "Europe may be the world's AI referee, but referees don't win", Politico, (February 17, 2020): https://www.politico.eu/article/europe-may-be-the-worlds-ai-referee-but-referees-dont-win-margrethe-vestager (accessed March 01, 2021).

45 Besides the expert groups on EU level, the Ad Hoc Committee on Artificial Intelligence (CAHAI) of the Council of Europe in the wider European context, the two expert groups at OECD level (comprising European states and the US) or the Ad Hoc Expert Group for the Recommendation on the Ethics of AI at the UNESCO deal with AI guidelines. In none of the mentioned fora, however, all three actors – the EU, US and China – have a common membership.

there are no roadblocks to AI adaptation and advancements. The EU and its member states should push towards a broad open-data mandate (based on successful open-access mandates) to unify currently siloed public data pools. Additionally, the EU needs to develop an approach to incentivize the creation of pools of industrial data as well.

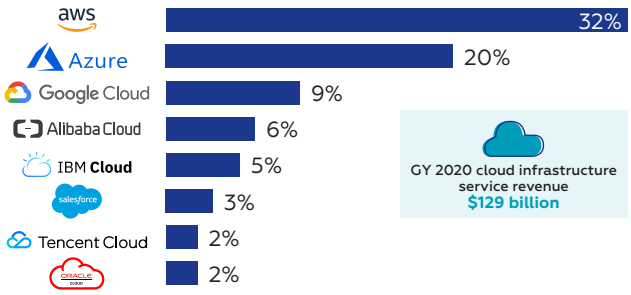
3. **Accelerate adoption of AI-based processes in the public sector:** The EU and its member states should leverage COVID-19 relief efforts to incentivize the adoption of AI in the public sector through procurement mandates, funding, and tax structures. The EU should also identify AI use cases that could have the biggest impact and actively seek out private partners to create them, emphasizing cooperation with SMEs and start-ups, to implement AI-based processes. This sets an example in AI adaptation, builds trust in AI, provides valuable first-hand knowledge about the use of AI to officials, and can help make public administration more efficient as well, directly connecting the EU and its people. Furthermore, it supports and nurtures the domestic tech ecosystem at the same time.

3.2 CLOUD COMPUTING

State of Play

The dominance of US cloud service providers in Europe is a recognized fact. The Stakeholder Snapshot shows that over 76 percent of participants believe Europe is overly dependent on external actors and those actors are majority US-based (92.7 percent). With an accumulated 52 percent global market share,[46] US tech giants Amazon (Amazon Web Services) and Microsoft (Microsoft Azure) are leading the field.[47] Tencent and Alibaba from China are the only non-American enterprises in the top eight of the approximately €300 billion cloud computing market. However, these two companies and, to a lesser extent, China Telecom and Huawei, are gaining market share in the domestic Chinese and broader East Asian markets.

FIGURE 16: AMAZON LEADS 130-BILLION CLOUD MARKET. WORLDWIDE MARKET SHARE OF LEADING CLOUD INFRASTRUCTURE SERVICE PROVIDERS IN Q4 2020



*includes platform as a service (PaaS) and infrastructure as a service (IaaS) as well as hosted private cloud services. Source: Synergy Research Group

Source: Statista 2021: https://www.statista.com/chart/18819/worldwide-market-share-of-leading-cloud-infrastructure-service-providers

The cloud computing landscape favors large first movers that are able to develop path-dependent service relations with their users. Cloud users are locked into relationships with providers whose suite of offerings and terms of service regarding data interoperability and portability make it difficult to move to other providers. As noted in the stakeholder survey, first mover advantage is seen as both the most important and most difficult barrier holding back European competitiveness in key enabling technologies likes cloud computing. Developing a cloud infrastructure is also highly capital-intensive, requiring large networks of data centers and IT professionals maintaining operations. These high barriers to entry have been partially responsible for a relatively concentrated cloud market landscape in Europe. This is why Europe is highly dependent on US cloud providers such as Amazon, Microsoft, Google, and IBM. European players such as Deutsche Telekom, Orange, and OVHcloud are among the top five cloud providers in their respective countries but trail behind American companies, even in terms of usage across Europe.[48]

European attempts to gain a meaningful foothold in cloud computing have so far proven unsuccessful, even in the domestic market. France's Andromède sovereign cloud project, launched in 2009 as a response to US cloud computing advances, poured over €200 million into two cloud providers only to see the initiative wound down in 2014 with little fanfare.[49] Projects like the European Alliance on Industrial Data and Cloud as well as GAIA-X, which are designed to create a cloud-based infrastructure on European standards, could face similar challenges.[50]

Current Policy Approach

The EU Data Strategy bluntly states that the EU needs to reduce its dependency on foreign cloud infrastructure and cloud providers. The EU has warned against the extraterritorial jurisdictional assertions in the US CLOUD Act and China's Cybersecurity Law, which includes possible access provisions for data servers of American and Chinese servers, based in Europe.[51] This warning has been echoed by EU member states, particularly in Germany and France. Germany's January 2021 Data Strategy also refers to GAIA-X as a means of emancipating Europe from locked-in cloud services (currently all American), which are seen as an immediate challenge given Europe's accelerated adoption of cloud services for public administration, schooling, and healthcare during the COVID-19 crisis.

The European Commission has proposed investing up to €2 billion in high impact data spaces and federated cloud infrastructure with a potential additional €2-4 billion com-

46 This counts for platform as a service (PaaS), infrastructure as a service (IaaS) and for hosted private cloud services.

47 Felix Richter, "Amazon Leads $130-Billion Cloud Market," Statista, (February 4, 2021): https://www.statista.com/chart/18819/worldwide-market-share-of-leading-cloud-infrastructure-service-providers (accessed March 01, 2021).

48 Mike Robuck, "Report: Amazon and Microsoft reign supreme in European cloud market," Fierce Telecom, (May 7, 2020): https://www.fiercetelecom.com/operators/report-amazon-and-microsoft-reign-supreme-european-cloud-market (accessed March 01, 2021).

49 Serge Leblal, "285 millions d'euros pour Andromède, le cloud souverain français" ["285 million euros for Andromède, the French sovereign cloud"], Lemonde Informatique, (September 21, 2011): https://www.lemondeinformatique.fr/actualites/lire-285-millions-d-euros-pour-andromede-le-cloud-souverain-francais-41990.html (accessed March 01, 2021). Christof Kerkmann, "Microsoft and Deutsche Telekom's 'German cloud' wafts away", Handelsblatt Today, (March 13, 2018): https://www.handelsblatt.com/english/companies/remote-access-microsoft-and-deutsche-telekoms-german-cloud-wafts-away/23581454.html (accessed March 01, 2021).

50 European Commission, "Towards a next generation cloud for Europe", (October 12, 2020): https://ec.europa.eu/digital-single-market/en/news/towards-next-generation-cloud-europe (accessed March 01, 2021).

51 Kaan Sahin and Emilia Neuber, "Bright or Cloudy?," Berlin Policy Journal, (June 18, 2020): https://berlinpolicyjournal.com/bright-or-cloudy (accessed March 01, 2021).

TABLE 4: TIMELINE GAIA-X

October 2019	Announcement of the set-up of GAIA-X at the Digital Summit 2019 in Dortmund by German Economy Minister Peter Altmaier.
February 2020	Germany and France sign a joint position paper on GAIA-X which solidifies France's role in the project.
June 2020	Germany and France present the technical concept and the organization's structure.
September 2020	22 German and French companies found the Brussels-based GAIA-X AISBL, a non-profit organization steering the project.
November 2020	180 organizations and 4,000 participants attend GAIA-X Summit. Intent to launch seven national hubs is made public.[1]
December 2020	The German federal government's intention to use GAIA-X participating cloud service providers is announced at the German Digital Summit.
Early 2021	GAIA-X Policy Rules Committee to establish basis for governance and access.
Mid 2021	French OVHcloud and German Deutsche Telekom plan to provide a European cloud service based on GAIA-X.

Source: GAIA-X, "Pan-European GAIA-X Summit", (November 18, 2020)

ing from member state and industry co-investment. All 27 member states have agreed to participate in a so-called €10 billion Alliance for Industrial Data and Cloud. This effort could eventually roll into an Important Project of Common European Interest (IPCEI), a special industrial policy vehicle aimed at an indigenous European federated cloud that can avoid being subject to state-aid restrictions. Some member states have already taken matters forward, for example with the GAIA-X project, which was initiated and developed by Germany and France and evolved into a legal non-profit organization in Brussels with the name GAIA-X AISBL. GAIA-X is a federated, pan-European cloud infrastructure project that aims to increase competition in the European cloud market and achieve "data sovereignty".[52] GAIA-X is not an alternative European platform to rival the likes of Amazon Web Services or Microsoft Azure, but it should contain a common set of rules and standards for portability, interoperability, and interconnectivity of data. Most recently, the European Commission announced the target of deploying 10,000 secure edge computing nodes by 2030.[53]

Other attempts at building native European cloud services have proved difficult. The German attempt at establishing a tool for secure communication as an alternative to email called De-Mail was not successful, neither was the Franco-German initiative to create a European search engine called Quaero. Nonetheless, the GAIA-X project will be an important part of the new European cloud federation, which was announced by all 27 EU member states in a common declaration under the auspices of the German European Council Presidency in October 2020.[54] The declaration aims to politically underpin the native cloud concept from a multilateral perspective.

