CAMBRIAN FUTURES

KONRAD ADENAUER STIFTUNG

Analysis of current global AI developments with a focus on Europe

Olaf Groth
Tobias Straube

#KAS4 INNOVATION

www.kas.de

Analysis of current global AI developments with a focus on Europe

Olaf Groth
Tobias Straube

With the support of:
Johannes Glatz
Dan Zehr
Lauren Hildenbrand

At a glance

1. Europe has recognized the potential of AI and is utilizing it. However, the coordination of national AI strategies in Europe should be improved.

2. With its human-centered approach Europe is a defining norm setting power in the field of AI and data science, especially in the protection of privacy and human rights. The distinctive European approach also constitutes a strength of the European AI innovation ecosystem for the international AI arena.

3. In addition, Europe has the resources to become a leading player in the global AI race. Europe offers a high degree of automation of its strong industrial base, a great pool of industrial data, an excellent research and development landscape that generates innovations and AI talents, a high number of Internet users and a large internal market.

4. At the same time, Europe's normative strength is associated with weaknesses in regards to its AI innovation ecosystem – especially in terms of data availability. It is necessary to find ways to realize European values while at the same time enabling large and high-quality data pools. Other areas that must be improved are the availability of AI talents and supercomputers, strong dependencies on foreign semiconductor industries and the commercialization of AI.

5. Furthermore, Europe lacks consistency in the performance of national innovation ecosystems. This asymmetry poses a risk to Europe's economic cohesion and thus also to future political stability.

Contents

Executive summary

The European Union (EU) and its members have recognized the potential for artificial intelligence (AI) to drive economic, business and societal prosperity. Critically, they have also recognized many of the risks that accompany AI and the various applications and systems it empowers. Many of these considerations are reflected in the various national and EU-wide AI strategies and standards. Perhaps more than any other region or country in the world, Europe has made human rights and privacy the "North Star" of its strategies, partnerships, governance, and commercialization of advanced technologies.

This has become a primary strength as the EU and its members develop their AI ecosystems, but it also drives many of the region's key weaknesses. Perhaps nothing exemplifies this duality better than the General Data Protection Regulation (GDPR). While the GDPR has become a global standard for the preservation of individual data privacy and a key check on the hegemonic power of the large digital service platforms, its structure has also curbed innovation, commercialization, and the collection of massive data pools that drive the development and training of AI systems. Careful consideration of ways to calibrate and recalibrate their approach to partnerships, governance and commercialization will allow the EU and its member states to expand their influence on global AI development, while fostering a domestic environment that allows their companies and research institutions to compete more effectively with the United States of America (USA) and China.

Such calibrations must be based on a deliberate and clear-eyed understanding of the factors that currently limit AI development across the EU. While the EU is home to 446 million residents – representing the third-largest market in the world after India and China – a collective pool of usable data has not yet coalesced to power AI research and development (R&D). This is particularly true for European industry, where concerns about trade secrets and governance requirements (e. g. GDPR) have hindered possibilities of industrial data sharing. The EU also struggles to develop and retain key data science talent. Although European institutions produce world-class talent and research in AI-related fields, they have yet to reach the scale or influence of US and Chinese institutions, and much of the talent they develop has migrated to those two countries. Nor does the EU possess a deep reserve of high-end computing power, a fundamental requirement for world-class AI innovation at scale. Finally, while the climate for commercialization varies from one EU member state to the next, the overall ecosystem for innovative risk-taking, technology transfer, venture investment and startup growth lags behind that of global AI leaders.

Nevertheless, many strengths remain, and they underpin the EU's continued emergence as a critical player in the science, geopolitics and ethics of AI and related fields. To the extent it coalesces and becomes available to developers, its common market can generate a deep pool of data for cutting-edge R&D. Its leading research institutions still develop world-class AI talent, and the increasing digitalization of the existing industrial power base is starting to generate more local opportunities for those experts. Furthermore, the region continues to lead the world in its awareness of and emphasis on human-centric, private and ethical uses of AI and data science. These are critical, indispensable strengths on which the EU – and, in many respects, the world as a whole – will rely in the decades to come.

However, these advantages are not enough to enable the EU to stand on its own as a "Third Way" alternative to the US and China. Ultimately, countries will have to individually or collectively align, at least in part, with a US or Chinese mindset regarding technology, geopolitics, and economic development. We have argued elsewhere that the EU best aligns with the liberal democratic ideas embodied in the US constitution. For the purposes of this report, however, we have focused on the

EU's current strengths and weaknesses compared to other global AI leaders, and how the EU could enhance its strengths and mitigate its weaknesses. The report begins with a look at the current state of AI in Europe and elsewhere, before moving onto a summary of the EU's AI strategy. It then looks at the preconditions for any country or region to lead in AI development and how those conditions are changing. This provides a foundation for the report's final chapters, which survey the next frontiers in AI and the forces that will drive uptake of AI across the economy and society. We include 20 recommendations throughout the course of these discussions, but each recommendation falls into one of four main categories – partnerships, governance, commercialization, and talent and research.

Partnerships: To enhance strengths and offset weaknesses, the EU should seek to establish formal collaborations with countries and institutions outside its borders. Monitoring and securing its place in global semiconductor supply chains would safeguard the EU's access to the computing power that drives advanced technology development. A special science and innovation zone between the UK and EU would mitigate potential losses from Brexit. An Indo-Pacific partnership on AI would establish the EU as a leading force for the protection of a liberal world order, while also deepening ties to the Global South, where new Digital Economy Agreements would establish digital trade rules and collaborations across multiple economies. Despite their current differences, an EU-US sequential bridging model would enhance their shared values and provide other countries with a crucial alternative to China's Belt and Road Initiative. All of these alliances could help the EU to champion the use of AI for public good, seeding vital breakthroughs in health care, climate change, education and other fields currently underserved by the private sector.

Recommendations on Partnerships
(R3), (R6), (R7), (R9), (R10), (R20)

Governance: The EU can solidify its global leadership in ethical and human-centric AI governance, but it must continue to evolve its standards to maintain that crucial authority. Improving and harmonizing administrative processes would accelerate the creation of a digital single market, facilitate trusted data sharing, and foster a more robust data-driven economy across the EU. Similarly, a pan-European regulatory body would enable a type of "growth with guardrails" that promotes and enforces privacy and other human-centric data protections without sacrificing innovation and global influence. Establishing shared technical standards and benchmarks across the EU would operationalize the region's ethics and ideals within AI development in Europe and around the world. By crafting these new governance and regulatory models in a way that encourages large European companies to build smart procurement ecosystems with startups, the EU would promote more joint research, accelerate innovation, and create greater economic resilience.

Recommendations on Governance
(R1), (R8), (R13), (R18)

Commercialization: By rebalancing its regulatory and legal standards, the EU can create an environment that promotes greater commercialization of technologies without sacrificing data privacy and other AI-related concerns. Promoting cybersecurity and AI safety as an integral part of national and regional security would channel more public-sector resources into advanced R&D and innovation. Fostering greater permeability between public, military and private digital ecosystems would allow the results of that research to spill over into the private sector. Encouraging experimentation with new data marketplace designs could lead to a data exchange model that preserves privacy, establishes tangible value for data, and rebuilds trust between individuals and companies – and thereby leads us into the next growth horizon for the digital economy. Recalibrating the governance of and investment in hardware, perhaps through a CERN-like development hub, would ensure that the EU can build the AI infrastructure of the future, rather than having to buy it. Tax policies and publicly backed fund-of-funds models would promote venture investment that fosters "creative upgrading" rather than "creative destruction". By encouraging companies and entrepreneurs to adopt new business models, such as B2B2C and P2P models, the EU would address problems of data access while preserving its protections of the individual.

Recommendations on Commercialization
(R5), (R11), (R12), (R17), (R19)

Talent and Research: The EU can take a leading role in shaping future AI trends if it recognizes and capitalizes on the fact that the experts and researchers who drive progress work across a range of geographies and academic disciplines. While talent outflows reflect the weakness of the European digital economy, tapping into the same outflows to forge international talent networks and training programs would help the EU to capture more value from the expertise its institutions produce. Tax policies that promote investment in labor upskilling over technology spending would foster more corporate investment in such initiatives, while programs that frame AI as a multidisciplinary field of research would allow EU academic institutions to build on existing strengths in fields that intersect with AI (e. g. climate and peace and conflict research). Closer to computer science itself, creating a European Center of Excellence for "contextual AI" would leverage the existing expertise in Europe to drive innovation at the nexus of various advanced-technology fields. As AI powers increasingly sophisticated and invasive applications and technologies, the EU's ability to establish clear, tangible and actionable frameworks for trustworthy AI would ensure that it is prepared to safeguard against brain-computer interfaces and other near-future technologies that will shape our lives in currently unknown ways.
Recommendations on Talent and Research (R2), (R4), (R14), (R15), (R16)

The recommendations in this report do not represent an exhaustive list of strategies the EU and its member countries could employ. However, each of these suggestions would allow the EU to expand its capacity for AI development and commercialization without sacrificing its commitment to ethical and human-centric AI standards.

1. Current state of AI in the EU and beyond

Since the first initiative launched by the Obama administration in 2016, more than 50 countries have adopted national AI strategies, elevating AI as an issue of geopolitical importance. Following the publication of a comparative study of national AI strategies, a number of organizations have set up systems to monitor the outcome of AI promotion and the implementation of these national plans, making AI policy a subject of study in itself and pushing it into other subject areas (e. g. industrial promotion, education, and defense and security). These monitoring initiatives, most notably the second edition of Stanford's AI Index, the OECD's AI Policy Observatory, and the EU's AI Watch,[1] provide a more granular picture of AI readiness in the EU (see Annex 1). Based on this, we can compare the oft-touted narrative of a strong research and manufacturing landscape as key pillars for building an EU-focused AI model with the reality. As a benchmark, we have chosen the EU member states, Norway, Switzerland and the UK as well as countries that we consider global leaders, including the US, China and eight others.[2] One of the EU's strengths is that it collectively encompasses a market of considerable size and scale with a data pool that could help produce powerful AI systems. Benchmarking more than 20 data-points as proxies for AI readiness reveals country clusters that correlate with geographical regions, highlighting a fragmentation of the EU along five, partially overlapping regions.[3] Understanding and addressing the strengths and weaknesses of these regions will highlight the collective strengths upon which the EU can build.

1.1. Data – Europe's "Achilles heel"

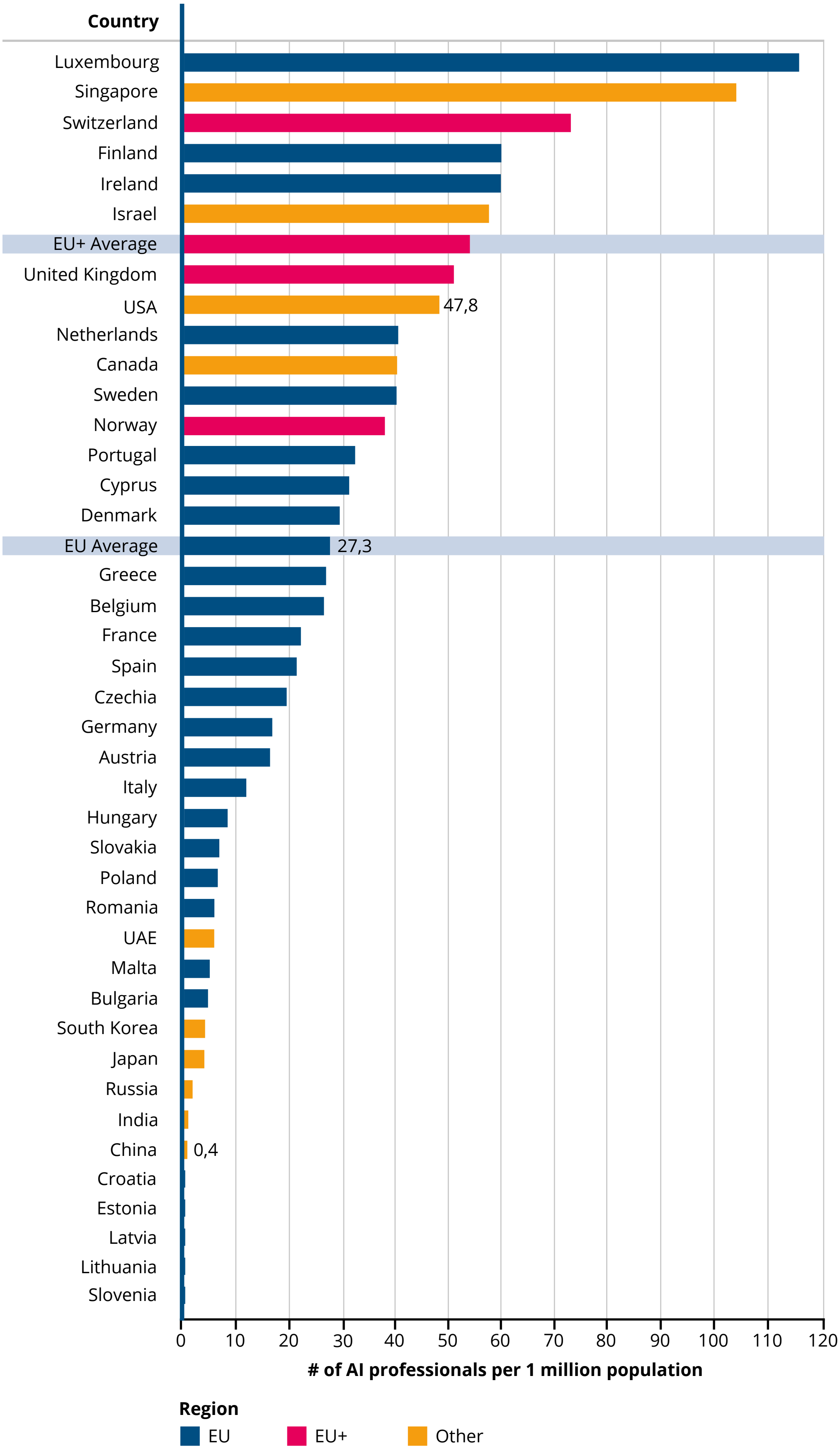
Data, the fuel of the emerging AI age, comes from four primary sources: individuals, companies, governments, and other AI systems (in the form of synthetically generated data). Because it lags in the consumer data space, Europe aims to position itself in the global landscape with AI strategies that rely more heavily on enterprise and government data.

The size of the EU data pool generated by individuals and end-users, as measured by the number of internet users, expanded to 397 million in 2019 (474 million when including Norway, UK and Switzerland), trailing only China (854 million) and India (560 million).[4] Platform companies such as Facebook, Twitter, Google, Tencent and Baidu have had the biggest success in tapping into these pools, collecting and storing data from individuals to continuously improve their algorithms and services. With only 3 percent of the world's data-platform market capitalized by European companies and only two significant B2C platforms (Sweden's Spotify and Germany's Zalando), the EU lacks actors that could shape the AI age with a European point of view.[5] The EU's failure to capitalize on the world's third-largest population of data producers (i. e. internet users) means that being more proactive with respect to AI development in the region's industrial sector is critically important.