European cloud computing initiatives are still at an early stage. Even GAIA-X, for example, must still address fundamental questions about implementation, funding, and questions about whether anyone will use it. GAIA-X could also raise bureaucratic overhead with a potential abundance of technical specifications that could unintentionally strengthen the position of the leading American cloud providers if it turns out they already adhere to GAIA-X standards or only have to make very minor changes to do so. GAIA-X and efforts around it are a case study in Europe´s quest for enhancing its capacity to act in the technological realm. The fact that its focus is on a federated data infrastructure system rather than building a European company that could scale massively shows that the initiators are well aware of the difficulties of entering the cloud market. GAIA-X tries to circumvent the weaknesses of European cloud players and combine the EU's regulatory and data protection strengths with potential new market entries.

52 BMWi, "Project GAIA-X," (December 29, 2019): https://www.bmwi.de/Redaktion/EN/Publikationen/Digitale-Welt/project-gaia-x.pdf (accessed March 01, 2021).

53 "2030 Digital Compass: the European way for the Digital Decade", (March 09, 2021): https://eur-lex.europa.eu/resource.html?uri=cellar:12e835e2-81af-11eb-9ac9-01aa75ed71a1.0001.02/DOC_1&format=PDF (accessed April 07, 2021).

54 European Commission, "Commission welcomes Member States' declaration on EU cloud federation", (October 15, 2020): https://ec.europa.eu/digital-single-market/en/news/commission-welcomes-member-states-declaration-eu-cloud-federation (accessed March 01, 2021).

Recommendations

Europe's data is a valuable asset and the EU should make sure it is able to derive value from it rather than giving it freely to other global players by allowing it to be hosted by foreign companies. The EU can make an impact in the cloud computing space if it can:

1. **Learn from past mistakes and failed initiatives**: Initiatives like De-Mail, Andromède, and Quaero failed to reach a wide audience. While the push for data sovereignty, currently spearheaded by the European Alliance for Industrial Data and Cloud and GAIA-X, is admirable, the initiatives can only be successful in the long-term if they can find users. And the most important factor in finding users is ensuring the cost is competitive and the services are reliable. Currently, European providers are not competitive in the market and the bureaucratic overhead (technical specifications and regulations that GAIA-X would enforce) is unlikely to change this for the better.

2. **Lower barriers for market entry**: Discussion about cloud providers and infrastructure often centers on the big players already active in the market. The initiators of GAIA-X hope that European companies will benefit from the opportunity of this new federated cloud infrastructure project. But the EU should be careful that the project does not put more barriers in the way of large companies as well as SMEs and start-ups that may want to either use European cloud providers or develop technologies that use GAIA-X.

3. **Protect privacy as a matter of fundamental rights, not industrial policy**: In its January 2021 Data Strategy, Germany cited the invalidation of the EU-US Privacy Shield as a reason Europe should decouple from US cloud services. Others have justified the need for air-gapped cloud infrastructure[55] on the basis of asymmetric extraterritorial access by US authorities in European cyber-space. The EU must enforce rules to protect its citizens' data. It can do so by setting and enforcing clear rules and leveraging its regulatory power to ensure abidance. The EU should use the GDPR to impose fully compliant protections on cross-border data transfers as part of an enhanced EU-US Privacy Shield framework and seek to create a mutual lawful access framework through a possible e-evidence directive.

55 Air gapping refers to the virtual isolation of network compartments to avoid compromising them by being connected to unsecure clients and nodes.

3.3 SEMICONDUCTORS

State of Play

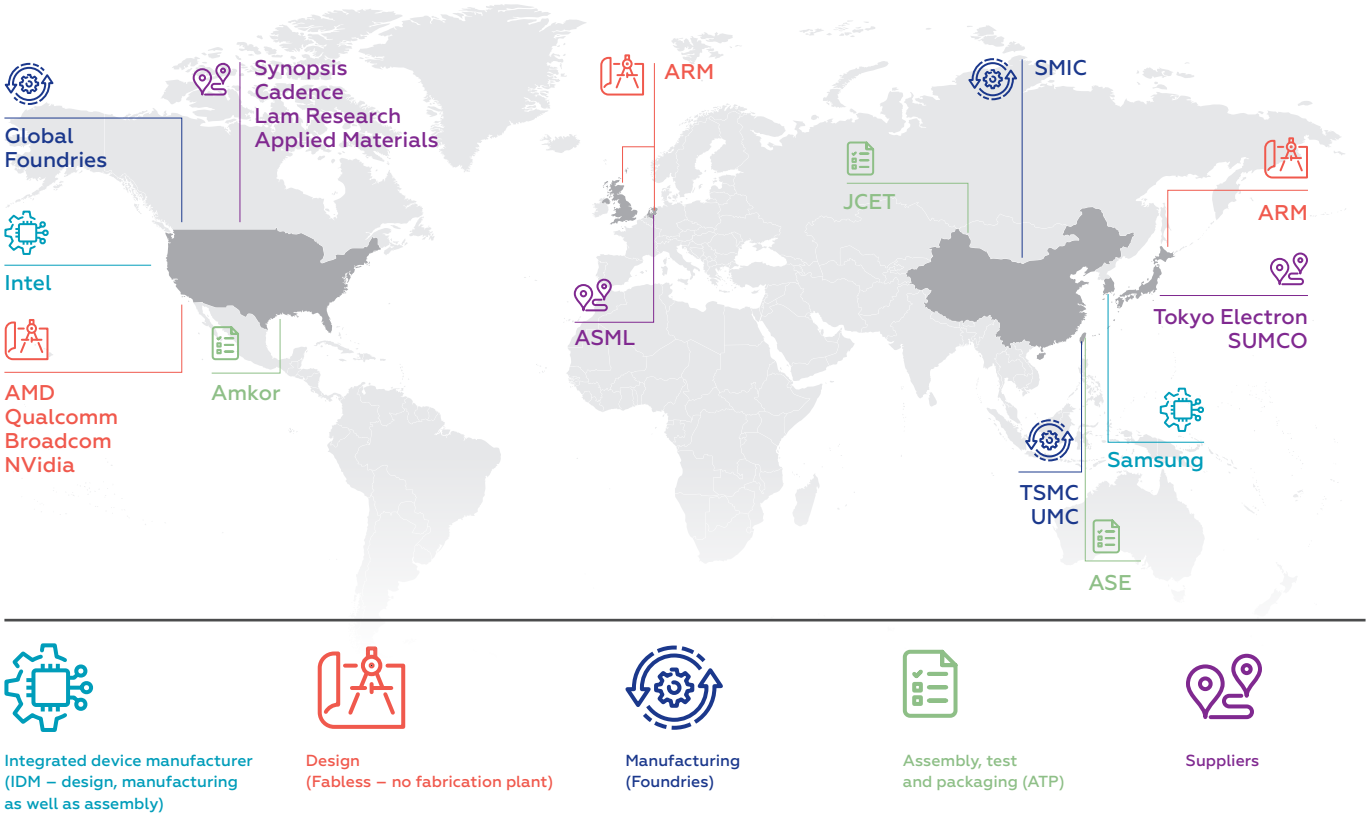
The semiconductor industry manufactures chips and microprocessors, which are the key enabling components for computer systems. Europe has never been a major player in this space and has lost even more ground in the sector over the last three decades. It is now highly dependent on American and Asian manufacturers for access to top-tier microchips.

In the case of semiconductors, the EU will find it very difficult to compete with incumbents. The three main steps in the production of microchips are design, manufacture, and then assembly, test, and packaging. Only a few companies such as Intel (US) or Samsung (South Korea) cover all three steps by themselves and even the ones that do, depend on suppliers to deliver crucial equipment for the manufacturing process. Even though the EU does contribute to this supply chain, it lacks a major player in either of these production steps

Players from the US and East Asia dominate all stages of production in the high-end microchip market. Barriers to entry for cutting-edge products are very high, since cutting-edge chip production requires both extensive knowledge about processes as well as huge production facilities, which in turn depend on highly specialized personnel.