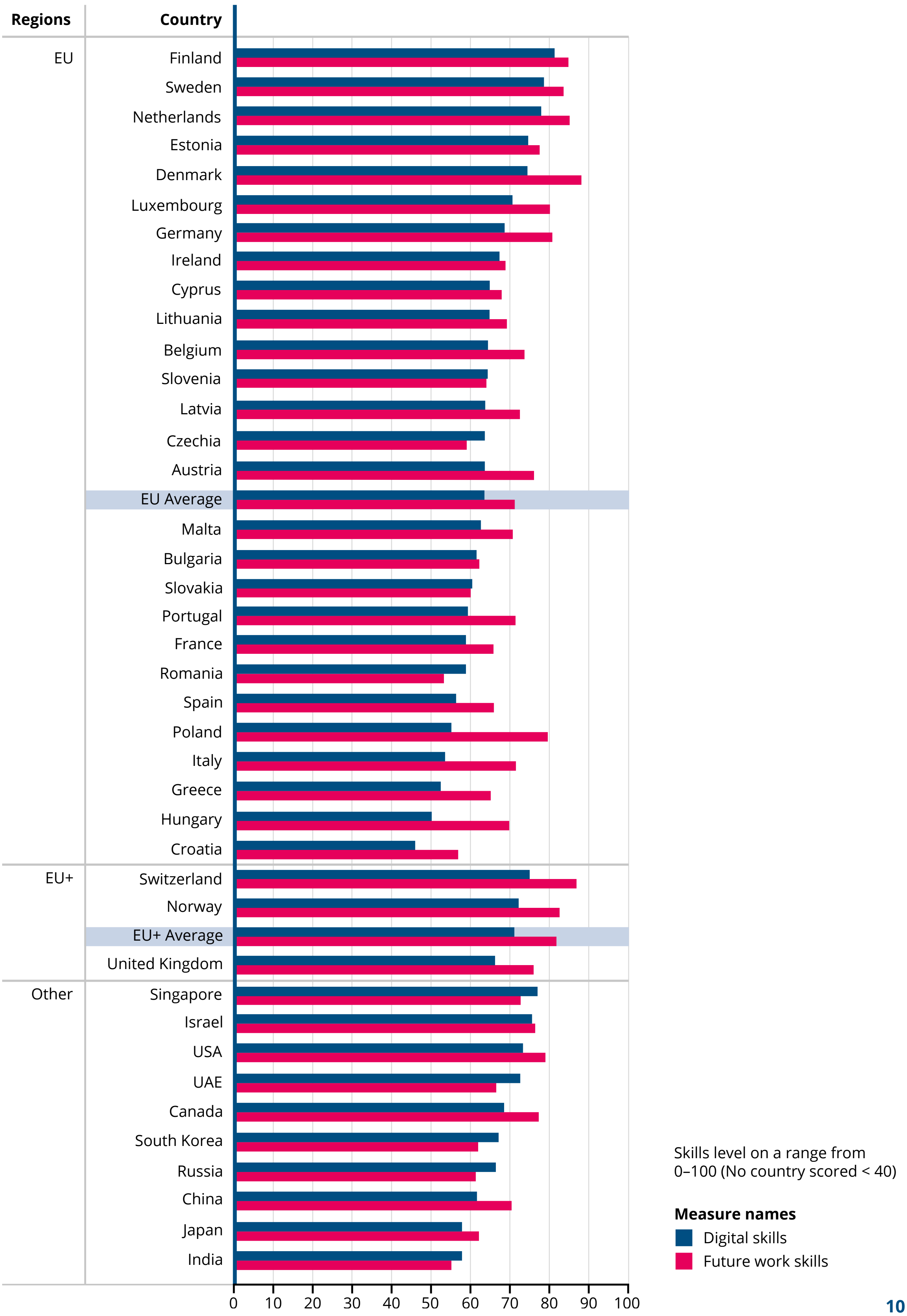
The EU, and Germany in particular, sits on a wealth of data from modern factories and world-class automation and robotics capabilities. For example, Europe reached a new peak of more than 75,000 robot units installed in 2018, with Germany among the top five major markets for robots worldwide (in comparison: US organizations installed about 55.000 units).[6] In addition, the data spheres, albeit not yet integrated, in Europe, the Middle East and Africa are expected to grow to 43.3 zettabytes in 2025 – larger than the US at 30.6 zettabytes[7] – with 22 percent coming from production activities and 19 percent from the Internet of Things (IoT).[8] While only a fraction is currently labeled (3 percent globally) and analyzed (0.5 percent globally), this data and know-how, when processed by AI, has the potential to change the face of manufacturing and production around the world. Recognizing this potential, the EU has set out to focus on AI in the economy as part of the broader framework of Industry 4.0. However, this requires effective mechanisms to access and exchange this industry data – a tricky task as companies fear risking the loss of competitive advantages when they share data. If the EU's AI strategies do not address this concern, few companies will participate and share data with entrepreneurs, potential competitors or researchers, making this the "Achilles' heel" of the EU's Data Strategy (see Chapter 2.2).[9] Other external factors will also influence data sharing, including many dynamics that, at first glance, have little to do with digital systems. In particular, the diversity of domestic regulations in individual EU member states will present barriers for the generalization of data created in the region. For example, even if collective data on the creditworthiness of EU companies and individuals would become available for the training of AI-powered financial services, it would have limited use because insolvency law – and thus the data on the financial health of companies – is not harmonized across the EU.

Recommendation 1 – Improve legal frameworks and harmonize administrative processes: Speeding up the creation of the digital single market, experimenting with different forms of data sharing mechanisms (e. g. data trustees, a concept pioneered by the German government)[10] and advancing standardization for data sharing and data-sharing interfaces are key to fostering a data-driven economy across the EU. However, a coherent legal framework for the digital single market needs to go beyond core digital domains and intertwine with the broader economic integration of the region. For example, fragmentation in insolvency laws – that impede the generalizability of financial data (see above) – runs deeper than the differences between the many languages spoken throughout the EU. Addressing the full array of different obstacles will require new ways to align some of these laws – perhaps, for example, in the context of the "data spaces" foreseen in the EU's data strategy (see Chapter 2.2). However, a legal framework alone will not foster a digital single market in which privacy is assured. In addition to rules and regulations, it will require the harmonization of administrative processes and an agreement between organizations on issues such as standardized technical interfaces. Data-sharing advisers deployed and networked across the EU, similar to the AI trainers foreseen in the German National AI Strategy, could help organizations ensure legal certainty and technical feasibility for their data-sharing initiatives.
Recommendations on Governance (R1), (R8), (R13), (R18)

AI professional density by country



Digital skills and future work skills by country and region



1.2 Talent – A resource to keep

Countries cannot fully research and commercialize AI opportunities, nor manage the associated risks of AI systems, without a data-savvy and digitally literate population. The EU ranks second on the basic digital skills of the active workforce (i. e. computer skills, basic coding, digital reading), ahead of China, Russia and India, but trailing the AI leadership group of nations, which includes the US, Israel, the UK, South Korea, and Singapore. However, vast differences exist within Europe. Central and Northern Europe are home to a digitally skilled active workforce and have better frameworks in place for future skills development, while Southern and Eastern Europe lag on this measure.[11] The assessment is similar when looking more narrowly at AI professionals per capita (i. e. the number of AI professionals per one million inhabitants). Despite vast differences between EU member states, the region as a whole falls well behind leading nations such as Singapore, the UK, the US, and Canada.[12] It is therefore understandable – and, in fact, critical – that all EU AI strategies focus on talent development and talent retention to counter "brain drain" to more attractive research ecosystems. Of all AI researchers and current students in the field who completed their undergraduate studies in the EU, less than half (46 percent) deploy their skills in the EU. A quarter end up working in the US, either in graduate programs or after fully completing their education within the EU.[13, 14] However, these numbers might be impacted due to the tightening of US immigration policy, including the White House's controversial move to ban new international students.[15] While the training and availability of AI and data scientists is critical for any country to benefit from the AI, operationalizing AI needs developers and engineers, AI-savvy business experts, and product developers. This talent is more likely to emerge from corporate training programs or skill-focused, rather than degree-focused, educational programs.

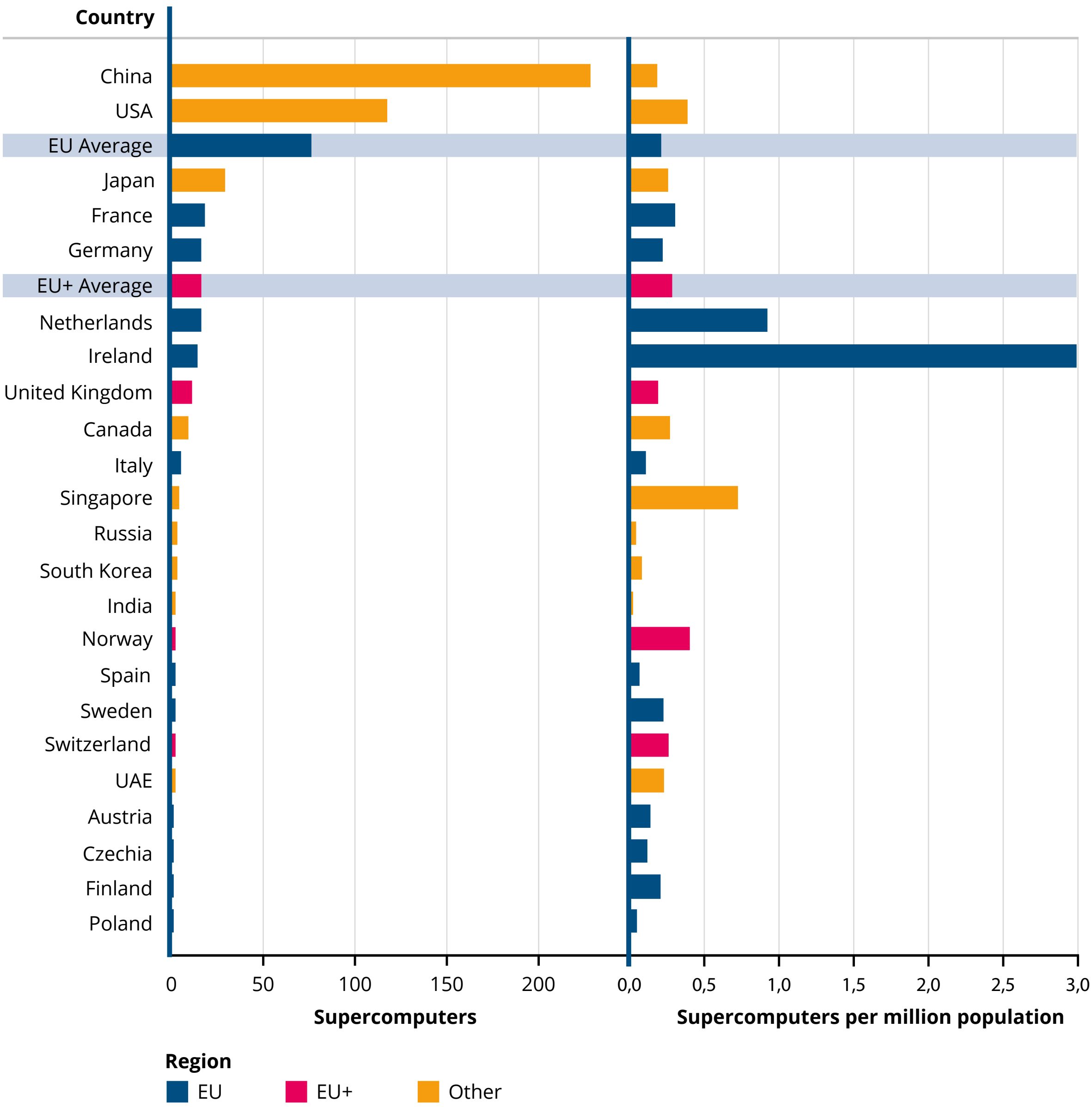
Recommendation 2 – Create global AI talent networks and foster advanced (corporate) training programs. While the outflow of AI talent shows the weakness of the European digital economy, it also offers an opportunity. European AI experts gain access to ecosystems abroad, especially in the US, which can also benefit the European economy – provided networks support the return of knowledge. The EU can facilitate this repatriation of knowledge through virtual and part-time secondment programs. In this way, AI experts could support the European economy without having to leave their new home outside Europe. In order to leverage the existing talent base within Europe itself, EU member states should reconsider their tax schemes for companies as they seek to rebound from the COVID-19 pandemic. Changes to tax policies should focus on making advanced (corporate) training programs tax-deductible in a manner that incentivizes the upskilling of personnel. While general tax incentives allow companies to create cash reserves or savings, which helps them respond quickly to disruption, companies will not invest those resources in human labor if the same investment in technology, particularly in software, will yield greater productivity.[16] Thus, tax incentives should target (corporate) training programs that provide humans with a defensible edge over machines and will help workers to transition to more future-resilient jobs, in which machines are used to unburden and augment humans, not take their jobs.

Recommendations on Talent and Research (R2), (R4), (R14), (R15), (R16)

1.3 Computing Power – No strategic assets in the EU (yet)

If data is the fuel of the modern global economy, then computing power and semiconductors are its engines. Complex AI used in pharmaceutical research, climate change modelling or other deep tech research requires access to supercomputers. Of the top 500 supercomputers in June 2020, 76 were located in the EU (equaling 0.17 per 1 million inhabitants) with an additional 15 in the UK, Norway and Switzerland combined. This compares to 117 in the US (0.35 per 1 million inhabitants) and 228 in China (0.15 per 1 million inhabitants). Depending on the complexity and strategic importance of a project, AI can also be trained through computing power based in the cloud or in private data centers. However, despite the critical importance of semiconductor design and production for AI training and applications,

Number of supercomputers and supercomputers per capita per country
(Not shown countries have no supercomputer)



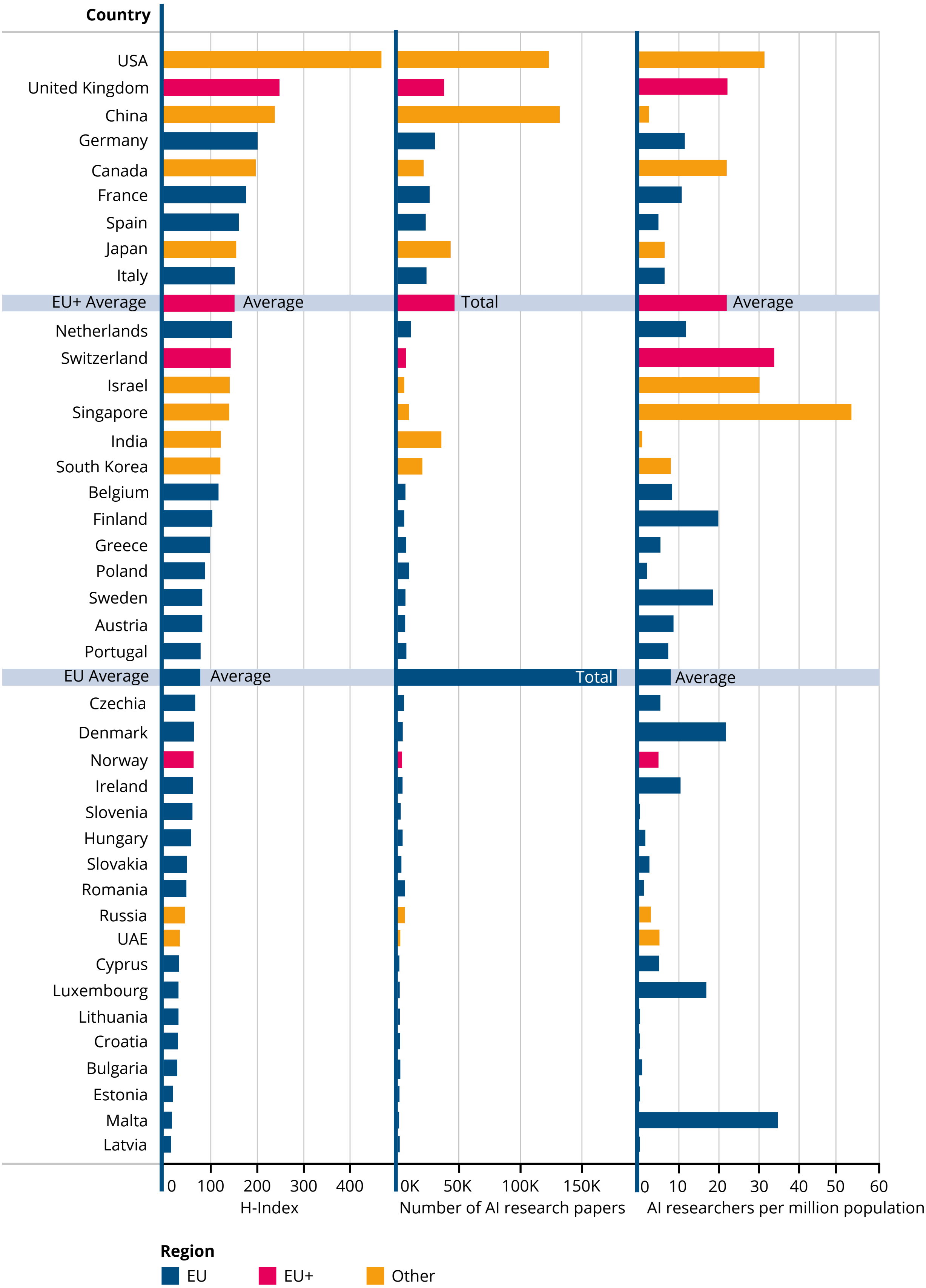
only three companies globally currently have the capacity to produce the most advanced, 5-to-10-nanometer chips – TMSC (Taiwan), Samsung Electronics (South Korea), and Intel (US).[17] Given their central role in the digital and hybrid analog/digital economy, semiconductors have become a core issue in the trade conflict between the US and China, elevating semiconductors alongside AI as an issue of geopolitical importance.

In Europe, Germany's Infineon or Bosch and Austria's AT&S manufacture chips for major clients (e. g. Apple), but EU-produced chips accounted for just 9 percent of the global market in 2018.[18] In the hopes of catching up with the current state of "China, America and silicon supremacy",[19] the EU has started the Electronic Components and Systems for European Leadership Joint Undertaking (ECSEL JU), which aims to fund key strategic pillars via their lighthouse projects: Industry4.0, Mobility.E, and Health.E.[20] In addition, the European Processor Initiative (EPI), funded through the EU's Horizon 2020 program, could help reduce European dependency on this core technology[21] or, alternatively, integrate Europe within the value chains of US, Korean and Japanese supercomputing via complementary assets. At its core, the EPI is focused on advancing European capabilities in the areas of High-Performance Computing (HPC), energy-efficient general purpose computing, research in the traditional sciences (e. g. chemistry and physics), and deep learning architectures aimed at high-efficiency inference in the industrial and automotive sectors.[22]

Recommendation 3 – Monitor and secure access to global supply chains in the semiconductor industry: Although intellectual property, commoditized code, and data are key elements of any digital economy, they all flow easily across borders. The remaining backbone element, computing power, remains tied to a physical location. Despite the widespread availability of computing power through the cloud, connecting with it or building cloud servers requires dedicated hardware and core talent. Hence, semiconductors – the building blocks of computing power – have become assets of geopolitical importance and "systemic relevance". Finding adequate responses to global supply chain disruptions requires an in-depth understanding of global actors in the industry and the dynamics at play in the value creation of chips. Complementing existing AI observatories at the national and EU level, a semiconductor observatory could provide intelligence for informed policy decisions. However, the EU should also ensure continuous access to the chip supply chain by creating complementary capacities in the value creation of semiconductors. Dedicated special economic zones (or clusters) could serve as building blocks for EU-based niche players and attract international firms in this space, from which European actors could gain know-how for building complementary assets, such as firmware (software that resides in the chip). These closer international interactions and knowledge transfers would help the EU to secure access to semiconductor supply chains. The support scheme provided by the German government to Bosch's chip production in Dresden in 2017 could serve as a blueprint for such special economic zones,[23] if opened to a broader range of actors.

Recommendations on Partnerships (R3), (R6), (R7), (R9), (R10), (R20)

H-Index, number of AI research papers, and AI research density by country

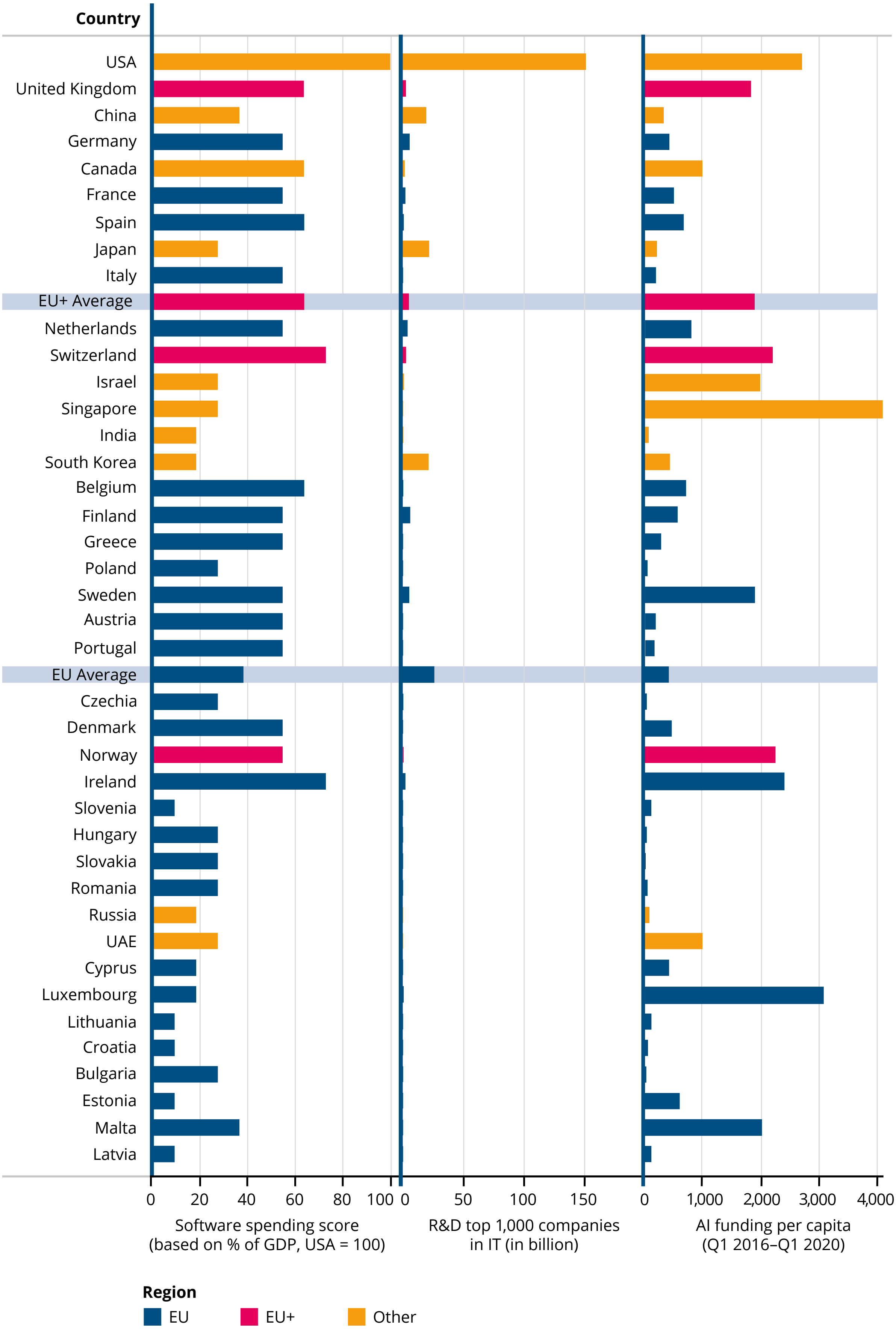


1.4 Research – Not world-class across the region

Europe possesses a strong international research landscape. Across the EU, Norway, Switzerland and the UK, scholarly output on AI as measured by SCImago Journal & Country Rank totaled 223,879 publications between 1996 and 2018 – 1.7 times greater than the output of China (131,001) and 1.8 times greater than the output of the US (122,617). However, the research strengths vary widely across the region and do not always achieve world class standards – in some cases they fall well below. EU member states are home to far fewer AI researchers on average when compared with other research-forward countries. With the exception of Malta, no member state had as many AI researchers per capita as Singapore, Switzerland, the US, Israel, the UK, or Canada.[24] Based on this measure, the UK is the strongest research location in Europe. While the Scandinavian countries lead within the EU, most Eastern and Southern European countries play a marginalized role in AI research at best, often relying on research collaboration with researchers in other nations. On average, 43 percent of all AI-related research publications originating from a EU member state are written by at least two authors in different countries – an indicator for the academic network strength of each country. In this regard, the EU trails only the UAE (65%), Singapore (61%), Norway, the UK and Switzerland (combined average 58%), Canada (48%), and Israel (44%). Furthermore, the average influence of AI-related publications (75.8) measured in terms of the H-Index lags the other two leading AI research nations (US: 465 and China: 236), with a wide range across the European countries. One reason for the low H-Index is likely the fact that many papers are published in languages other than English, which can decrease citation rates. Efforts to improve the EU's influence on the research landscape would face additional headwinds under the proposed funding cuts to Horizon Europe, with funding slashed to €75.9 billion (plus €5 billion from the COVID-19 recovery fund).[25] The European Parliament, which wanted €120 billion for Horizon Europe, can still veto the settlement.

Recommendation 4 – Foster AI as a cross-cutting academic discipline. AI, especially its machine learning subfield, has started to find its entrance into academic programs outside of computer science. Peace and conflict researchers are using AI models to predict the outbreak of conflicts, and climate science uses it for weather forecasts. While the promotion of AI dedicated computer science programs remains of paramount importance, the EU must find ways to make a basic introduction to AI and ML a cornerstone across academic programs – for example, by integrating it into general courses such as the "Introduction to Scientific Work" offered in many German university programs.
Recommendations on Talent and Research (R2), (R4), (R14), (R15), (R16)

Software spending, R&D spending an AI funding density by country



1.5 Commercialization – Varying economic readiness

The EU's manufacturing base, often considered a key focus of the continent's industrial and technology policy, is at risk of missing an important upgrade. On average, companies in the EU invest less in emerging technologies[26] than all other countries in the sample except Russia.[27] However, wide regional differences exist here, too. Above-average investment in emerging technologies generally occurs more frequently in Western and Northern Europe than in Eastern and Southern Europe, thanks largely to the concentration of public ICT companies with large R&D budgets such as Nokia in Finland, Telefonaktiebolaget LM Ericsson in Sweden, SAP in Germany, and semiconductor firms such as NXP and ASML Holding in the Netherlands. The large public ICT companies based in these four countries accounted for four-fifths of the USD 25.8 billion spent on R&D by all the EU-based ICT companies ranked among the world's 1,000 largest public companies. These disparities within the EU further exacerbate a relative lack of investment in emerging technologies overall.[28] The total R&D budget of the EU's leading ICT firms was a fraction of the R&D budget of their counterparts in the US (USD 151.2 billion), although still ahead of Japan (USD 21.5 billion), South Korea (USD 21.1 billion), and China (USD 19.1 billion). Furthermore, from an AI startup funding perspective, investments in young companies in the EU between Q1 2016 and Q1 2020 (USD 180 billion) trailed far behind the investment volume in the US (USD 877 billion) and China (USD 458 billion). In terms of AI startup funding per capita (AI startup funding per one million inhabitants), the situation looks even more dire. Although the average ratio in the EU (USD 406) is better than in China (318), it is far behind Singapore (4,060), the US (2,697), UAE (1,176) and Canada (987) – a shortfall that underscores the need for action to make the EU economy future-ready. When assessing the agility of legal framework conditions for digital businesses, we find that digitally advanced nations adapt their legal frameworks faster than those EU member states which need to do more to promote a digital economy.

The government and public sector play key roles in regulating emerging technologies such as AI, but they also are key drivers of the support and the development of innovation – both as an investor (e. g. public funding of fundamental research, directly through research programs, and indirectly through university funding) and as a market maker (e. g. the sheer volume of public procurement).[29] The latter can be given a number. Public procurement accounts on average for 12 percent of GDP in OECD countries, while general public-sector expenditure can account for 35 to 60 percent of GDP.[30] In Germany alone, the digitization of the public sector could save citizens 84 million hours per year.[31] This potential is anything but theoretical. Estonia has already digitized 99 percent of its public services, with only weddings, divorces, and real-estate transactions still requiring face-to-face interaction with a civil servant.[32] However, across the EU as a whole, governmental purchasing decisions on average provided fewer technology innovation incentives than in all other countries in the sample with the exception of Canada.

As we now enter a likely low-growth period as a consequence of COVID-19, this lack of incentives presents a missed opportunity. The comprehensive government stimulus packages indicate the return of the "strong" state, with the power to create new markets and incentivize AI-powered innovation. However, once again, public procurement of advanced technologies tends to be low across the EU as a whole, and it varies greatly on a country level. A clear divide exists again between Western and Northern European countries such as Germany (84.2), Luxembourg (78.2), Sweden (65) and The Netherlands (60.5) on one side, and mainly Eastern European countries such as Croatia (12.9), Romania (13.7), Greece (18.5) and Slovenia (22.8) on the other. However, it is important to note that government procurement of advanced technology does not automatically necessarily translate into better public sector services.