China's biggest technological weakness lies in the semiconductors space. It has been trying to decrease its decades-long dependence by spending the equivalent of several billion euros to support its own domestic semiconductor industry and by engaging in industrial espionage to steal proprietary knowledge from others.[56] Nevertheless, the gap between Chinese firms and global top-tier enterprises remains significant, and homegrown Chinese chips are roughly five years behind their US counterparts. While China is capable of handling semiconductor manufacturing to some extent, it has so far struggled to acquire the knowledge base and IP to design its own chips. However, Taiwan is home to one of the leading semiconductor manufacturers

FIGURE 17: SELECTED MAJOR PLAYERS IN THE SEMICONDUCTOR INDUSTRY



Source: Own work

56 CyCraft Research Team, "APT Group Chimera - APT Operation Skeleton Key targets Taiwan Semiconductor Vendors", CyCraft, (April 15, 2020): https://cycraft.com/download/%5BTLP-White%5D20200415%20Chimera_V4.1.pdf (accessed August 16, 2020).

(TSMC) – a capability China desperately seeks. If geopolitical tensions in the region escalate beyond aforementioned industrial espionage through to cyber-attacks, the world's chip supply will be seriously impacted.

Europe has lost ground in top-tier semiconductor production. ARM Limited – a British company owned by the Japanese Softbank and one of the very few leading European players – is in the process of being sold to American microchip developer Nvidia, although the acquisition's completion is in question. ARM's chips are used in almost all smartphones worldwide and Apple recently switched from Intel based CPUs to ARM. ARM is a so-called fabless company, meaning it does not produce chips itself but instead commissions foundries to produce chips. This production generally occurs outside of Europe. Still, the importance of ARM's intellectual property should not be underestimated. The British government is acutely aware of this and there is a significant chance that it – or another power – will block the sale to Nvidia. However, due to Brexit, the EU has already lost this expertise, which is a major blow to its capabilities in this area.

But European players do continue to lead in certain niche areas, such as automotive chip design, with stand-out companies including the Dutch-based NXP Semiconductors and the German-based Infineon. ASML, another Dutch production company, has developed the most advanced method of miniaturization of chip structures via its Extreme Ultra-Violet (EUV) lithography system and has been caught in the crosshairs of the US-China tech rivalry for its sales to Chinese companies.[57] Without this technology, high-end chip production is not possible. So the international spotlight on ASML is well justified. Despite these pockets of competitiveness, Europe is not likely to be able to catch up in large-scale state-of-the-art semiconductor manufacturing in the medium-term.[58] The participants of the Stakeholder Snapshot who rated semiconductors as the most difficult area to improve the EU's capacity to act, also shared this assessment.

Instead of trying to close this gap, a promising approach – also pursued by China[59] – is to gain a foothold in emerging new microprocessor applications (e.g. special purpose microchips to train AI algorithms (AI chips) or for specific applications in the IoT and industry production). One particularly interesting new technology in this regard is RISC-V, a new and open chip standard that could wipe out the advantage of US players if it becomes competitive with current chip designs.[60] It is not surprising that China is currently very active in driving development of RISC-V. However, both US and European contributions to this new standard are significant and all players stand to benefit from an open microprocessor ecosystem.

TABLE 5: THERE ARE ONLY 3 MAJOR EUROPEAN SEMICONDUCTOR MANUFACTURERS, RANKING 12TH, 13TH AND 14TH IN SIZE WORDWIDE IN 2019

	TABLE (€ MILLIONS)	EMPLOYEES
STMicroelectronics	7,954	45,554
Infineon	7,525	41,400
NXP Semiconductors	7,450	29,400

Sources: Anysilicon, "Top 15 Semiconductor Sales Leaders – 2019", (2019); Infineon, "Facts & Figures", (2020); Macrotrends; "NXP Semiconductors: Number of Employees 2009–2020 | NXPI," (2020); Macrotrends, "STMicroelectronics: Number of Employees 2006–2020 | STM," (2020)

Europe is well-positioned to leverage these new applications because of its strengths in existing niche markets, as well as its strong base in semiconductor research, led by the Inter-university Micro Electronics Center (IMEC) in Belgium, Laboratory of Electronics and Information Technology (LETI) in France, and Fraunhofer Institute in Germany.

Another option for Europe to reduce its supply chain dependencies is to ensure production capabilities within Europe, but not necessarily by European companies. To this end, the EU is weighing deals with high-end manufacturers like TSMC and Samsung.[61]

Current Policy Approach

Compared to the other technology areas, the semiconductor industry has been relatively low on the agenda of the EU institutions and member states. While the IPCEI Microelectronics focuses on five areas of chip technology (energy efficient chips, power semiconductors, sensors, advanced optical equipment, and compound materials) it is important to note that cutting-edge central processing units, as they are used in modern computers, are not among them. The need for novel legislation to regulate a completely new

57 Alexandra Alper et al., "Trump administration pressed Dutch hard to cancel China chip-equipment sale: sources," Reuters, (January 6, 2020): https://www.reuters.com/article/us-asml-holding-usa-china-insight/trump-administration-pressed-dutch-hard-to-cancel-china-chip-equipment-sale-sources-idUSKBN1Z50HN (accessed March 01, 2021).

58 Fraunhofer IMW, "GLOBAL COMPETITION IN MICROELECTRONICS INDUSTRY FROM A EUROPEAN PERSPECTIVE: TECHNOLOGY, MARKETS AND IMPLICATIONS FOR INDUSTRIAL POLICY," (March 2018): https://www.imw.fraunhofer.de/content/dam/moez/de/documents/Working_Paper/180301_021_Microelectronics%20from%20a%20European%20perspective_Dornbusch_öffentlich.pdf (accessed March 01, 2021)

59 Kaan Sahin, "What China's "Chips Endeavor" Can Teach Europe," Berlin Policy Journal, (October 14, 2019): https://berlinpolicyjournal.com/what-chinas-chips-endeavor-can-teach-europe (accessed March 01, 2021).

60 Ed Sperling, "RISC-V Gaining Traction," Semiconductor Engineering, (July 30, 2020): https://semiengineering.com/risc-v-gaining-traction (accessed March 01, 2021).

61 Natalia Drozdiak and Helene Fouquet, "EU Weighs Deal With TSMC, Samsung for Semiconductor Foundry," Bloomberg (February 11, 2021): https://www.bloomberg.com/news/articles/2021-02-11/europe-weighs-semiconductor-foundry-to-fix-supply-chain-risk (accessed March 01, 2021).

field, for instance, when it comes to AI, is very limited, and promoting European players in the high-end chip market would incur a huge cost.

Even though European Commission President Ursula von der Leyen claimed that the EU needs "mastery and ownership of key technologies in Europe [such as] critical chip technologies",[62] the EU and German government have not been forthcoming with initiatives to realize these goals. However, since chip-making has evolved into a focal point of the US-Chinese tech competition, the EU has slowly started to become more active in this area. Twenty EU member states in December 2020 signed a declaration to launch a new European initiative aimed at making the EU competitive in high-end manufacturing and design.[63] However, the declaration came with no actionable plans to back up those goals.

Increasing the EU's semiconductor capabilities is also a major aspect of the recently announced Digital Compass,[64] although the goals set out in this compass are rather vague and questionable from a technological perspective. For example, the Digital Compass 2030 mixes up total and top-tier semiconductor manufacturing and reduces the definition of what top-tier manufacturing processes actually are to mere descriptions of nanometer processes – lacking the level of accuracy necessary to be actionable.

While the EU is trying to play catch-up, the US is already formulating the next step in its journey to reduce supply chain dependencies on China by furthering decoupling the manufacturing process.[65] The EU will have to decide whether it wants to join the US effort or chart its own, independent path. The Stakeholder Snapshot shows that even with primarily European participants, there is only a very narrow majority in favor of charting an independent path.

Recommendations

Europe has lost ground in semiconductor capabilities in the last decade and it is not realistic to expect it to catch up in terms of cutting-edge design and manufacturing capabilities. Furthermore, the few remaining top-notch European chip companies will come under more pressure amid the US-Chinese tech competition. An EU semiconductor strategy dealing with these developments is needed and should include the following objectives:

1. **Preserve current chip production capabilities within Europe:** To achieve this, the EU needs to protect essential companies in the semiconductor value chain, such as ASML, from foreign takeovers. Here, for instance, the EU should make use of its newly added instruments in the areas of foreign investment screening.

2. **Support the growth of local manufacturing capabilities**: This includes creating manufacturing capabilities for foreign companies within Europe as well as helping private entities to enter the market in emerging new microprocessor applications. The EU should focus on special purpose microchips to train AI algorithms (AI chips) and leverage its existing strengths in IoT and the associated microchips IoT applications rely on.