ZOOM OUT: AI in the EU member states – an incoherent landscape

Eastern Europe: Deficient public sector commitment, weak research landscape, and lack of commercialization. The combination of a lack of government procurement of technologies (–29% compared to the EU average), lower levels of ICT use and efficiency (–41%), and inefficient legal frameworks for digital businesses (–18%) leads to minimal rates of successful commercialization in this cluster. This results in significant shortcomings in the private sector and lack of investments (–36%), as signaled by private sector R&D (–98%) and startup funding (–89%). However, there is a ray of hope. Despite few international research collaborations and publications in comparison to the EU overall, the impact of research from this cluster is disproportionately strong. Hence, strengthening international research ties to Eastern Europe could tap significant potential.

Central and Northern Europe: Strong overall investments and applications, including impactful research, possible improvements in tech exports and digital skills. This cluster of countries is characterized by a general leadership across all metrics. On average, these countries are 66% higher on all measured AI related capabilities, with a special focus on international research collaboration and impactful AI publications, ICT efficiency, enterprise R&D and AI investments. Although generally leading, they are only on par with the European average regarding high tech exports, future work skills and digital skills of the current workforce, which leaves room for improvement.

Northern and Southeastern Europe: Skilled population but economically and technologically disadvantaged. A lack of private and research investments by public companies in the ICT industry have left this cluster lagging, measuring only half the EU average. It especially lacks supercomputing capacity and researchers. While internet penetration is just below the average, this cluster profits from EU-enabled ICT regulation, strong cybersecurity levels, and digital and future work skills of the general population that are on par with the EU average, signaling strong potential for incentives that encourage investment in the private and research sectors.

West European Belt: Scientifically impactful high-potentials. Featuring a high level of impact in academic research (+50%) and an above average measure of AI researchers and professionals in the market (+23%), there is untapped potential for small research and commercialization volume that could shore up lagging high tech exports (–24%) and private R&D (–54%).

Luxembourg and Malta: Special Characters. Fueled by the strong public sector application of AI and their unique positioning for headquarter locations, both these countries lead enterprise AI funding (+331% on average between the two), AI professional density in Luxembourg (+522%), and researcher density in Malta, (+441%). However, while funding is allocated to the countries for tax reasons, the actual intellectual impact is spread across Europe, essentially making both countries the administrative mailboxes of AI companies rather than effective and vital AI ecosystems.

Recommendation 5 – Promote cybersecurity and AI safety as drivers for innovation and commercialization. Promoting the commercialization of AI is a multidimensional task that requires the consideration of all recommendations contained in this study. However, while most of these recommendations look at governance, academic and private-sector initiatives, the EU should also consider the military's role as a strategic actor in the digital ecosystem. Likewise, it should consider security and safety as drivers of innovation, not just military domains. Within the broader public sector, the military is a key investor in the research, development, and commercialization of advanced technologies. Because the spillover effects into other industries can be significant – as the US and Israel demonstrate – the EU should foster greater permeability between its military and digital ecosystems. Achieving this will require the introduction of entrepreneurial training components in the cyber units of EU member states' militaries, creating a European network of the emerging civil and military innovation agencies (e. g. the Federal Agency for Disruptive Innovation or the Cyber Innovation Hub in Germany). The EU can further enhance these cybersecurity efforts through closer collaboration with the Joint European Disruptive Initiative (JEDI), the US Defense Advanced Research Project Agency (DARPA) and the new Israel-UAE alliance to advance operational capacity and automation beyond autonomous weapon systems.
Recommendations on Commercialization (R5), (R11), (R12), (R17), (R19)

1 European Commission (2020): AI Watch: Monitor the development, uptake and impact of Artificial Intelligence for Europein: https://ec.europa.eu/knowledge4policy/ai-watchen [2 Nov. 2020].

2 India, Russia, Israel, Japan, South Korea, UAE, Canada and Singapore.

3 Even though no indicator of these regions was present in the data.

4 India is likely to overtake China in the next decades as its population is expected to surpass China's by 2026. In comparison, the US is home to 292 million internet users.

5 Dr. Holger Schmidt (2020): Plattform Ökonomie. Dr. Holger Schmidt Netzökonom in: https://www.netzoekonom.de/plattform-oekonomie/ [2 Nov 2020].

6 International Federation of Robotics (2019): Executive Summary of World Robotics 2019 Industrial Robots. Available: https://ifr.org/downloads/press2018/Executive%20Summary%20WR%202019%20Industrial%20Robots.pdf [2 Nov 2020].

7 Gantz, Reinsel, Rydning (2019): The US Datasphere: Consumers flocking to cloud. International Data Corporationin Available: https://www.seagate.com/files/www-content/our-story/trends/files/data-age-us-idc.pdf [2 Nov 2020].

8 Reinsel, Venkatraman, Gantz, Rydning (2019): The EMEA Datasphere: Rapid growth and migration to the edge. International Data Corporation In: https://www.seagate.com/files/www-content/our-story/trends/files/data-age-emea-idc.pdf [2 nOv 2020].

9 Heikkilä (2020): The Achilles' heel of Europe's AI strategy, in https://www.politico.eu/article/europe-ai-strategy-weakness/ [2 Nov 2020].

10 Balser (2020): Schatz aus dem Netz. Süddeutsche Zeitung, in: https://www.sueddeutsche.de/politik/digitale-gesellschaft-schatz-aus-dem-netz-1.4769008 [2 Nov 2020].

11 Schwab (2019): The global competitiveness report. World Economic Forum, in: http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf [2 Nov 2020].

12 On average we find 27 AI professionals per 1 million inhabitants in the EU as per an analysis of LinkedIn data, a number that again varies across the region. Luxembourg is leading in this metric with 115.6 AI professionals per 1 million inhabitants, followed by Finland and Ireland with 59.5 and 59.4 respectively. Bulgaria, Malta and Poland, on the other hand, are lagging behind with 4.3, 4.6 and 6.1 AI professionals per 1 million inhabitants respectively. For comparison, at a global level, Singapore, the UK, US, and Canada are home to 103.7, 50.6, 47.8 and 39.9 AI professionals based on the same data set.

13 Of the remaining 29%, 3% go to work in Canada, 6% in the UK and 20% are not employed yet, currently finishing their graduate programs.

14 Macro Polo (2020): The global AI talent tracker, in: https://macropolo.org/digital-projects/the-global-ai-talent-tracker/ [2 Nov 2020].

15 Hartocollis (2020): 17 states sue to block visa student rules. The New York Times, in https://www.nytimes.com/2020/07/13/us/f1-student-visas-trump.html [2 Nov 2020].

16 Groth (2017): Sorry, congress: the tax bill won't create the jobs of the future. Wired in: https://www.wired.com/story/sorry-congress-the-tax-bill-wont-create-the-jobs-of-the-future/ [2 Nov 2020].

17 Hao (2020): A new $12 billion US chip plant sounds like a win for Trump. Not quite. MIT Technology Review, in: https://www.technologyreview.com/2020/05/19/1001902/tsmc-chip-plant-and-huawei-export-ban-not-trump-win/ [2 Nov 2020]

18 Ott (2018): European chip industry aims to get back on the map. Handelsblatt, in: https://www.handelsblatt.com/english/companies/semiconductors-european-chip-industry-aims-to-get-back-on-the-map/23582014.html [2 Nov 2020].

19 The Economist (2018): Chip wars: China, America and silicon supremacy, in: https://www.economist.com/leaders/2018/12/01/chip-wars-china-america-and-silicon-supremacy [2 Nov 2020].

20 ECSEL Joint Undertaking (2020): Lighthouse initiatives, in: https://www.ecsel.eu/lighthouse-initiatives [2 Nov 2020].

21 European Processor Initiative (2020): EPI, in https://www.european-processor-initiative.eu/project/epi/ [2 Nov 2020].

22 Deep learning or convolutional neural networks is an approach based on layers of artificial neural networks that detect increasingly granular patterns of detail and attach corresponding labels. It is most commonly used in image recognition and supervised learning.

23 Miethke, Rothe, Binninger (2017): Bosch baut Chip-Werk in Dresden. SächsischeSZ, in: https://www.saechsische.de/bosch-baut-chip-werk-in-dresden-3705198.html [2 Nov 2020].

24 Across the EU, member states are home to 7.5 AI researchers on average compared to Singapore (59.2), Switzerland (33.7), US (31.3), Israel (30), UK (22) and Canada (21.9). Within the EU, Malta (34.6), Denmark (21.6), Finland (19.8) and Sweden (18.4) are leading. In terms of total numbers of AI researchers, Germany is topping the list, given the UK has left the EU.

25 General Secretariat of the Council (2020): Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020). Page 5, 18, 20. European Council, in: https://www.consilium.europa.eu/media/45109/210720-euco-final-conclusions-en.pdf [2 Nov 2020].

26 For example, the IoT, advanced analytics and artificial intelligence, augmented virtual reality and wearables, advanced robotics, and 3D printing.

27 US (100), Israel (95), Japan (79), UAE (77) Singapore (76), Canada (65), India (61), China (56) and South Korea (56).

28 Average answer to the question: In your country, to what extent do companies invest in emerging technologies (e. g. Internet of Things, advanced analytics and artificial intelligence, augmented virtual reality and wearables, advanced robotics, 3D printing)? [1 = not at all; 7 = to a great extent] | 2017–18 weighted average. Source: Schwab (2017): Executive Opinion Survey 2017: The global competitiveness report 2017-2018. World Economic Forum, in: http://www3.weforum.org/docs/GCR2017-2018/eos2017_questionnaire.pdf [2 Nov 2020].

29 Mazzucato (2013): Government-investor, risk-taker, innovator. TED, in: https://www.ted.com/talks/mariana_mazzucato_government_investor_risk_taker_innovator/discussion [2 Nov 2020].

30 McKinsey & Company (2018): Government 4.0 – the public sector in the digital age, in: https://www.mckinsey.de/publikationen/leading-in-a-disruptive-world/government-40-the-public-sector-in-the-digital-age [2 Nov 2020]. OECD (2017): Government at a glance 2017. OECD Publishing, in: https://www.oecd-ilibrary.org/docserver/gov_glance-2017-enpdf?expires=1600781962&id=id&accname=guest&checksum=9339163D5F129BD544B854D8DF0C749D [2 Nov 2020].

31 McKinsey & Company (2018): Government 4.0 – the public sector in the digital age, in: https://www.mckinsey.de/publikationen/leading-in-a-disruptive-world/government-40-the-public-sector-in-the-digital-age [2 Nov 2020].

32 Barbaschow (2018): e-Estonia: What is all the fuss about? ZDNet, in: https://www.zdnet.com/article/e-estonia-what-is-all-the-fuss-about/ [2 Nov 2020].

2. Summary of the EU's AI strategy

The US and China lead the global "AI race," but other countries have started to promote AI as a national priority. While some countries in Europe, such as the UK, France and Germany have a foundation in place to build AI capabilities for the economy and society, the EU as a whole faces the imminent risk of falling behind due to the weak AI ecosystems in many member states. Some influential voices see no hope at all for the continent's AI sector.[33] Against this background, and building on strategic initiatives by EU member states, the European Commission under the new President von der Leyen declared AI a priority and released a range of policies designed to make "Europe fit for the Digital Age." This chapter provides an overview of the national AI strategies and EU policy documents, before concluding with an assessment of the EU's strategic options for global AI competition.

2.1 Similarities and differences of national AI strategies in the EU

As of February 2020, 15 EU member states (including the UK) had followed the call of the EU and published a national AI strategy. All other member states are in the process of finalizing and publishing their strategies.

All national AI strategies agree to some extent on the geopolitical importance of AI,[34] but they diverge on whether to approach AI in a holistic manner or to focus on specific sectors. Of the existing AI strategies and drafts, ten are more refined, avoiding approaches that would spread state efforts too thinly, and explicitly identifying or highlighting priority sectors in which AI should be fostered. The healthcare sector receives the most attention,[35] followed by transportation and energy,[36] agriculture and public administration,[37] and industry and manufacturing.[38] However, it should be noted that the EU is better equipped to tackle some areas than individual governments. While transportation, energy, agriculture and mobility are key areas for the EU administration, healthcare and public administration are very much country specific and therefore require national rather than EU approaches. Defense and security on the other hand only appear in the French AI strategy. The French Ministry of Defense underlined the importance of AI for the military in early 2018, when it announced plans to invest €100 million per year in AI research.[39] Although several European projects are developing AI-enabled defense technologies, Europe's political and strategic debate on AI-enabled military technology is underdeveloped. This leaves the EU at a strategic disadvantage, considering that the debate about the ways in which AI might change warfare and military organization is at an all-time high in the US and China.[40] Given reports of significantly increased AI investments by those governments, we can expect these dynamics to remain in place for the foreseeable future.

Looking more at the detail, the existing strategies and drafts, these details tend to focus on two of the three requisite pillars – talent, data, and computing infrastructure – and how they support the development and deployment of AI on a national scale. While most plans tend to promote talent development and encourage open access to data, they generally fall short in support for much-needed advances in computing infrastructure. Current versions seek to promote a digital society by enhancing student and professional training, providing models for data sharing, fostering research, increasing permeability between research and companies, supporting commercialization through the private and public sector, and providing a conducive yet human-centered governance and regulatory framework. Various forms of massive open online courses (MOOC), as piloted in Finland ("Elements of AI"), have been adopted in Belgium, Estonia, Hungary, Latvia, Malta and the Netherlands, among others. In the hope of increasing permeability between research and the private and public sectors, the idea of "innovation vouchers" has found its way into a number of different strategies, putting a focus on small and medium-sized enterprises (SMEs) and startups – the latter with a view to market access and capital. While many strategies reflect a commitment to open data, there is a range of ideas on data-sharing agreements for data exchanges, data markets, data trusts, and measures to increase the interoperability or API standards – with some countries yet to take a view. For example, Latvia plans to conduct a survey of practitioners to understand data needs. The Dutch strategy foresees the compilation of an inventory of data-sharing mechanisms. However, virtually all the national strategies lack sufficient consideration of critical computing infrastructure needs, which are either neglected or limited only to references to EU initiatives (e. g. the €1bn European High-Performance Computing Joint Undertaking, Euro HPC[41], and the European Open Science Cloud[42]). Some versions note national supercomputer initiatives (e. g. the Spanish Super Computing Network of 13 supercomputers, France's plans to invest €115 million in a new supercomputer, or the €18 million supercomputer developed at SURF in the Netherlands). Others focus on improving 5G coverage – another computing-related issue that made the headlines in 2019, as it unveiled the dependency of Europe and even the US on technology components from China.

ZOOM OUT – Brexit: Strong implications for flows of data and talent

In many regards the UK provides a more attractive environment for AI talent, R&D and commercialization than any of the EU member states. Since 1996, AI-related research publications from the UK have exerted greater influence on the field than work from any other EU member state. Of the USD 302 billion in venture investments to AI startups in the EU and the UK between Q1 2016 and Q1 2020, companies located in the UK's startup hubs received USD 120.5 billion. Beyond startup funding, the UK has produced the most successful startups, further cementing its draw for AI development and talent. Among London's big names in AI are companies like the USD 600 million-backed Improbable; recently minted unicorn BenevolentAI; Ocado, arguably the most advanced logistics AI firm after Amazon; and the Alphabet-owned algorithm-builder DeepMind, which might employ the world's strongest AI team.

With regard to talent, many of Europe's brightest minds go to the UK for education and employment – an important factor considering the EU's need to fill talent gaps on the continent. In 2017, there were approximately 496,000 unfilled positions in the field of big data and analytics in the EU27. This is set to change. As of June 2020, the UK announced that EU citizens will no longer qualify for home status fees and student loans, meaning a possible 60 percent decrease in the number of EU students in the UK. In addition, partnerships defining the rules that govern AI are less likely to move forward. In a speech in summer 2018 at the International Federation for European Law, the EU's chief Brexit negotiator Michel Barnier rejected the notion of anything other than a so-called "adequacy decision" with the UK after its exit. An adequacy decision is an EU mechanism that enables citizens' personal data to flow more easily to third countries, which is how the UK is classified after Brexit.

Recommendation 6 – Establish UK-EU special science and innovation zones. The UK is home to some of the most crucial AI research labs, access to which is critical for the EU to advance AI. The EU on the other hand offers research partnerships and some of the most relevant research funding schemes (e. g. EU Horizon 2020), access to which provides a vital funding stream for ongoing academic and research efforts in the UK. Despite the EU's stance on trade and the likely "hard" Brexit at the end of 2020, science and innovation has not been a controversial subject in the negotiations between the two sides, providing the basis for a special science and innovation zone that would allow collaboration between research labs and startups without legal, institutional or political barriers to the flow of ideas, talent, and investment capital. Those zones should embrace the linkages between the R&D and startup hubs in Oxford, Cambridge and London on one side, and Helsinki, Copenhagen, Berlin, Munich, Hamburg, Paris, etc. on the other, so as to ease the commercialization of R&D. The European Digital Innovation Hub initiative[43] and the FinTech-focused European Forum for Innovation Facilitators[44] could serve as building blocks for such zones.

2.2 An evolving human-centered EU AI policy framework

Amidst concerns that Europe is losing ground, in October 2017 the European Council asked the European Commission to develop a European approach to AI. Building on the "Declaration of Cooperation" signed by EU member states, Norway and Switzerland in 2018, the European Commission issued a communication that contains reflections on the geopolitical importance of AI for Europe's future, as well as Europe's mixed competitive position within the global AI landscape.[45]

The White Paper on AI aims to foster the uptake of AI technologies, underpinned by what it calls "an ecosystem of excellence" that is aligned to European ethical norms, legal requirements, and social values (for example an "ecosystem of trust"). Thus, in contrast to the US and Chinese AI strategies, the EU – in light of its aim to foster "human-centered AI" – pays significant attention to human rights and human and societal welfare, calling for global and European cooperation and a collective commitment to an inclusive, multi-stakeholder deliberation. In this regard, the White Paper is a particularly sensible and clear step on from where the debate started a few years ago.[46] However, at the same time, more needs to be done at both a policy and an implementation level. For example, the White Paper's definition of AI as "a collection of technologies that combine data, algorithms and computing power" needs to be sharpened to include non-data-driven AI and the surrounding socio-technological systems. Also, several experts have questioned the risk classifications of AI systems, noting that the White Paper's current use of only high- and low-risk systems is insufficiently differentiated, lacking nuance. Deliberations regarding the balance between promoting the opportunities of AI and regulating its possible dangers were also the reason why the German government submitted its feedback in June 2020, long after the official deadline. To translate the policy into concrete AI applications and research breakthroughs, the foreseen budget of €6.8 billion for 2021–2027 for Digital Europe, a capacity-building program for AI, supercomputing, and cybersecurity might not be sufficient, considering the cuts to the EU research program Horizon.

Highlighting the importance of data, the European Commission, in conjunction with the White Paper on AI, released the European Data Strategy that plugs into the European Digital Market Strategy and seeks to free up the flow of non-personal data to complement the EU's focus on personal data protections. This shall be achieved by creating a single market around "Common European" data spaces, which would ensure that data becomes available in a responsible and safeguarded manner.

Although the EU's GDPR has succeeded in setting a global standard for data protection, its enforcement and its impact on the digital economy remain a work in progress. Its protection mandate is not sufficiently verticalized to accommodate the experimentation and application design in certain societal or economic sectors, which means its protections are not yet projected out into the market through commercially scalable and privacy-assured data business models. In 2019, the Data Protection Commission of Ireland, where many multinational tech companies have their EU headquarters, received 7,215 complaints, an increase of 75 percent on 2018 (4,113) and up from just 2,642 in 2017, the year before GPDR was introduced.[47] Across the EU's 27 member states, around 300,000 complaints have been filed.[48] However, since 2018, European watchdogs have only levied around €150 million in fines under the regulation, leading Commissioner Vestager to conclude that tech companies perceive the fines as a mere cost of business, rather than them triggering a re-think and providing a redistribution measure to back public funding of AI R&D.[49] While the GDPR has empowered internet users on paper, its implementation has degraded the user experience of many digital services, with few practical means for users to understand and navigate through legal language and few suitable technical solutions.[50] Furthermore, it has created a high degree of legal uncertainty for companies that deal with data, especially new market entrants, and many companies opt to train their AI systems in other countries owing to concerns about violating the GDPR requirements.[51] While large technology companies have the resources to ensure compliance, the costs associated with the GDPR have effectively created a barrier to market entry for smaller digital innovators, consolidating the power of established companies, rather than leveling the playing field. This is a clear warning sign that should prompt a review of the GDPR and the rapid promotion of a uniform, comprehensible legal framework for the handling, transport, storage, and processing of data (whether personal or industrial) – an essential element if Europe seeks to progress its own data economy model.

To address the governance of AI beyond data protection, the EU established a High-Level Expert Group on AI (HLEG-AI) to develop Ethics Guidelines based on the EU's Charter of Fundamental Rights. The Guidelines define "trustworthy AI" applications along three axes: lawfulness, ethics, and robustness. To make the concept more practical, the HLEG-AI translated these components into a set of six requirements that AI systems must satisfy in order to be considered trustworthy:

1. protect human agency and ensure human oversight of their operation and impact;
2. be technically and environmentally robust and safe to use;
3. respect individual privacy and be based on good governance;
4. ensure they are non-discriminatory and fair;
5. protect societal and environmental wellbeing;
6. and be transparent and accountable.

The results of the expert group have received global attention. The public consultation on the Ethics Guidelines on Trustworthy AI resulted in 562 pages of feedback, not only from EU-based national and international companies and organizations but from across the globe,[52] underscoring the EU's convening power and its ability to set AI benchmarks in the fields of regulation and governance. However, as indicated above, there is also a growing sense that, rather than introduce a generic AI regulation, the EU will need to adopt a more nuanced risk approach, possibly one that is technology-, application- or industry-specific. Application-specific regulation, for example, could refer to the regulation of facial recognition technology – there was speculation that the EU would impose a three- to five-year moratorium on this application but this has not been the case.[53] Cases of industry-specific AI regulation based on the Ethics Guidelines for Trustworthy AI have already emerged. The European Union Aviation Safety Agency (EASA) established a task force on AI in October 2018 and has now published its "Artificial Intelligence Roadmap: A human-centric approach to AI in aviation." This sets out a roadmap to autonomous flights and surveys the extensive regulatory changes that are necessary to ensure the responsible and safe use of AI.[54]

DRILL DOWN: The importance of the Digital Service Act (DSA)

The Digital Service Act (DSA), a revision of the eCommerce Directive that has governed online services in the EU since 2000, is likely to become the most ambitious and controversial policy initiative under the umbrella of EU's digital market initiatives, despite having not yet been formally introduced. The Act's core goal is to update pan-EU liability rules for internet platforms, addressing thorny issues such as fake news and illegal content. While the DSA is expected to set the global benchmark for platform regulation, as the GDPR did for data protection, it is likely there will be a lengthy process to reach an agreement, possibly lasting up to five years.

Closely interlinked with the DSA are considerations regarding antitrust regulation reform, an issue that has risen to the top of many agendas in the US Congress as well. In their current form, antitrust regulations still focus on consumer price increases, which are not the driving factor in the digital economy. Technology platform models are based on an exchange of user data for "free services," rather than making their profits from users directly. Combined with the network effects amassed through huge user bases, platform companies, especially in the social media space, have started to monopolize information and attention in addition to market power, increasing the access barriers for new market entrants. In the era of data science, concerns about the diversity of opinions – long the territory of media regulators – become questions of economic and political power. This transformation, combined with antiquated laws, have prompted calls for a review of antitrust regulation as it applies to new models in the data economy. Proponents of antitrust reform, however, have to defend themselves against promoting protectionism.

Recommendation 7 – Seek Indo-Pacific partnerships for governance of AI and the digital economy at large: As a global leader in digital regulation, the EU can take even greater initiative at the government level to protect the liberal world order in the cognitive age. With the US government in retreat globally, the EU needs to seek partnerships to formulate AI standards (e. g. around thorny issues such as facial recognition technology); build audit mechanisms for digital infrastructure (e. g. 5G); and promote greater resource sharing (e. g. with regard to data). These partnerships should begin with India, Australia, Japan, and South Korea – China's neighboring democracies are current frontliners in defending liberal norms and institutions in the power play between the West and China. In the long run, these partnerships should increasingly reach out to the next three billion users in other countries in the Global South, in particular Africa – Europe's neighbor and a growing digital market. While the Eastern European countries have played a sub-

ordinate role in the development and commercialization of AI, they could serve a bridgehead function in this new partnership, especially if it extends to the Global South. Member states in Eastern Europe bring crucial experience in having to make difficult decisions – between economic models (leverage a cheap manufacturing center or transition toward a knowledge-based economy) as well as political models (follow liberal or authoritarian approaches). Hence, they can moderate the EU side of such partnerships, especially with emerging powers like India, many of which are grappling with similarly complex questions.
Recommendations on Partnerships (R3), (R6), (R7), (R9), (R10), (R20)

Recommendation 8 – Promote and enforce user-centric data protection: Despite increasingly sophisticated regulations for the digital economy and data protection, the implementation of these rules often leads to poor user experiences and clunky enforcement, as the GPDR demonstrates. Rather than adding to the regulatory framework, improving outcomes will rely on designing standards that enhance usability and creating enforcement structures that make privacy infringements more than just a "cost of doing business". Efforts to improve the design of data protection could come in the form of incentives for more user-friendly legal language or support for technical solutions that centralize privacy management in user specific privacy charters. As of now, users must manage privacy and data settings across dozens of websites and digital services. Meanwhile, improving enforcement of existing privacy regulations requires a pan-European regulator, rather than national and sub-national authorities. Institutional foundations already exist for a pan-European regulatory body, and a path has already been chartered with the G29 Network (network of Data Protection Authorities) and the European Data Protection Supervisor (EDPS). This will not only improve coordination and enforcement, but also strengthen the EU's voice in digital regulatory matters on a global stage – as of April 2020, 132 countries had data protection regulations in place.[55]
Recommendations on Governance (R1), (R8), (R13), (R18)

2.3 The EU and the global AI competition

Until the EU's AI policies unfold and empower member states to build independent AI capabilities, European countries must ask themselves whether the "third way" model can truly stand on its own or if they must align with a US or Chinese model. Protection and regulation cannot survive without economic projection, so a passive "circling of the wagons" will not generate sufficient economic or societal value to create the kind of growth that Europe's economies need to remain vibrant in the cognitive era. Despite their significant differences in approach, Europe needs to keep the US as its closest and most trusted partner. Due to the increasing penetration of AI in all social and economic areas, the future is not only determined by the actors with AI capabilities, but also by the values of the creators of algorithms and increasingly intelligent machines. Even if the two partners disagree strongly from time to time, nowhere else in the world have two powers as influential as Europe and the US placed equal emphasis on respect for individual freedoms and the transparent rule of law – even if President Trump does his best to undermine it, and President Xi and President Putin do their best to separate them.

In their turbulent history, US institutions have shown remarkable resilience in terms of transparent rule of law, civil liberties, personal choice, and representation and democracy. While the current US government pays lip service to AI ethics, American companies, industry groups, civil society organizations and scientific communities are driving the national and international discourse on AI and ethics, as evidenced by the thoughtful and comprehensive feedback that American actors provided to the consultation on the EU Guidelines on Trustworthy AI and the White Paper on AI (see above). The system of transatlantic institutions and partnerships between academia and business provides a further basis for trustful cooperation – something that will not be easily replaced by China. Despite recent tensions and challenges, research cooperation between the US and Europe has grown steadily since 2003. There is a wealth of framework conditions that guide responsible technology development and deployment, such as the GDPR, which finds a parallel in the Californian Consumer Protection Act (CCPA). All of this is welcomed by the majority of the 727 million internet users on both sides of the Atlantic. Over 535 million of them are concerned about the possible misuse of data by internet companies. This combined number is too large to be ignored by Chinese internet companies looking for global markets, especially since digital power emerges from the scaling of offers and news.

Despite the current rhetoric, these shared values have persisted for most of post-war history in terms of free trade and economic relations. Trade between the US and the EU in 2018, two years after the rise of President Trump, was still larger (USD 1.3 trillion) than US or European trade with China (around USD 737 billion and USD 670 billion respectively). Such considerable economic relations will only benefit from an AI-induced upgrade. It should not be underestimated, for example, that the American success story of "two steps forward, one step back" is beginning to shift and adapt to some of the more EU-centric concerns around data security and data protection. US companies are usually quick to bring new, often immature products to market, and then learn and correct "on the fly". This dynamic lies at the heart of US innovation. Following a series of scandals involving almost all major American technology companies, new regulations and an increasingly skeptical user base are prompting digital companies to revise their approaches and pay more attention to privacy and stakeholder governance. While China has gained advantages in the field of AI applications by virtue of its massive consumer market, applied research and a powerful AI innovation ecosystem, the US still holds the best position from which to bring about the next generation of scientific breakthroughs. The US and the EU must therefore continue to work together if they are to preserve democracy in a global system that is increasingly challenged by less representative systems – especially since new technologies can either support or undermine democratic values.

Recommendation 9 – Establish a Sequential Bridging Model with the US: Despite political differences, it is imperative that both sides of the Atlantic embrace a deeper partnership – with Germany, the US federal government, and the US state governments (especially California) leading. This is rooted in our shared values of community, our democratic legacy, and our enlightenment heritage. We call this a Sequential Bridging Model (SBM),[56] a network of networks around research and commercialization of AI that would grow to include other Western countries, such as Australia, Canada, South Korea or Japan – and eventually serve as a platform for cooperation with China. While generally being open to the large and established tech companies, this SBM would bring together a wide range of small and medium-sized advanced, AI-based platforms to empower local businesses with complementary assets in consumer and enterprise data, IoT infrastructure, automation and manufacturing. Such a network could deal more effectively with antitrust concerns and establish guardrails for data sharing (see Chapter 3.1 Recasting the data economy). American and European academic institutions should serve as cornerstones for this model because they align and complement in ways that promise significant, mutually beneficial advances. Both sides of this transatlantic partnership are already seeking ways to enhance these academic ties, including in ongoing discussions under the umbrella of the EU's multibillion-dollar research program Horizon 2020.[57]

Recommendations on Partnerships (R3), (R6), (R7), (R9), (R10), (R20)

33 Minsky (2018): One former google exec says there's no hope for Europe's artificial intelligence sector. Sifted, in: https://sifted.eu/articles/interview-google-kaifu-lee-ai-artificial-intelligence/ [2 Nov 2020].