3. **Promote open standards in chip design and architecture**: Europe is lacking IP in this regard and lost its only major global player in chip design – ARM Limited. Open standards (e.g. RISC-V) can help level the playing field and reduce barriers for European companies to enter the market.

62 Ursula von der Leyen, "Speech by President-elect von der Leyen in the European Parliament Plenary on the occasion of the presentation of her College of Commissioners and their programme," European Commission, (November 27, 2019): https://ec.europa.eu/commission/presscorner/detail/enpt/speech_19_6408 (accessed March 01, 2021).

63 European Commission, "Member States join forces for a European initiative on processors and semiconductor technologies", (December 7, 2020): https://ec.europa.eu/digital-single-market/en/news/member-states-join-forces-european-initiative-processors-and-semiconductor-technologies (accessed March 01, 2021).

64 European Commission, "Europe's Digital Decade: digital targets for 2030", (March 9, 2021): https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030 (accessed April 07, 2021).

65 Taisei Hoyama, Yu Nakamura, "US and allies to build 'China-free' tech supply chain," Nikkei Asia, (February 24, 2021): https://asia.nikkei.com/Politics/International-relations/Biden-s-Asia-policy/US-and-allies-to-build-China-free-tech-supply-chain (accessed March 01, 2021).

3.4 5G AND MOBILE NETWORKS

State of Play

In 5G, Europe has good global positioning with two leading players – Ericsson (Sweden) and Nokia (Finland). These two companies compete directly with Chinese enterprises Huawei and ZTE (see fig. 6).[66] The US, in this case, does not have globally competitive industrial leaders.

TABLE 6: GLOBAL MARKET SHARE FOR 5G RADIO ACCESS NETWORKS (RAN)

Supplier	2020 market share
Huawei	33%
Ericsson	27%
Nokia	17%
ZTE	15.4%
Samsung	4.3%

Source: "Huawei strengthens leadership in RAN market," Telecomelead, (December 7, 2020)

The US may not have much skin in the game, but it would be premature to believe that 5G equipment leadership centered on two European companies and two Chinese companies will hold. Seoul-based Samsung, for example, is already challenging the 5G oligopoly with a massive expansion of 5G tech investment and growth of crucial 5G standard essential patents (SEPs).

In the 5G context, control of standard essential patents is a direct measure of potential market power.[67] So much that companies often spoof control of standard essential patents through "over declaration", to create the impression of market competitiveness. Clear estimations of SEP control are difficult to make because of its opacity. However, serious attempts to assess the SEP race adjusting for over-declaration show that the European Union is leading.

Still, Huawei's pressure on Ericsson and Nokia is intense, and motivated by the singular goal of grabbing mobile infrastructure market share in Europe by using massive amounts of state aid, price dumping, and political strong-arming by the Chinese government.

As 5G is being rolled out, market players are already working on strategic positioning for the next generation of mobile networks – 6G. With their patent leadership and strong market share both at home and abroad, European companies are currently well positioned in this regard with Ericsson recently intensifying its research and development and Nokia steering the EU-funded 6G wireless project called Hexa-X.[68] With the proposal for a strategic European partnership for the Smart Networks and Services Joint Undertaking, the European Commission plans to spend up to €900 million for 6G research programmes and 5G development over the budget period of 2021-2027.[69] Furthermore, the German Federal Ministry of Education and Research launched the first German research initiative on 6G technology in April 2021 which provides €700 million for 6G research until 2025.[70] However, the international competition is fierce. Huawei already embarked on developing 6G in its research facilities in Ottowa, Canada, in 2019. This also mirrors the early engagement of Chinese state research programs in 5G development since around 2008.

Current Policy Approach

5G will lay at the heart of countries' digital infrastructures and assume central importance for further economic competitiveness, since the existence of 5G enables further technological innovations such as the Internet of Things or autonomous vehicles. Political decision-makers themselves have been increasingly confronted with questions on 5G equipment sourcing, with particular concerns regarding the threat of cyberespionage, dependencies, geopolitically motivated service disruptions, and the support of Europe's own players for the technology. Concretely, it boils down to whether Huawei – the Chinese telecom giant with an opaque governance structure and connective tissue with the Chinese Communist Party – should be an equipment provider for Europe's 5G infrastructure. The US has

66 Jamie Davies, "Nokia, Ericsson and Huawei dominance beginning to fade – analyst," telecoms.com, (August 04, 2020): https://asia.nikkei.com/Politics/International-relations/Biden-s-Asia-policy/US-and-allies-to-build-China-free-tech-supply-chain (accessed March 01, 2021).

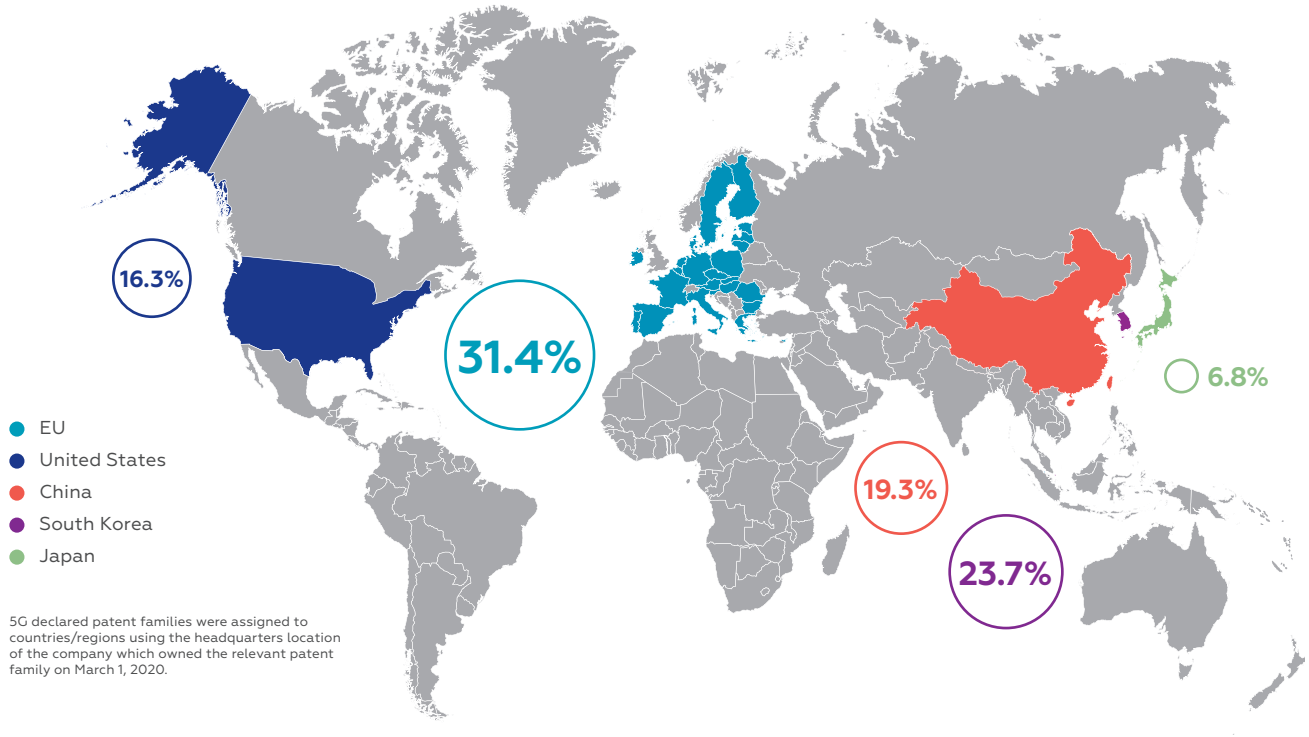
67 Matthew Noble et al.,"How to tell who's winning at 5G - and why all reports are not equal," iam, (May 28, 2019): https://www.iam-media.com/frandseps/5g-seps-part-one (accessed March 01, 2021).

68 Ericsson, "Ericsson a key player in EU drive to develop 6G multi-antenna technologies" (Jan 25, 2021): https://www.ericsson.com/en/news/2021/1/ericsson-in-eu-6g-drive (accessed March 01, 2021); Scott Moritz, "Nokia Leads a 6G Wireless Project for European Union," Bloomberg, (December 7, 2020): https://www.bloomberg.com/news/articles/2020-12-07/nokia-will-lead-a-6g-wireless-network-project-for-european-union (accessed March 01, 2021).

69 European Commission, "Europe puts forward proposal for Joint Undertaking on Smart Networks and Services towards 6G", (February 23, 2021): https://ec.europa.eu/digital-single-market/en/news/europe-puts-forward-proposal-joint-undertaking-smart-networks-and-services-towards-6g (accessed March 01, 2021).