34 In particular, France's AI strategy and the EU's White Paper on AI embrace AI as a geopolitical issue.

35 Appearing as priority sector in eight strategies: Healthcare: Denmark, France, Hungary, Italy, Latvia, Lithuania, Poland, and Spain.

36 Appearing each as priority sectors in seven strategies: Transportation: Denmark, France, Italy, Latvia, Lithuania, Poland, and Portugal; Energy: Denmark, Hungary, Italy.

37 Appearing each as priority sectors in five strategies.

38 Appearing as priority sectors in four strategies.

39 Bauer (2018): La défense va consacrer 100 millions par an à l'intelligence artificielle. LesEchos, in: https://www.lesechos.fr/2018/03/la-defense-va-consacrer-100-millions-par-an-a-lintelligence-artificielle-969508 [2 Nov 2020].

40 Brooks (2018): Technology and future war will test US civil-military relations. War on the rocks, in: https://warontherocks.com/2018/11/technology-and-future-war-will-test-u-s-civil-military-relations/ [2 Nov 2020].

Kania (2019): Learning without fighting: new developments in PLA artificial intelligence war-gaming. Centre for a New American Security, in: https://www.cnas.org/publications/commentary/learning-without-fighting-new-developments-in-pla-artificial-intelligence-war-gaming [2 Nov 2020].

41 EuroHPC (2020): EuroHPC: Leading the way in European Supercomputing, in: https://eurohpc-ju.europa.eu/ [2 Nov 2020].

42 European Commission (2020): European Open Science Cloud (EOSC), in: https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud [2 Nov 2020].

43 AI DIH network (2020): Project in: https://ai-dih-network.eu/project.html [2 Nov 2020].

44 Groth and Straube (2020): Analysis of current global AI developments with a focus on Europe, in: https://www.kas.de/de/veranstaltungsberichte/detail/-/content/deutschland-muss-sich-ranhalten-1 [2 Nov 2020].

45 The communiqué called for a "Coordinated Plan on the Development and Use of AI made in Europe," and was complemented by a White Paper on Artificial Intelligence, entitled "a European approach to excellence and trust", the "European strategy for data" and a digital strategy document entitled "Shaping Europe's Digital Future." This set of policy documents is embedded in one of six priority areas for 2019-2024 of the von der Leyen Commission, called "Europe's fitness for the Digital Age", promoting "An Economy that Works for People", and protecting the European way of life, a stronger Europe in the world, and a new push for European democracy where innovation occurs "within safe and ethical boundaries".

46 Cambrian, through the UC Berkeley ecosystem, provided extensive comments to the White Paper.

47 An Coimisiún um Chosaint Sonrai (2020): Data protection commission publishes 2019 annual report, in: https://www.dataprotection.ie/en/news-media/latest-news/data-protection-commission-publishes-2019-annual-report [2 Nov 2020].

48 Manancourt and Scott (2020): Two years into new EU privacy regime, questions hang over enforcement, in: https://www-politico-eu.cdn.ampproject.org/c/s/www.politico.eu/article/europe-data-protection-privacy-gdpr-anniversary/amp/ [2 Nov 2020].

49 Manancourt and Scott (2020): Two years into new EU privacy regime, questions hang over enforcement, in https://www-politico-eu.cdn.ampproject.org/c/s/www.politico.eu/article/europe-data-protection-privacy-gdpr-anniversary/amp/ [2 Nov 2020].

50 European Commission (2020): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Page 10, in: https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf [2 Nov 2020].

51 One example of these uncertainties concerns the separation of personal data. In many cases, personal data is mixed with machine and/or industrial data, making it difficult or virtually impossible to separate out the personal data covered by the GDPR.

52 Including from the World Privacy Forum, International Trademark Association, UNICEF, US based OpenAI, AI Now Institute, Electronic Privacy Center, Intel, Visa and Johnson & Johnson, Japan's Cabinet Office and RikenAIP, New Zealand's University of Otago, Hong Kong's Privacy Commission for Personal Data, Zimbabwe's Standard Association, and China's tech giant Huawei. Source: European Commission (2020): Stakeholder consultation on guidelines' first draft, in: https://ec.europa.eu/futurium/en/ethics-guidelines-trustworthy-ai/stakeholder-consultation-guidelines-first-draft [2 Nov 2020].

53 Chen (2020): The EU just released weakened guidelines for regulating artificial intelligence. MIT Technology Review, in: https://www.technologyreview.com/2020/02/19/876455/european-union-artificial-intelligence-regulation-facial-recognition-privacy/ [2 Nov 2020].

54 European Union Aviation Safety Agency (2020): Artificial intelligence roadmap: A human-centric approach to AI in aviation, in: https://www.easa.europa.eu/sites/default/files/dfu/EASA-AI-Roadmap-v1.0.pdf [2 Nov 2020].

55 The UN Conference on Trade and Development (2020): Data protection and privacy legislation worldwide, in: https://unctad.org/en/Pages/DTL/STI_and_ICTs/ICT4D-Legislation/eCom-Data-Protection-Laws.aspx [2 Nov 2020].

56 A similar model was proposed by the authors of this study (Cambrian) and the organizers of the Transatlantic Sync Conference in November 2019, the first AI conference between Silicon Valley and Germany. Source: Transatlantic Sync (2020): Germany and Silicon Valley: Shaping a shared digital future, in: https://www.transatlantic-sync.com/ [2 Nov 2020].

57 European Commission (2019): Horizon Europe. The next EU research & innovation investment programme (2021 –2027), in: https://ec.europa.eu/info/sites/info/files/research_and_innovation/strategy_on_research_and_innovation/presentations/horizon_europe_en_investing_to_shape_our_future.pdf [2 Nov 2020].

3. Evolving preconditions for AI leadership

Countries that seek to optimize the development, deployment and use of AI systems must promote the availability of and access to data and computing power, and they must regulate to safeguard against the irresponsible use of the powerful AI technologies that researchers, businesses and individual developers create. In this chapter, we will shed light on some of the key trends influencing these factors– the expansion of the digital economy, data, computing power and AI governance.

3.1 Expanding the digital economy – the race for the next 3bn internet users

Despite major technological advances, only 59 percent of the global population actively used the internet as of April 2020, resulting in a potential pool of 3.1 billion people that digital companies can reach as they come online.[58] These future internet users live mainly in the Global South. Despite a lower average purchasing power parity (PPP) per capita, the sheer size of and growth expectations for this untapped market affirms its strategic importance. The UN estimates that more than half of global population growth between now and 2050 will occur in Africa, reaching a total of 2.5 billion people.[59] India's population is expected to overtake China's in 2026[60] and current estimates suggest Nigeria will become the second-largest country in the world behind India by 2100 – making these countries increasingly attractive for technology actors. As author and investor Kai Fu Lee notes: "Whatever company wants to lead in AI and wants to become the next Facebook or Google needs to have a strategy to tap into the markets of developing countries."[61]

This potential has spurred increased attention and investments by entities from almost every global power. The US is leveraging corporate-driven models to get to the next three billion users, through projects such as SpaceX's Starlink, which has launched 60 new satellites to expand the ever-growing broadband mega-constellation.[62] Moreover, since 2015, CEOs of major tech companies such as Facebook and Twitter have visited African nations in an effort to expand their global reach and connect more users.[63] This attention by tech CEOs has also already translated into concrete investments.[64] Google opened its first AI research lab in Africa in 2019, located in Ghana's capital Accra, joining the ranks of Google AI research labs in Tokyo, Zurich, New York, and Paris.[65]

China has sought to reach tomorrow's internet users through a public-private expansion strategy called the "Digital Silk Road".[66] Since 2013, Beijing has signed 173 arrangements with 125 countries (including Italy, Switzerland, and Greece) and 29 worldwide associations, continuously adding to its massive Belt and Road Initiative (BRI).[67] China's infrastructural wings have already spread to Brazil and Cameroon in the form of submarine optical cables, the backbone of the world's internet connectivity, carrying about 95 percent of all worldwide traffic. Through its plans to connect African, Asian and South American countries with new cables, China aims to increase its control over internet traffic and introduce a policy regime for a new world order. In 2018, for instance, the state-owned China Construction Bank funded Huawei's construction of a sea cable that connects Kenya to China through Pakistan.[68] The same year, Tencent, famous for its all-in-one app WeChat, signed partnership agreements with Kenya's biggest payment provider, Safaricom, to open up direct trading and exchange channels between the hitherto disconnected countries. Going forward, Chinese businesses and tourists will no longer have to rely on a slow, expensive dollar-based transaction infrastructure, effectively replacing the US-based SWIFT transactions with Yen-denominated transactions via Chinese sea cables.

Recognizing its own potential, India has sought to position itself as the "Innovation Garage of the Global South." While it already has established platforms for collaboration with Africa (e. g. through a respective branch of the annual CyFy conference), built a partnership on AI with the UAE, and opened a branch of the World Economic Forum's (WEF) Fourth Industrial Revolution Center in Mumbai, the nation's global ambitions have not yet materialized. One of India's greatest exports – talent – is also one of its biggest obstacles. Of the 22,000 PhD-educated Indians in AI fields around the world, only 1.7 percent have returned to India.[69] While a study suggests that AI has the potential to add almost USD 1 trillion to India's economy in 2035, the country will not realize these gains without an overhaul of academia and education, and ways to retain talent in the country.[70] Nonetheless, in terms of reaching the unserved populations within the country, companies such as Reliance Jio, an Indian telco founded in 2016, show how innovation can quickly bring out the tremendous potential lurking in next-billion-user countries. Jio massively disrupted the Indian telecom market, adding more than 200 million subscribers in two years. Starting to realize its unique position, India has also pursued a digital form of import substitution, opting in July 2020 to ban China's WeChat, QQ and TikTok, the world's most valuable startup and short video content platform. These moves could pioneer an international trend as talks about similar measures emerge in the US.

Meanwhile, Europe remains a key partner for many African, Latin American and Asian governments and export markets, having invested €31 billion between 2014–2020 into the African economy alone.[71] Its emerging initiatives, such as the European Digital Innovation Centers, have not received the same publicity as other initiatives, even though they are part of the European Commission's planned Digital Europe Programme,[72] which looks to invest €9.2 billion in an effort to align the EU budget 2021–2027 with increasing digital challenges. European telecom companies, such as Orange, invested heavily in fiberglass cables, essentially providing the traditional hardware to connect the next three billion users to the internet. The EU also engages in digital diplomacy, having recognized 13 countries globally as providing adequate levels of protection for personal data (as of March 2020), and appointing a number of global ambassadors for the "digital world", notably in Germany and Denmark.

Recommendation 10 – Establish Digital Economy Agreements (DEA) with Key Partners in the Global South. Complementing its ongoing efforts through digital diplomacy, the EU should seek the establishment of DEAs with India, Nigeria and other countries in Africa and the Global South. These treaties could establish digital trade rules and digital economy collaborations between two or more economies. In the case of Africa, such DEAs could link with the recently launched African Continental Free Trade Area. In India, they could link with ongoing AI collaboration programs related to German development cooperation. Through DEAs with key partners in the Global South, the EU can develop international frameworks to foster interoperability of technology standards and systems and support EU businesses, especially SMEs, engaging in digital trade and electronic commerce.

Recommendations on Partnerships (R3), (R6), (R7), (R9), (R10), (R20)

3.2 Recasting the data economy

The digital economy is a major driver of Gross Domestic Product (GDP), but concerns are rising about the effects of digital technologies on privacy and income distribution. Research suggests that the allocation of data in today's digital economy is not optimal,[73] as only a few large platforms have access to meaningful data pools. According to some estimates, 99.5 percent of the data we produce is inaccessibly locked in organizational, application or industry silos.[74] The lack of access to data for non-digital platforms and smaller actors, particularly in the private sector and civil society, limits the ability of many people to participate in digital value creation. The large digital platforms that collect and hold data tend to overuse – and even abuse – the data they have, establishing themselves in oligopolistic market structures driven by reinforcing network effects. A digital platform's success typically requires a large user base to generate the volumes of user data needed to train and develop services, which then attract more users in a virtuous (or not so virtuous) cycle. In most cases, only established platform companies have access to such significant user volumes, which give them an edge over competitors in collecting data and designing attractive services and products. This limits new players from entering and serving markets, but it also tends to isolate data in ways that lead to one-dimensional use cases and limited value. Aside from a suboptimal allocation of data, we also see trust in the digital economy deteriorating. According to a 2018 Pew survey, only 31 percent of Americans aged between 19 and 28 believed tech companies do enough to protect their personal data. According to a 2014 Pew Survey, 91 percent of Americans "agree" or "strongly agree" that people have lost control over their personal data and that privacy has become a primary concern. About 45 percent of internet users are more worried about their privacy now than a year ago, and 37 percent of internet users in the US mentioned that companies collecting and sharing personal data with other companies is their top concern when it comes to their digital life.[75]

The numbers in the EU are similar, prompting a growing number of experts and organizations to call for a new data-economy model. Indeed, several national data and AI strategies seek to address this issue (see Chapter 2.1). However, we also see new private-sector approaches to data privacy and data sharing emerging. One particularly disruptive model revolves around the idea of data marketplaces, which aims to make user data tradeable while assuring and establishing a value for individual data privacy. A trusted and transparent marketplace would give data creators (i. e. everyday internet users) a new source of income, and it would allow startups to make data collection a mere cost item rather than a cumbersome strategic exercise. End users could share or trade data through the marketplaces in a series of trade-offs between privacy and economic benefits, essentially choosing the price at which they are willing to share different types of personal data. Such marketplace trade-offs are far more difficult for companies, however, especially since most established businesses associate data sharing with compliance risks and a loss of competitive advantage. Cracking this challenge and facilitating the collection of data from businesses to train B2B AI-powered solutions has stoked discussions in tech companies and governments alike. Microsoft, Adobe and German SAP, for example, have partnered to form the Open Data Initiative, a business initiative that offers AI-assisted data lakes to client companies, which can access broader sets of data to reap unrealized benefits from resources they already had[76]. Amazon is leveraging its position as the world's largest cloud provider by facilitating data exchanges between organizations and with individuals.[77] Most recently, companies in the EU – primarily 11 German and 11 French firms, as of June 2020 – joined forces to build GAIA-X[78]. This European cloud storage network creates a new gold standard for the industry, strengthens European data sovereignty, and builds the infrastructure for a collective European data market.