70 The Federal Ministry of Education and Research, "Karliczek: 6G wird unsere Kommunikation revolutionieren - rund 700 Millionen Euro für die Vernetzungstechnologie von übermorgen" ["Karliczek: 6G will revolutionize our communication - around 700 million euros for the network technology of the day after tomorrow"], (April 12, 2021): https://www.bmbf.de/de/karliczek-6g-wird-unsere-kommunikation-revolutionieren-rund-700-millionen-euro-fuer-die-14195.html?utm_source=hootsuite (accessed April 12, 2021).

FIGURE 18: ASSIGNING 5G DECRLARED PATENT FAMILIES TO COUNTRIES/REGIONS PUTS THE EUROPEAN UNION IN THE LEAD WHEN ESSENTIALLY AND JURISDICITION QUALITY FILTERS ARE APPLIED



Source: Richard Vary and Matthew Noble, "Who is leading 5G development? 2020 update," twoBirds Pattern (September 2020)

tried to pressure its European allies to exclude Huawei from Europe, including attempts to gain partnership for its Clean Network Initiative. In Central Europe, the 17+1 format provides a case study of divergent positioning within Europe. Countries like Poland and the Baltic states have deep security ties to the US and have come under considerable pressure to ban Chinese equipment providers. While others, like Hungary have been more open to Chinese connectivity and tech infrastructure. Greece has tried to strike a delicate balance between the US and China on Huawei in light of the changing security landscape in the Eastern Mediterranean. It agreed to the American 5G Clean Network, but it remains unclear whether or not they would deem Huawei an untrustworthy provider.[71] In total, 11 NATO members have not signed the Clean Network Initiative.[72]

The EU has been striving for a coordinated approach among its members. In March 2019, the European Commission, on the request of the European Council, proposed that member states should exchange 5G risk information with each other and the European Agency for Cybersecurity (ENISA). The result of this information sharing was an EU risk assessment report released in October 2019, which provides a comprehensive list of cybersecurity risks from 5G networks. The report also puts emphasis on risks stemming from individual vendors originating from non-EU countries: a clear reference to Huawei without explicitly naming the Chinese company.

Building on this, the European Commission published the non-binding paper called "Cybersecurity of 5G networks – EU Toolbox of risk mitigating measures" – a how-to guide for dealing with specific vendors. The Toolbox contains content, explaining the potential risk stemming from vendors such as Huawei and ZTE without naming explictly the Chinese companies. For instance, the toolbox calls on EU member states to take into account, as part of their assessments, the problem posed by state interference via so-called "high risk suppliers" and consider the possibility of restricting or even excluding suppliers from sensitive parts of core network based on their risk profile. It also promotes a multi-vendor strategy to avoid over-reliance on a single supplier. Beyond concrete aspects relating to risk, the Toolbox makes the case for leveraging procurement and funding to strengthen Europe's domestic industrial capacity. Hence, the European Commission acknowledges the importance of maintaining Europe´s comparatively strong market position

71 Eliza Gkritsi, "Huawei in Greece: How Snowden shaped EU's approach to Huawei," technode, (January 21, 2021): https://t.co/VpXgtssfEm?amp=1 (accessed March 01, 2021).
72 Florence Gaub, "What if...not? The cost of inaction", EUISS, (January 2021): https://www.iss.europa.eu/sites/default/files/EUISSFiles/CP_163.pdf (accessed April 07, 2021).

in mobile technology, but also the relevance of creating a first-mover advantage in 6G – the next cellular mobile communications development.

Both the EU's Risk Assessment Report and the 5G Toolbox attempt to achieve a coordinated approach among member states in a field in which the EU's decision-making power is limited. For instance, the EU's cyber frameworks – the NIS Directive and the Cybersecurity Act to protect electronic communications networks – have limited competencies in terms of telecommunication networks. Even though the choice of whether to exclude Huawei from the 5G infrastructure is still pending in several member states, different models of market and network access seem to be evolving (see Fig. 19). Some countries, including Sweden and many Eastern and Central European states, are opting for a complete exclusion of Huawei in near- or medium-term, whereas some Southern European countries such as Spain or Portugal seem to favor fewer restrictions. Another model could involve a partial ban and restriction of Huawei from just the core network. The British government's Huawei U-Turn – from a partial to a complete ban of Huawei in the beginning of 2020 – has probably had a signaling effect for other countries as well.

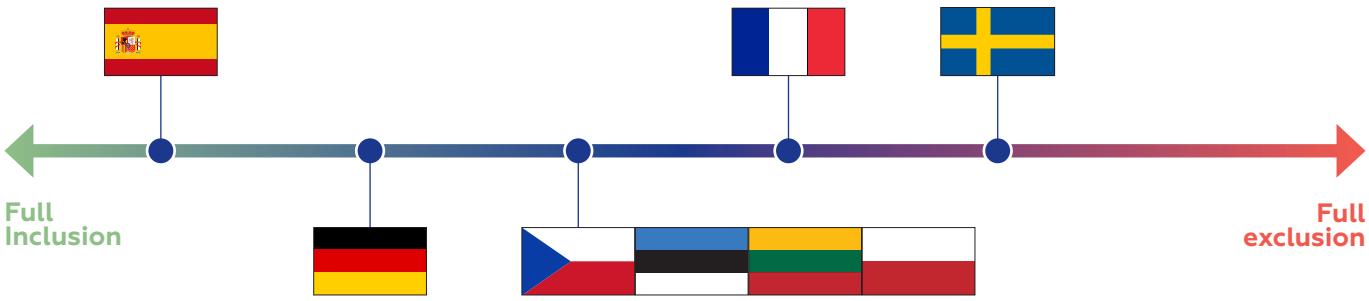
Germany's debate about Huawei encapsulates the difficulty and complexity of the decision. Initially in October 2019, two technical agencies[73] released a security catalogue on behalf of the German government, which ruled that the decision over 5G should be a purely technical one. In the aftermath, several members of the Bundestag, including from within the ruling coalition parties, and federal intelligence agencies protested against this approach. After a long deliberation process, the upcoming IT Security Act 2.0 should now comprise the necessary regulations concerning technical and political considerations for 5G vendors.[74] However, the law is likely to enter into force in the later part of 2021 after much of the 5G equipment sourcing and infrastructure rollout has already taken place.

FIGURE 19: HUAWEI DECISION AMONG SELECTED MEMBER STATES: TO BAN OT TO BAN?

SPAIN
There is no ban against Huawei and Spanish operator Telefonica has already started to deploy 5G equipment of the Chinese vendor in the country.

FRANCE
Defacto preferential treatment of European vendors Telecoms operators will only be able to get licenses for buying Huawei equipment limited up to eight years and Huawei's 5G technologies will be restricted to only non-sensitive areas. Defacto ban of Huawei after 2028.

SWEDEN
After an assessment of potential 5G vendors by the countries' armed forces and security services, Huawei/ZTE will be banned from its 5G networks and already installed equipment of the Chinese vendors will have to be removed until 2025.



GERMANY
The upcoming IT Security Law 2.0 will comprise a technical assessment as well as a 'political assessment' of the trustworthiness of manufacturers which may pave the way of excluding Huawei from the 5G network.

CZECH REPUBLIC, ESTONIA, LITHUANIA, POLAND, SLOVENIA
Those countries have signed memorandum of understandings with the US stating that, among others, 5G suppliers would not be subject, without independent judicial review, to control by a foreign government and have transparent ownership, partnerships, and corporate goverance structures. Basically, paving the way for Huawei ban.

Source: Own work

73 Namely the Federal Office for Information Security (BSI) and the Federal Network Agency (BNetzA).

74 Security Research & Consulting GmbH, "IT Security Act 2.0 passed by the cabinet", SRC, https://src-gmbh.de/en/it-sicherheitsgesetz-2-0-vom-kabinett-verabschiedet (accessed April 07, 2021).

The internet is predominantly built upon an open architecture, which allows products of different vendors to communicate with each other and in turn network the world. The 5G standard itself is open in principle, too. The infrastructure delivering 5G, however, is not. Infrastructure companies have each developed their own standards, which are like the Open RAN (O-RAN) Alliance,[75] an industry-driven group founded in February 2018 by mobile operators to promote new open interfaces and standards, shows. O-RAN could effectively decouple the software and hardware components in non-core 5G equipment breaking oligopolistic control over the technology by a small set of vendors and allowing for more flexibility and transparency in security specifications as well as easier upgrades. Support for this open software standard mainly originates in the US, which (unlike Europe and China) has no significant market player that benefits from a closed ecosystem.[76] According to forecasts, Open RAN is likely to produce about €2.7 billion in annual revenues by 2024 (in contrast to €59 million in 2019).[77] Besides this trend, the virtualization of network services is increasingly evolving and tech companies such as Amazon Web Services have already started to offer products in form of cloud-based 5G networks.[78] If this market trend gains momentum – and performance and cyber security issues are addressed – maintenance and operating costs can be reduced and the potential price advantages current market leaders such as Huawei benefit from, will be reduced.