However, data marketplaces are not the only proposal put forward to establish a better allocation of data and spur growth in the digital economy. Tim Berners-Lee, the inventor of the World Wide Web, is creating a new data infrastructure called Solid. In his model, platforms don't actually host all of the data, but serve as mere registries that interconnect individually stored (and still personally owned) consumer data. One key advantage is the prevention of vendor lock-in, which shifts negotiation power to the individual rather than the platform.[79] However, giving individuals power over their individual data doesn't mean they will use it. End users might refrain from exerting their ownership rights, feeling it is a hassle or not seeing enough economic potential to make the effort worthwhile. The UK Research and Innovations (UKRI) funds have backed a similar approach, but one that adds some third-party facilitation. The application, called Databox, proposes technical and legal solutions to data sharing, rather than the pure architectural innovation suggested by Berners-Lee. Databox users would contribute to a sort of consumer data trust, which aggregates consumer information on an independent platform, allowing for a secure and conscious supply of consumer data and redistributing the power between end-users and platforms.[80] Currently, platforms host the data, leaving consumers entirely out of the loop. Marketplaces and models like Solid and Databox keep data hosting under the control of the individual or an independent party, making platforms dependent and, thus, ready to negotiate.

Recommendation 11 – Foster experimentation with data marketplaces. The need for a new data economy model is imperative for digital business and human growth. In their national AI strategies (see Chapter 2.1), EU member states contemplate different ideas for fostering data exchange between individuals and companies, possibly building on a European cloud-infrastructure that is based on GAIA-X and the European Cloud Initiative. Observing and learning from these experiments will allow the EU to complement the idea of common data spaces[81] with market mechanisms that create incentives for companies and individuals to share data in ways that ensure privacy and trust. Encouraging further experimentation with data sharing mechanisms will also require the establishment of digital sandboxes that are overseen or coached by EU data experts who can give companies the advice and assurance that their data-driven innovations are in line with relevant regulations. By spearheading the piloting and introduction of a new data economy model – one that creates a more optimal allocation of data value through innovative data exchange mechanisms – the EU can solidify its role as an advocate for a free market economy and more balanced regulatory approaches for breaking up the power of platform companies.
Recommendations on Commercialization (R5), (R11), (R12), (R17), (R19)

3.3 Hardware innovations and the next frontier of computing power

Despite the strategic importance of computing power, the subject is often marginalized in conversations about AI promotion. However, a number of simultaneous trends will likely shape – if not disrupt – current computer technologies, including cloud computing and advanced chip design. Driven continuous evolution in efficiency and effectiveness in the semiconductor industry, we increasingly see a shift in paradigms from processing data and algorithms through the cloud to processing directly on end devices – a phenomenon dubbed "edge computing".[82] This has become possible in a wider variety of use cases because semiconductor companies have squeezed more power into smaller chips – and thus more power into common industry or consumer devices. Application areas for edge computing can mainly be found in the industrial space (e. g. transport and logistics), smart homes, healthcare, and smart city applications (e. g. traffic management or public security).[83] Given the overlap with many of its existing industrial and economic strengths, the EU has identified edge computing as a pillar for its AI ambitions, through which it aims to harvest business and industry data.[84] Despite a volume of USD 3.5 billion in 2019, the edge computing market is still nascent and set to grow by 37 percent on average between 2020 and 2027.[85] While edge computing holds promises, it also implies risks, not the least in relation to privacy and security. Every network endpoint (i. e. computer, smartphone, printer, WIFI router, even smart toothbrushes) is at risk of being hacked – concerns have given rise to investments in ways to secure edge computing and launch a new cybersecurity market.

ZOOM OUT – AI in cybersecurity, a double-edged sword

The more AI is directly deployed and actively advises or makes decisions, the more it will become the target of cybersecurity attacks, making reliable security crucial. Attacks can take the form of direct manipulation of the engines themselves or the feeding of misleading data to generate malicious patterns. Cybercriminal activity, in general, has increased by 67 percent over the last five years, with an average cost to each surveilled company of USD 13 million in 2018, an increase of 12 percent on the previous year, according to Accenture. While AI is being used for cybercrimes (e. g. bots or deep fakes), the technology itself also is the most promising technology to counter cyber criminality, with savings after the deployment of USD 11 million second only to security intelligence and the sharing of threats. Nonetheless, it is also the least applied technology to date, with 38 percent adoption in companies, ranking higher only than policy automation and analytics, two technologies that form the basis for AI.

However, instead of continuing the head-to-head race between black hat and white hat hackers that came to light when high stakes data leaks occurred, security by deliberate design is moving into focus. Most noteworthy are advances in blockchain and federated learning. Blockchain infrastructure can accelerate the R&D of AI models. Firstly, when a trustworthy track record of each individual contribution to a research project is stored online, the sharing, deployment and commercialization of AI models can be substantially increased and enhanced. Secondly, federated learning, allowing the deployment of an AI model on decentralized, sensitive and protected data, allows the utilization of AI on smaller datasets, without the need for prior aggregation. It also allows the processing of incredible amounts of data, each done locally, eliminating the need for one central high-utility computing center, all the while providing data security by design. On an international level, Europe ranks highest among the world's regions in terms of cybersecurity preparedness, stemming from much regulatory awareness, frameworks and guidelines. However, on a country level, Germany and Estonia (as the EU's best) both rank 5th, behind the USA, Canada, Australia and Malaysia. Finally, while IT Security "Made in Germany" is arguably a household name, effective measures are lagging behind, especially in the public sector, as made obvious by the 2018 hack advent calendar.

While today's race for market share in the chip industry is dominated by US and Asian power houses (see Chapter 1.3), it is worth looking at the next generation of computing chip design. Two rival technologies, which do not rely on the same core chip design, are gaining ground: neuromorphic computing (NC or Spiked Neural Networks) and quantum computing (QC).[86] Neuromorphic computing, which seeks to simulate human brain activity, could deliver a long-awaited technological leap toward a more efficient and "human" form of computation.[87] While it will in theory help to close the gap between machine and human cognitive processes, it remains in the fundamental stages, residing mainly in US private-sector and academic research labs. IBM's Watson has been pioneering this field, with Intel following closely with its NC chip designed to identify smells. But promising competitors can also be found in Europe with the Human Brain Project (HBP), a collaboration of universities and private researchers. Driven by both the biology and the computer science fields, the initiative is tasked with breaking the last digital barrier – thought by some experts to be the key to creating artificial general intelligence (AGI).[88]

The more immediate breakthroughs, however, will likely come from QC. Although still currently outside the planning horizon of most enterprises, QC could have strategic impacts in key businesses or operations. Recognizing the strategic importance of QC, the US White House called Quantum Information Science the "next technological revolution" in 2018[89] and placed "American Leadership in Artificial Intelligence, Quantum Information Sciences, and Strategic Computing" second on its list of R&D priorities for 2020, trailing only the "Security of the American People."[90] In 2020, the administration repeatedly ramped up funding, reaffirming its commitment to R&D of non-defense related AI and Quantum Computing Information Systems, approving almost half a billion dollars, and planning to increase the budget in 2021 to USD 1.5 billion for AI and USD 699 million to build its own quantum internet network.[91,92] While China is generally struggling to establish itself in fundamental research, it has achieved critical milestones in the quantum computing space, including the launch of the first quantum satellite in 2016 (a satellite using quantum entanglement as a means to hyper-secure communication across the 12,000 kilometers distance to earth)[93] and the establishment of a quantum network between Beijing, Shanghai and the satellite – a similar communication network establishing proof-of-concept for a "quantum-based internet"[94]. Key to achieving "quantum hegemony" – a national goal embraced by the Chinese leadership[95] – is also a reportedly USD 10 billion investment to build the National Laboratory for Quantum Information Sciences in Hefei.[96] The EU also recognized the strategic importance of QC, releasing a Quantum Manifesto in 2016[97] that served as a precursor for the "Quantum Technologies Flagship" announced in January 2020 by the new European Commission.[98] The initiative aims to shape Europe's quantum ecosystem over the next 10 years with a total budget of €1 billion. While the funding is significantly below the funding levels in the US and China, the European efforts could succeed based on close collaboration between scientific fields and international research cohorts – assuming coherent leadership execution, something the EU has struggled with in the past.[99]

Recommendation 12 – Governing hardware success to make, rather than buy, the AI infrastructure of the future. The race to lead the next 20 years of widespread AI deployment and use will be decided in the field of edge computing. As of today, Europe has left most of this market to non-European entities. Contrary to the purely science-focused pioneering mission of ECSEL (Electronic Components and Systems for European Leadership) and EPI (European Processor Initiative), the EU should not only aspire to research the best possible devices, but also to manufacture them for the best domestic market fit – perhaps through a CERN-like compute design and development hub as part of a renewed transatlantic partnership (see Chapter 2.3). By focusing its efforts on applicability and best-in-class edge devices, the EU can secure the critical hardware infrastructure in, for instance, automotive manufacturing and the underlying connectivity of emerging Industry 4.0 applications. Such infrastructure will in turn facilitate the development of increasingly advanced technologies, including QC, neuromorphic computing, and Brain-Computer Interface (BCI) systems. However, the creation of these manufacturing platforms will entail significant R&D costs, and it is likely that the benefits be limited to private entities if they are funded and spearheaded by private contributors. Public aegis, or at least governance, of these new technologically superior infrastructures must be the bedrock of any development.

Recommendations on Commercialization (R5), (R11), (R12), (R17), (R19)

3.4 AI Governance, beyond AI ethics and compliance

With steadily improving AI capabilities, the need for governance and regulation has quickly become a matter of consensus among policymakers and academia. Since 2014–15, private companies, research institutions and public sector organizations have issued more than 84 principles and guidelines for ethical AI,[100] with most government-driven initiatives coming out of Europe and Canada, and most civil society and industry-driven initiatives emerging in North America. One of the most recent and widely acknowledged set of AI principles was published by the OECD in May 2019 and has been adopted by 42 countries.[101]

These ethics principles have provided important "North Stars" for AI governance, allowing the emergence of a consensus around a number of central themes, including privacy, accountability, safety and security, transparency and explainability, fairness and non-discrimination, human control of technology, professional responsibility, and promotion of human values.[102] However, research shows that they have had a limited effect on decision making when it comes to the actual design of algorithms,[103] underlining the growing awareness that AI ethics principles are insufficient to shift paradigms in AI product development. Thus, the global debate on AI ethics has reached a stage at which companies and governments now need to translate AI ethics principles into actionable governance structures and systems, finding answers not to "what" is needed in AI governance but "how" it can be implemented.[104]

On the policy side, the World Economic Forum pursues this approach by promoting the concept of "agile governance,"[105] which aims to reshape existing technology policy development processes by incorporating a design thinking approach and making use of a whole spectrum of policy instruments – including laws, investment incentives, standards and certification, and regulatory sandboxes. Agile governance follows a pattern of research, ideation, testing, prototyping and other cycles in small test settings before scaling successful applications. At the level of implementation within organizations, it is increasingly understood that AI governance needs to address four dynamics:

1. data sourcing and cleaning;
2. machine learning models;
3. societal impact; and
4. organizational oversight. (See box below.)

The recognition of responsible technology as a key differentiating feature, rather than merely as a compliance issue, has driven more companies to pay greater attention to AI governance. Companies such as Microsoft and Apple have taken prominent stands on responsible, fair, and secure data technologies – in stark contrast to the oft-criticized approach to data privacy and utilization by Google and Facebook (e. g. the Cambridge Analytica scandal). In 2019, Apple changed the underlying architecture of its voice assistant "Siri" to a technique called federated learning, which deployed the actual machine learning inference right on the phone, rather than in the cloud, thus proving the concept of data security-by-design. Put simply, data that never makes it to the cloud, but remains with its owner, cannot be appropriated or stolen in hacks that typically target huge aggregations of centrally stored data. Similarly, privacy-by-design products serve an increasing market demand in response to continuing data leak and misuse scandals. In 2019, Deutsche Telekom launched its data-secure smart assistant "Hallo Magenta." Leveraging the EU's reputation for its focus on data privacy, the demand for "Hallo Magenta" outstripped supply only a short while after the product release. While quantifying the specific market trends for products with privacy at their core is difficult, the introduction of CCPA, GDPR and HIPAA[106] have prompted data-protection market projections that show an increase from USD 57 billion in 2017 to USD 198.6 billion by 2026.[107]

DRILL DOWN: Governing the value creation of AI-powered products and services

Data sourcing and cleaning: Machine learning algorithms can be very good for inferring the relationship between variables in a dataset, allowing data scientists to predict, prescribe or optimize a target variable. However, such predictions are inherently based on relationships within the dataset. If there are systematic biases or injustices in the past data, a machine learning algorithm will include and possibly amplify them. A company in search of top-notch managers might design a machine learning model that predicts the qualities of top corporate executives, but the model might recommend that the company hire nothing but Caucasian men from economically advantageous backgrounds, simply because this is one of the clearest patterns in the historic dataset.

Machine learning models: Even in data sets with little bias, AI systems themselves can lead to discriminatory predictions or recommendations, which makes it important for any AI governance process to also audit the machine learning models. Machine learning uses statistical models to recognize patterns in data (input), to predict events or to prescribe actions (output). Those models are usually based on the creation and selection of features, stemming from the engineers' understanding and framing of the problem. Unequal access to digital skills has resulted in a mostly Caucasian and male group of high-level computer scientists who reinforce a small set of conscious or subconscious biases.

Societal impact: An AI system working well and relatively bias-free at a technical level can still lead to unintended impact if the creators fail to understand second- and third-order effects of the system. The consequences can be observed in frequent headlines about ethically and morally questionable actions by tech companies. High-profile cases of fraud and ethical violations are of a different quality in the tech space, as AI obfuscates and modularizes processes to the point where a single human cannot comprehend an algorithm's performance at all possible scales and in all potential scenarios. One notable example is the Centrelink debt recovery scandal, in which a revamped government benefits system in Australia replaced manual compliance checks, forcing many vulnerable Australians into a difficult process to prove their eligibility for much-needed welfare support. The "political disaster" that Centrelink caused continued into 2020, underscoring the need for organizations – public and private alike – to consider the far reaching implications of the AI systems they develop and deploy. Hence, to ensure healthy economies and societies, AI governance should include requirements for societal impact tests – using the principles of system mapping, for example – to anticipate unintended second- and third-order effects.

Organizational oversight: Ensuring that the above-mentioned safeguards are established and operationalized requires oversight processes and structures at the organizational level. As a new domain that requires close governance, AI presents an opportunity to re-think organizational governance as a whole. Aside from the design of guidelines, staff training, the introduction of new positions such as ethics architects and external oversight bodies, one emerging approach is to integrate "nudging" into governance design. This feeds off behavioral economics insights that show rules and training programs often fail to produce the desired change because humans are not rational beings and do not adapt behaviors in response to new rules or knowledge. Nudging often works better.