Recommendations

Communications infrastructure is essential for a free and democratic society. And any potential threat to it is also a threat to Europe's democratic foundations. Europe should not risk compromising its security and should strive for a coordinated approach. The EU should maintain and further expand its strong position concerning 5G, which should pave the way for also assuming a leading position in 6G technology. Here are some actions the EU could take now to protect itself and strengthen its position on 5G:

1. Look for ways to tighten the EU's coordinated approach: The EU should further push for a concerted approach to avoid fragmentation within the EU and to learn from the initial roll-out and its effects. The new EU Cyber Security Strategy goes in the right direction by insisting on the implementation of the 5G Toolbox in each EU member state by the second quarter of 2021. The NIS Cooperation Group should produce risk assessments to permanently evaluate potential risks and experiences from member states with 5G equipment from different vendors. The upcoming set up of the Joint Cyber Unit at the EU level or EU INTCEN could be used to collect the necessary information. The political assessment of the involvement of Chinese vendors must be further increased on EU level in a coordinated fashion (e.g. via constant meetings in the context of the Council of the European Union and its working groups). This should also help like-minded countries communicate about 5G issues with one voice, mitigating any political rifts among member states.

2. Support open standards: In order to provide a consistent approach across technological areas, the EU should promote open standards for mobile communication networks. While this might weaken the position of major EU players compared to the US, it will strengthen the EU compared to China and enable more competition, ultimately leading to more efficient mobile networking in the EU as well. By supporting initiatives like the O-RAN Alliance, the current vendor-specific debate regarding 5G deployment might be avoidable for 6G.

3. Maintain 5G strengths while investing in 6G: Closely monitor the market to see which of the technologies 5G promised to enable are ultimately flourishing. It is important to assess industrial applications, expectations versus reality, and the potential for future growth. As 6G is being developed, the EU should lend support via its innovations programs and already start to develop a coordinated (and early) approach to 6G standard-setting.

75 See the O-RAN site for more information: https://www.o-ran.org (accessed April 07, 2021).

76 James Sanders, "Huawei starting 6G research in Canada, where it faces prospect of 5G ban," TechRepublic, August 16, 2019: https://www.techrepublic.com/article/huawei-starting-6g-research-in-canada-where-it-faces-prospect-of-5g-ban (accessed March 01, 2021); Ericson and Nokia have also already started to research 6G capacities.

77 Alan Weissberger, "Omdia and Dell'Oro Group increase Open RAN forecasts," IEEE ComSoc, (December 4, 2020): https://techblog.comsoc.org/2020/12/04/omdia-and-delloro-group-increase-open-ran-forecasts (accessed March 01, 2021).

78 Telefonica, "Telefónica Germany / O2 builds new 5G core network in the cloud", (September 01, 2020): https://www.telefonica.de/news/press-releases-telefonica-germany/2020/09/cooperation-with-amazon-web-services-and-ericsson-drives-new-industrial-5g-solutions-telefonica-deutschland-o2-builds-its-new-5g-core-network-in-the-cloud.html> (accessed March 17, 2021).

3.5 QUANTUM COMPUTING

State of Play

Quantum computing is still in its infancy and commercial applications are limited. The field is in the incubation phase in academic and non-commercial research with expected development of full-scale error-corrected quantum computers more than a decade away.[79] Once matured, however, it is sure to be a major disruptive force in the tech market and an important geo-economic and security tool. Quantum computers employ the principles of quantum physics for extraordinarily efficient parallel computing, which in turn can revolutionize many fields from AI to chemical simulation to communication and encryption. In 2019, the total quantum computing market size was just about €500 million but it is expected to grow to about €65 billion in 2030 as the technology matures.[80]

Europe and the US are the current leaders in quantum investment and research,[81] hosting key quantum research groups. American quantum research groups have a long tradition of working with major American tech companies (e.g. Princeton[82] and Yale[83] working with IBM, which is one of the leading companies in quantum computing today).

Drawing on the US public-private partnership tradition as a model, Germany's Fraunhofer Institut – like Princeton and Yale – cooperates with IBM. The partnership has seen IBM install the Q System One quantum computer in Germany, the first of its type in Europe.[84] With the dominance of US companies for quantum computing hardware it is not surprising that the Stakeholder Snapshot shows a high perceived dependency on the US in this field (41 percent believe EU is too dependent on external actors for quantum technology and 50.4 percent believe the EU is most dependent on the US).

The quantum computers that are currently deployed are only able to execute short algorithms and can solve only a very limited set of problems. Even achieving quantum supremacy[85] – the ability to use quantum-physics-based

TABLE 7: SIGNIFICANT QUANTUM COMPUTING USE CASES

AI and machine learning	Quantum computing can offer significantly improved computational speed and lower resource cost for training AI through quick optimization of problem solving and significantly better parallel computing capabilities during the learning process.
Chemistry and materials	Enabling new simulation methodologies, quantum computing can offer more precise simulations of chemical reactions, which will allow for progress in chemical and material sciences. Quantum algorithms in this field already exist and can be implemented once quantum computers become sufficiently large and reliable.
Financial industry	Quantum computing enables faster simulations and optimization algorithms for more accurate and current pricing.
Mobility and smart cities	Superior optimization through the use of quantum computing enables efficient planning of inter-city traffic and real-time operation of smart cities.
Supply chain, logistics and energy	Complex networks and optimization problems can be analyzed more efficiently using quantum computing, leading to more efficient energy grid usage that can potentially reduce the environmental impact of energy generation.

Source: Dr. Rosenkranz et al., "Taming Quantum Computers with High-Level Software Stacks", d-fine, (July 2020)

79 Riken, "Wiring a new path to scalable quantum computing," PHYS.ORG, (July 3, 2020): https://phys.org/news/2020-07-wiring-path-scalable-quantum.html (accessed March 01, 2021).

80 Prescient & Strategic Intelligence Private Limited, "2020. Quantum Computing Market is poised to surpass $64,988.3 Million by 2030: P&S Intelligence", (February 10, 2020): https://www.globenewswire.com/news-release/2020/02/10/1982087/0/en/Quantum-Computing-Market-is-Poised-to-Surpass-64-988-3-Million-By-2030-P-S-Intelligence.html (accessed March 17, 2021).

81 "Global Quantum Computing Market Research Report – Industry Share, Growth, Drivers, Trends and Demand Forecast to 2030," Business Wire, April 8, 2020: https://finance.yahoo.com/news/global-quantum-computing-market-research-095900153.html (accessed March 01, 2021).

82 Zandonella, C., "2019. Princeton announces initiative to propel innovations in quantum science and technology", (September 25, 2019): https://www.princeton.edu/news/2019/09/25/princeton-announces-initiative-propel-innovations-quantum-science-and-technology (accessed March 01, 2021).

83 Julie Bort, "Have you ever wanted to try a quantum computer? Now you can,", Business Insider, (May 4, 2016): https://www.businessinsider.com/ibm-launches-first-quantum-computer-cloud-service-2016-5?r=DE&IR=T (accessed March 01, 2021).

84 Frauenhofer, "IBM and Fraunhofer team up to promote quantum computing in Europe", (September 12, 2019): https://www.fraunhofer.de/en/press/research-news/2019/september/ibm-and-fraunhofer-team-up-to-promote-quantum-computing-in-europe.html (accessed March 01, 2021).

85 Frank Arute et al., "Quantum supremacy using a programmable superconducting processor," nature, (October 23, 2019): https://www.nature.com/articles/s41586-019-1666-5 (accessed March 01, 2021).

TABLE 8: OVERALL PERCENTAGE OF QUANTUM COMPUTING PATENTS PER REGION (TO 2017)

US	43.8%
Japan	18%
Canada	15.1%
Europe	9.8%
China	5.2%
Rest of world	8.1%

Source: Martino Travagnin, "Patent analysis of selected quantum technologies", JRC Technical Reports, (2019): <https://ec.europa.eu/jrc/en/publication/patent-analysis-selected-quantum-technologies> (accessed August 20, 2020).

computing to solve computational problems that take traditional computers a very long time in a fraction of the time – currently only applies to a very limited set of problems with no practical applications.[86] Nonetheless, opening access to quantum computing to the public has enabled the development of a huge quantum computing community with over 200,000 users and over 200 published research papers,[87] and has enabled the scientific community to start building software fit for quantum computers. There still are significant barriers to unlocking the disruptive potential of quantum computing. Simply scaling up existing quantum computing technologies is unlikely to be successful because fundamental questions of physics and engineering still need to be addressed.[88]

Given its incumbent research, Europe is well-positioned to compete in the race for full-scale error-corrected quantum computers. However, Europe is held back by factors that also plague it in other areas of technology: lack of public-private partnerships, lack of commercialization of its research, lack of venture capital, and lack of innovation ecosystems.

With this new technology, both funding and research prowess can change quickly, even on a yearly basis. In 2019, for example, breaking the trend of US funding dominance, 58 percent of quantum venture capital funding went to European start-ups (e.g. UK's Riverlane, Austria's Alpine Quantum Technologies, Finland's IQm), compared to 32 percent in the US and 5 percent across Asia.[89] Whether this is an exception or a trend that might continue and allow Europe to catch up, and whether those start-ups will be able to compete with the dominant (primarily US) tech giants, remains to be seen. This hopeful perspective was also confirmed by the Stakeholder Snapshot, in which the majority (57 percent) placed the EU as a peer in quantum technologies, although a significant portion (37 percent) did see the EU in the category of risk management.

The field of quantum technologies is much bigger than quantum computing itself. Communication, sensors, simulation, and AI can benefit from quantum technology as well, either through directly using quantum computers or leveraging different quantum effects altogether. China is currently pioneering secure quantum communication[90] while Europe has a strong position in quantum sensors, which are expected to have major applications in medical sciences.

Current Policy Approach

The EU added quantum computing to its agenda at the end of the 1990s. Nevertheless, there is no white paper or official clear-cut EU strategy yet. Considering the rather distant tangible effects of quantum technologies (for instance in comparison to AI or 5G), this is not surprising. However,

86 Felix Knoke, "Dieser übermächtige Computer ist praktisch nutzlos" ["This superior computer is practically useless"], SPIEGEL Netzwelt, October 23, 2019: https://www.spiegel.de/netzwelt/web/googles-quantenueberlegenheit-praktisch-nutzlos-a-1292904.html (accessed March 02, 2021).

87 "NUS Expands its Quantum Computing Efforts in Southeast Asia with IBM,", PR Newswire, (April 9, 2020): https://finance.yahoo.com/news/nus-expands-quantum-computing-efforts-000000390.html (accessed April 14, 2020).

88 RIKEN, "Wiring a new path to scalable quantum computing," PHYS.ORG, July 3, 2020: https://phys.org/news/2020-07-wiring-path-scalable-quantum.html (accessed March 02, 2021).

89 Atomico, "The State of European Tech 2019", (2019): https://2019.stateofeuropeantech.com/chart/255-1016/ (accessed March 02, 2021).

90 Karen Kwon, "China Reaches New Milestone in Space-Based Quantum Communications," Scientific American, (June 25, 2020): https://www.scientificamerican.com/article/china-reaches-new-milestone-in-space-based-quantum-communications (accessed March 02, 2021).

TABLE 9: SHORT TERM IS RIGHT NOW TO A FEW YEARS, MEDIUM TERM IS ABOUT 3-7 YEARS, LONG TERM IS LONGER THAN THAT

Applications of quantum computing	Expected timeframe for usability
Communication	Short-term
Encryption	Short-term
Sensors	Short-term
Simulation	Medium-term
AI	Medium-term
Computing	Long-term

Source: Own work based on Antonio Acín et al., "The quantum technologies roadmap: a European community view", 2018

the previous European Commission already stated the goal of becoming a world leader in quantum technologies[91] and many quantum projects have been funded as part of the Future and Emerging Technologies program within Horizon 2020.[92]

The EU has two major quantum projects: the Quantum Flagship and PlanQK. The Quantum Flagship scatters resources over a wide area of possible quantum applications, although its funding is not sufficient to ensure excellence in particular fields. Its ambition hinges on translating its scientific breakthroughs into commercialized applications.[93] PlanQK, on the other hand, is highly specialized and aims at providing a software ecosystem for quantum AI. However, the project depends on quantum computing hardware, which Europe cannot provide on its own.

EU funding remains broad, unfocused, and somewhat thinly spread making it difficult to concentrate resources in the pursuit of building a quantum computer. But individual member states have taken action. Germany has committed €2 billion for building quantum computers and France has pledged €1.8 billion for quantum technologies. Both pledges are around twice the total expected funding of the entire European Quantum Flagship program.[94] Some regional governments are also increasing quantum investment. For instance, Bavaria's €300 million Quantum Valley.[95] Given that the breakthrough in quantum computing is probably a decade away, the investment represents a far-sighted bet on an unproven, somewhat experimental strategic technology.[96]

The goal to bolster the EU's quantum computing capabilities is also reflected in the Digital Compass.[97] However, the goal, as currently phrased, only envisions Europe having its first quantum computer by 2025 – something that the cooperation between IBM and Fraunhofer Institut has already provided. Even if this goal was to be expanded with quantum computing capabilities being provided by a European company, this is a low bar. By setting such a low target, the EU risks being left behind, just as it was in semiconductor production.

While Europe is trying to catch up to the US in quantum computing, other areas should not be neglected either. Since funding via the Quantum Flagship is spread rather thinly, significant programs with specific goals from the US or China can leave Europe at a disadvantage. For example, the US has recently started to take the lead in quantum communication with the US Department of Energy's program to create a global quantum communication network – the Quantum Internet.[98] If successful, the US could consolidate its dominance over international communication networks, which have started to diminish in recent years due to the push by China to decouple networks. Once again, the US is positioning itself to strengthen its geopolitical power by being the first to translate current research into products available to the market. If the US can provide a service the rest of the world depends on, it can strengthen its capacity to act. Europe can learn from this example.

91 For instance, Andrus Ansip, Commission Vice-President for the Digital Single Market, issued the statement in 2018: "Europe is determined to lead the development of quantum technologies worldwide."

92 European Commission, "Future and Emerging Technologies", (2020): https://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies (accessed March 02, 2021).

93 European Commission, "Quantum Technologies Flagship", (November 5, 2020): https://ec.europa.eu/digital-single-market/en/policies/quantum-technologies-flagship> (accessed March 02, 2021).

94 "Emmanuel Macron, "Veut mettre la France dans le trio de tête mondial des technologies quantiques" Le Monde, (January 21, 2021): https://www.lemonde.fr/politique/article/2021/01/21/emmanuel-macron-presente-un-plan-quantique-de-1-8-milliard-d-euros-sur-cinq-ans_6067037_823448.html (accessed March 02, 2021).

95 Max-Planck-Gesellschaft, "Munich Quantum Valley – a leap forward for quantum science and technology", (January 12, 2021): https://www.mpg.de/16258573/munich-quantum-valley (accessed March 02, 2021).

96 Felix Knoke, "Dieser übermächtige Computer ist praktisch nutzlos" [„This superior computer is practically useless"], SPIEGEL Netzwelt, (October 23, 2019): https://www.spiegel.de/netzwelt/web/googles-quantenueberlegenheit-praktisch-nutzlos-a-1292904.html (accessed March 02, 2021).

97 European Commission, "Europe's Digital Decade: digital targets for 2030", (March 9, 2021): https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030 (accessed April 07, 2021).

98 U.S. Department of Energy, "U.S. Department of Energy Unveils Blueprint for the Quantum Internet at 'Launch to the Future: Quantum Internet' Event," July 23, 2020: https://www.energy.gov/articles/us-department-energy-unveils-blueprint-quantum-internet-launch-future-quantum-internet (accessed March 02, 2021).

Recommendations

Quantum Computing is a chance for the EU to establish a lead in a new and quickly growing area of technology. The EU should take the following steps to set it on that path:

1. **Create an overarching quantum strategy focused on enabling development of technology:** Current EU projects are spread too thin and, while they do cover a wide area of quantum technologies, do not cover quantum computing itself adequately. While recent national and regional quantum computing initiatives fill the gap in funding in EU projects, the EU needs to aim for a concerted approach instead of relying on national initiatives. The EU quantum strategy should not implement a pie cemeal approach. Instead, it should identify key areas in which excellence is possible and aim for global leadership in those key areas.

2. **Enable public-private partnerships:** The loss of competitiveness in the area of semiconductors should serve as a warning and must not be repeated. Industry is already significantly driving quantum research and without a strong industry base the EU will not be able to maintain its scientific edge. The EU has to make sure to enable private players – preferably SMEs and start-ups – to bring quantum research to market. The EU should make sure that its funding is paired with private investment and that commercial applications with a proven real-world impact are incentivized.

3. **Use the EU's regulatory power to enable open standards for quantum computing:** The technology is still maturing, which is the ideal opportunity for the EU to ensure both interoperability and competitiveness. PlanQK is already pursuing this goal in the field of quantum AI and it should be expanded to other areas of quantum technology.

Conclusion

In her first statement in the European Parliament as president of the European Commission, Ursula von der Leyen stated that "[i]t is not too late to achieve technological sovereignty in some critical technology areas",[99] naming quantum computing, artificial intelligence, blockchain, and critical chip technologies among them. The EU's quest for mastery in all of the key enabling technology areas in this study will be difficult in the medium-term. Europe's "catch up" position vis-à-vis the US and China clearly shows that the EU and its member states need to adopt a sophisticated approach to enhance their capacity to act in the technological realm.

Europe's goal should be to increase its technological capabilities as far as possible while avoiding or mitigating against over-dependencies on third-countries or competitor powers such as the US and China.

4.1 GENERAL RECOMMENDATIONS

There is one central aspect necessary to strengthen Europe's capacity to act in the technological realm, which spans across all sectors: Fostering a culture of innovation where digital companies and start-ups can thrive. The EU should consider the following recommendations if it wants to remain competitive and grow the reputation of Europe as a place of technological progress:

1. **Nurture a high-skilled workforce through flexible working conditions, education, and immigration:** Making advances in technology requires access to a skilled and flexible work force. Not just technical expertise but also adaptability, creativity, critical thinking, and willingness to learn – not just in school or university but also in all aspects of life.[100] Focusing parts of the educational system on technologies and building valuable skills into the workforce is necessary if Europe wants to have an effective long-term strategy. The Digital Compass 2030 contains some targets in that direction (e.g. 80 percent of all adults in the EU should have basic digital skills, plus 20 million should become ICT specialists in the EU until 2030), but these targets have to become more precise.
2. **Remove roadblocks to the use of innovative technologies:** Completing the EU's digital single market is central to a competitive European tech base. The EU's tendency to be a "first mover" in regulation puts additional burdens on European companies, which can making it harder to bring innovation to the market. Finding a balance that preserves European values but supports innovation is essential if the EU wants to become globally competitive, especially considering how quickly China can build and prototype, while worrying much less about regulation.
3. **Develop a deeper culture of risk tolerance:** About 90 percent of start-ups in Silicon Valley fail. Still, Silicon Valley currently is the world's center of innovation with regard to new technologies. The EU should support the creation of a tech community of researchers and entrepreneurs in which people are encouraged to take risks and supported if they fail.

4.2 RECOMMENDATIONS FOR EUROPE'S TECHNOLOGY FOREIGN POLICY

Politically, and especially in terms of the technological clash between the US and China, the EU and its member states have to ground their tech policy in a way that preserves European independence, resilience and values:

1. **Maintain a globally open Internet and innovation ecosystem:** The EU and its member states should promote the merits of global innovation. However, it will be a delicate balancing act to do so since, in some instances, the EU has to address the practices of the US (e.g. in terms of taxation of US tech companies, market power of platforms, privacy and content moderation) and China (e.g. by potentially excluding Huawei technologies on national security grounds, being mindful of data protection and data localization, attempts of introducing a Huawei-backed New Internet Protocol and guarding against cyber IP theft, the use of repressive technology, and how it is exported to other countries). In that context, it will be important that the EU clearly signals that it preserves an open internet environment and innovation ecosystem that serves its *own* strategic, political, security and economic interests.
2. **Develop and lead international coalitions with like-minded actors in standard-setting bodies and technology governance:** It will be crucial for the EU to work with like-minded states to ensure that a semblance of the multilateral order can be maintained, and access to key technologies, even if not produced in Europe, is se-

99 Maria Chiara Morandini et al., "Facing the Digital Transformation: are Digital Skills Enough?", European Commission, (July 08, 2020): https://ec.europa.eu/info/publications/facing-digital-transformation-are-digital-skills-enough_en (accessed March 02, 2021).

100 Ibid.

cured. The EU's Digital Compass proposes a format for "inclusive multilateralism" that can promote a global tech order in an "open but assertive manner, based on European values."[101] As perhaps the world's leading convening power, the EU should help lead in new informal groupings as part of an effort to shape the global digital market and push back against authoritarian tech governance. The EU and its member states could also form the core – along with the US, UK, South Korea, Japan and others – for democratic caucuses in standard-setting bodies like the International Organization for Standardization (ISO), on cybersecurity norms, on Internet governance, and in joint strategies on connectivity in the Global South. Together, they can make technology adoption and emissions targets mutually reinforcing through standards and incentives that operate globally. This effort should start with cross-cutting strategic engagement with the US through a new EU-US Trade and Technology Council that ties both parties together on values, market access, tech governance, and industrial policy.

3. **Incorporate the Global South into a strategy that fuels development, connectivity and regional empowerment.** Competition for tech dominance is increasingly being waged in the Global South where "tech takers" in areas like AI, 5G, and payment systems come under the sway of systems developed in Silicon Valley and in China. Third country tech adoption and standard-setting in areas like 5G and mobile payments can create path dependencies that lead to the emergence of digital spheres of influence. The EU should work with countries in the developing world and like-minded states to link connectivity, digital infrastructure, and development in a way that provides a democratic answer to China's Belt and Road Initiative, gives local communities more ownership of their digital futures, and seeks to address the UN's sustainable development goals (SDGs). The EU's Connectivity Strategy, tech diplomacy, regional dialogues and newly announced Digital Connectivity Fund can help create conditions that favor greater competition and preserve European values in the Global South.[102]

4. **Address the role that military and defense modernization can play in advancing Europe's innovation industrial base.** Even though this issue has not been tackled predominantly in this report, the EU and its member states must start a fact-based examination on the ethical development and usage of emerging, disruptive technologies in military contexts – both as a component of technological innovation and as a key to building a capable and future-ready armed forces. The US and China are actively leveraging the dual use of technologies for their militaries. Since the Obama Administration, the Pentagon has worked assiduously to create cooperation between Silicon Valley and the US military through programs like the Defense Innovation Unit (DIU), the Joint Artificial Intelligence Center (JAIC), and expert commissions like the National Security Commission on Artificial Intelligence (NSCAI). Most European states have yet to catch up and examine how emerging tech should be developed and deployed in their militaries. The EU should push for a Europe-driven initiative on how to bridge the technology objectives of NATO, the EU, and individual member states. This conversation must extend beyond arms control and lethal autonomous weapons systems to address joint operational and ethical codes of conduct. Member states and EU institutions, such as the European Defence Agency (EDA), must find a way to integrate Europe's innovative technologies.

To enhance the EU's capacity to act on the global stage, the bloc and its member states must be able to promote the human-centered approach beyond Europe. A cohesive, integrated EU approach to technology on the international stage should be shaped in tandem with efforts to rethink the bloc's relations with China.

The Stakeholder Snapshot shows that China is expected to take global leadership in artificial intelligence and semiconductor production by 2030 in addition to leading in mobile equipment, and China has become more belligerent during the COVID-19 crisis. Its disinformation campaigns, data theft and cyberattacks on European infrastructure have become more brazen amid the COVID-19 crisis. Digital crackdowns and mass surveillance have become the instruments of oppression from Hong Kong to Xinjiang. And China has shown it is willing to play hardball to force Europeans to accept Huawei equipment in its 5G infrastructure. Ursula Von der Leyen's calling out of Chinese cyberattacks on EU hospitals during the COVID-19 crisis, the March 2021 EU sanctions against four Chinese officials over Xinjiang abuses, and invocation of the Cyber Diplomacy Toolbox against foreign actors for the first time last year are steps in the right direction. But the EU should work to marshal a more effective partner-based opposition while at the same time recognizing that China's existence is a permanent economic reality and one to which Europe's export capacity is increasingly tied.

The EU and its member states should also avoid fueling the trend of digital decoupling while at the same time promoting the merits of an open, human-centric innovation system. Pulling together the various strands that make up the

101 "2030 Digital Compass: the European way for the Digital Decade", (March 09, 2021): https://eur-lex.europa.eu/resource.html?uri=cellar:12e835e2-81af-11eb-9ac9-01aa75ed71a1.0001.02/DOC_1&format=PDF (accessed April 07, 2021).

102 Ibid.

EU's tech policy together into one concerted EU effort will be a delicate undertaking. By integrating the tools of tech diplomacy, development, industrial policy, regulation, and values into a coherent identity, the EU will be better positioned to promote democratic tech and check the techno-authoritarianism. If that effort works, the EU can have a leading stake in building a global digital order based on openness, dynamism, innovation, and value creation within the EU. And in doing so, it can create a marketplace that guarantees wide access while protecting users' rights, security, and the principles of democracy that lie at the heart of the European system.

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