Recommendation 13 – Set deep tech standards and benchmarks for the operationalization of AI ethics and promote responsible tech through an "AI TüV" for ethics certification.
Considering the so-called "Brussel's Effect"[108] and the EU's expertise in shaping international standardization regimes, the region is well-positioned to shape the tech standards for the next generation of the digital economy. The EU has already proven itself as an international standard-setter for data protection and guidelines for ethical AI, but this can only be the first step. Now, operationalization of AI ethics is required, spearheaded by companies that see AI ethics and data protection not only as a mere compliance issue, but also as a key business differentiator. Building on the EU's experience in consumer protection, for example through certification processes and labels for ecological products or responsible supply chain management, the EU has the tools to develop trusted certificates or labels that inform users about the responsibility of technology products and services. Such a certification could help consumers make informed decisions and thus create incentives for companies and organizations to operationalize their AI ethics principles. Labels could be awarded by an audit and certification body modelled after the US Food and Drug Administration (FDA), which assesses and approves drugs before they are released to the general public.[109]
Recommendations on Governance
(R1), (R8), (R13), (R18)

58 Clement (2020): Global digital population as of July 2020. Statista, in: https://www.statista.com/statistics/617136/digital-population-worldwide/ [2 Nov 2020].

59 The Economist (2020): Africa's population will double by 2050, in: https://www.economist.com/special-report/2020/03/26/africas-population-will-double-by-2050 [2 Nov 2020].

60 Our World in Data (2020): Research and data to make progress against the world's largest problems, in https://ourworldindata.org/ [2 Nov 2020].

61 Lee (2018): AI Superpowers: China, Silicon Valley, and the New World Order. Houghton Mifflin Harcourt, in: https://www.amazon.de/AI-Superpowers-China-Silicon-Valley/dp/132854639X [2 Nov 2020].

62 Thompson (2020): SpaceX to launch next 60 Starlink internet satellites today. Here is how to watch live. Space, in: https://www.space.com/spacex-starlink-5-internet-satellites-launch-webcast.html [2 Nov 2020].

63 Kenya (Nadella 2015, Chesky 2015, Zuckerberg 2016, Ma 2017); Ethiopia (Dorsey 2019, Ma 2019); Rwanda (Ma 2017 and 2018); Tunisia (Brin 2018); Ghana (Dorsey 2019, Ma 2019); Togo (Ma 2019); and Nigeria (Zuckerberg 2016, Pichai 2017, Dorsey 2019, Ma 2019). Cuvellier (2019): Tech giants' visits to African countries. Twitter tweet Dec. 10, 2019, in: https://twitter.com/Cvllr/status/1204367469030367232 [2 Nov 2020].

64 Dorsey (2019): Tweet Nov. 27, 2019, in: https://twitter.com/jack/status/1199774792917929984 [2 Nov 2020].

65 Adeoye (2019): Google has opened its first Africa Artificial Intelligence lab in Ghana. CNN, in: https://edition.cnn.com/2019/04/14/africa/google-ai-center-accra-intl/index.html [2 Nov 2020].

66 In 2016, the Chinese Academy of Sciences set up two provincial exploration habitats in Hainan and Xinjiang as a feature of a "Computerized Earth under the Information Silk Road" activity to assemble space-based remote detecting information for various tasks under the BRI, especially in South and Southeast Asia. Simultaneously, Chinese ventures have been advancing the development of Beidou#, a Chinese-developed, worldwide satellite route framework, GPS equivalent that will increase China's surveillance and military capabilities.

67 Dann, Lubig, Schmand, Xiong (2019): China's belt and road initiative: A guide to market participation. Deutsche Bank, in: https://cib.db.com/docs_new/DB_Belt-and-Road_Report.pdf [2 Nov 2020].

68 Converge! Network Digest (2018): China funds peace subsea cable from Pakistan to Kenya, in: https://www.convergedigest.com/2018/01/china-funds-peace-subsea-cable-from.html [].

69 Dewan (2019): In the race for AI supremacy, has India missed the bus? The Economic Times, in: https://economictimes.indiatimes.com/small-biz/startups/features/in-the-race-for-ai-supremacy-has-india-missed-the-bus/articleshow/69836362.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst [2 Nov 2020].
Wheeler (2020): China's Digital Silk Road (DSR): the new frontier in the digital arms race? Silk Road Briefing, in: https://www.silkroadbriefing.com/news/2020/02/19/chinas-digital-silk-road-dsr-new-frontier-digital-arms-race/ [2 Nov 2020].

70 Menon, Vazirani, Roy (2017): Rewire for growth: Accelerating India's economic growth with artificial intelligence. Accenture, in: https://www.accenture.com/_acnmedia/PDF-68/Accenture-ReWire-For-Growth-POV-19-12-Final.pdf#zoom=50 [2 Nov 2020].

71 European Commission (2018): State of the Union 2018: Towards a new 'Africa – Europe Alliance' to deepen economic relations and boost investment and jobs, in: https://ec.europa.eu/commission/presscorner/detail/en/IP_18_5702 [2 Nov 2020].

72 European Commission (2020): Digital Innovation Hubs (DIHs) in Europe, in: https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs [2 Nov 2020].

73 Jones and Tonetti (2019): Nonrivalry and the economics of data. Graduate School of Stanford Business, in https://www.gsb.stanford.edu/faculty-research/working-papers/nonrivalry-economics-data [2 Nov 2020].

74 World Economic Forum (2020): q. Datum: The marketplace for big data, in: https://f69aa27b9b6c6702e27b-ffbfdeddb5f7166a1729dfea28599a63.ssl.cf3.rackcdn.com/raw_54206_15080ceb05f4b9ba9be630b4ccb74c06_qDatum-Presentation-Investors14-PDF.pdf [2 Nov 2020].

75 TrustArc (2016): 2016 TRUSTe/NCSA Consumer Privacy Infographic – US Edition, in: https://www.trustarc.com/resources/privacy-research/ncsa-consumer-privacy-index-us/ [2 Nov 2020].

76 Microsoft (2020): The Open Data Initiative, in: https://www.microsoft.com/en-us/open-data-initiative [2 Nov 2020].

77 AWS Marketplace (2020), in: https://aws.amazon.com/marketplace [2 Nov 2020].

78 GAIA-X (2020): Germany and France take the lead as Europe makes first step towards building a European data infrastructure, in: https://www.data-infrastructure.eu/GAIAX/Redaktion/EN/Press-Releases/20200604-germany-and-france-take-the-lead-as-europe-makes-first-step-towards-building-a-european-data-infrastructure.html [2 Nov 2020].

79 Solid (2020): Home, in: https://solid.mit.edu/ [2 Nov 2020].

80 UK Research and Innovation (2020): Databox: Privacy-Aware Infrastructure for managing personal data, in: https://gtr.ukri.org/projects?ref=EP%2FN028260%2F2 [2 Nov 2020].

81 European Commission (2020): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, in: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1593073685620&uri=CELEX-%3A52020DC0066 [2 Nov 2020].

82 "Edge computing" generally refers to the processing and storing data close to the source in smart devices, rather than in centralized data centers that are spread across the globe, as is the current practice. It is estimated that by 2021, 25 billion things will be connected, creating a wealth of data and increasing demands for processing the data on the devices or nearby. Closer proximity promises lower latency rates, saving response time, bandwidth cost savings as well as data safety and privacy – crucial in autonomous vehicles, precision manufacturing, or healthcare.

83 Grand View Research (2020): Edge computing market size, share and trends analysis report by component (Hardware, software, services, edge-managed platforms), by industry vertical (healthcare, agriculture), by region, and segment forecasts, 2020–2027, in: https://www.grandviewresearch.com/industry-analysis/edge-computing-market [2 Nov 2020].

84 European Commission (2020): White paper: On artificial intelligence: A European approach to excellence and trust. Pages 4 and 8, in: https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf [2 Nov 2020].

85 Fior Markets (2020): Global edge computing market is expected to reach 18.36 Billion by 2027: Fior Markets, in: https://www.globenewswire.com/news-release/2020/06/23/2052306/0/en/Global-Edge-Computing-Market-Is-Expected-to-Reach-18-36-Billion-by-2027-Fior-Markets.html#:~:text=Newark%2C%20NJ%2C%20June%2023%2C,the%20forecast%20period%202020%2D2027 [2 Nov 2020].

86 Quantum physics introduces two specific circumstances: superposition and entanglement. Superposition is the state quantum bit (qubit) that allows it to be not only "0" or "1" (as a traditional binary bit, the basic unit of information in silicon-based computing), but also "0 and 1" as a state in itself. Quantum entanglement is a phenomenon in which two particles are in connected states (the same or opposite), independent from their physical location. These two phenomena allow QC to solve certain types of complex problems that traditional supercomputers cannot.

87 Neuromorphic computing is a chip infrastructure designed based on the human brain's neurons to run AI more effectively. The market of neuromorphic computing in the US alone is expected to grow to USD 6.48 billion in 2024, up from 1.49 billion in 2016.

88 Jilk, Herd, Read, O'Reilly (2017): Anthropomorphic reasoning about neuromorphic AGI safety. Taylor & Francis Online, in: https://www.tandfonline.com/doi/full/10.1080/0952813X.2017.1354081 [2 Nov 2020]. For the definition of artificial general intelligence, see chapter 4.1.

89 Executive office of the President of the United States (2018): National strategic overview for quantum information science, in: https://www.whitehouse.gov/wp-content/uploads/2018/09/National-Strategic-Overview-for-Quantum-Information-Science.pdf [2 Nov 2020].

90 Mulvaney and Kratsios (2018): Memorandum for the heads of executive departments and agencies, in: https://www.whitehouse.gov/wp-content/uploads/2018/07/M-18-22.pdf [2 Nov 2020].

91 A Budget for America's Future (2020): Advancing United States leadership in the industries of the future, in: https://www.whitehouse.gov/wp-content/uploads/2020/02/FY21-Fact-Sheet-IOTF.pdf [2 Nov 2020].

92 Castellanos (2020): White house plans to boost AI, Quantum funding by 30%. The Wall Street Journal, in: https://www.wsj.com/articles/white-house-plans-to-boost-ai-quantum-funding-by-30-11597420800 [2 Nov 2020].

93 Popkin (2017): China's quantum satellite achieves 'spooky action' at record distance. American Association for the Advancement of Science, in: https://www.aaas.org/ [2 Nov 2020].

94 Division of Quantum Physics and Quantum Information (2020): Quantum communication backbone network (Beijing-Shanghai), in: quantum.ustc.edu.cn/web/en/node/350 [2 Nov 2020].

95 Kania and Costello (2018): Quantum Hegemony? China's ambitions and the challenge to US innovation leadership. Center for a new American Security, in: https://www.cnas.org/publications/reports/quantum-hegemony [2 Nov 2020].

96 Katwala (2018): Why China's perfectly placed to be quantum computing's superpower. Wired, in: www.wired.co.uk [2 Nov 2020].

97 Binosi (2016): Quantum manifesto endorsement. Qurope, in: qurope.eu/manifesto [2 Nov 2020].

98 European Commission (2020): Quantum Technologies Flagship, in: https://ec.europa.eu/digital-single-market/en/policies/quantum-technologies-flagship [2 Nov 2020].

99 Kupferschmidt (2019): Europe abandons plans for 'flagship' billion-euro research projects. American Association for the Advancement of Science, in: https://www.sciencemag.org/news/2019/05/europe-abandons-plans-flagship-billion-euro-research-projects [2 Nov 2020].

100 Jobin, Ienca, Vayena (2019): The global landscape of AI ethics guidelines. Nature Machine Intelligence, in: https://www.nature.com/articles/s42256-019-0088-2 [2 Nov 2020].

101 The Observatory publishes practical guidance on how to implement the AI principles, and supports a live database of AI policies and initiatives globally. It also compiles metrics and measurement of global AI development and uses its convening power to bring together the private sector, governments, academia, and civil society.

102 Newman (2020): Decision points in AI governance: Three case studies explore efforts to operationalize AI principles. Center for Long-Term Cybersecurity. UC Berkeley, in: https://cltc.berkeley.edu/wp-content/uploads/2020/05/Decision_Points_AI_Governance.pdf [2 Nov 2020].

103 McNamara, Smith, Murphy-Hill (2018): Does ACM's code of ethics change ethical decision making in software development? Association for Computing Machinery, in. https://people.engr.ncsu.edu/ermurph3/papers/fse18nier.pdf [2 Nov 2020].

104 Newman (2020): Decision points in AI governance: Three case studies explore efforts to operationalize AI principles. Center for Long-Term Cybersecurity. UC Berkeley, in: https://cltc.berkeley.edu/wp-content/uploads/2020/05/Decision_Points_AI_Governance.pdf [2 Nov 2020].

105 WEF (2019): Global Technology Governance: A Multistakeholder Approach. Page 10-11, in: www3.weforum.org/docs/WEF_Global_Technology_Governance.pdf [2 Nov 2020].

106 California Consumer Privacy Act (CCPA), General Data Protection Regulation (GDPR), Health Insurance Portability and Accountability Act (HIPAA).

107 Verified Market Research (2019): Global data protection market size by industry vertical (BFSI, IT and telecom, government and defense, healthcare, manufacturing, and others), by geographic scope and forecast, in: https://www.verifiedmarketresearch.com/product/data-protection-market/ [2 Nov 2020].

108 The "Brussels effect" refers to the way standards set by the EU for, say, cars or chemicals are then adopted globally,

109 Wired (2019): AI algorithms need FDA-styles drug trials, in: https://www.wired.com/story/ai-algorithms-need-drug-trials/ [2 Nov 2020].

4. The next frontier in AI R&D

The vast benefits of AI have yet to be reaped. For the past five decades, AI has cycled between periods of intense hype and the "AI winters" that followed as the technologies failed to reach over-inflated expectations and investment in the field evaporated. Even in the current environment of widespread funding, research and adoption, development remains constrained by the current state of statistics research, the limited understanding of AI technology outside expert circles, and the high complexity of its deployment. Unleashing AI for humanity's benefit will rely on the field's ability to make the technology easier to explain, the introduction of regulatory spheres that ensure transparency and accountability, and the introduction of new approaches to AI's basic underlying mechanisms. In addition to discussing some of these challenges, this chapter analyzes "explainable AI," a crucial sub-field that could help to address many of these barriers.

4.1 Creating and understanding AI or the barrier of contextualization

Over the past few years, AI has arrived in mainstream public debate and stirred a necessary discourse about its potential and its risks. Unfortunately, however, AI is too often improperly described as a "magic" tool or an all-knowing, all-powerful entity that exerts its influence and leaves humans with no power to control it. Luminaries such as Stephen Hawking have fueled this discussion by warning that AI "could spell the end of the human race."[110] Elon Musk, despite having toned down his earlier dire warnings about AI, still says that it "scares the hell out of"[111] him. While AI over the last decade has developed at a breathtaking speed, current AI capabilities remain narrow – each algorithm can only solve one very specific or narrow task. To move from narrow AI to an AI system that can tackle a wider variety of complex problems, and ultimately reach cognitive capabilities similar to or better than those of humans (a state referred to as artificial general intelligence or AGI) will require a solution to a critical bottleneck – causality and an understanding of the relationship between cause and effect.

Contextualization and causality are drivers of human learning. When children drop a toy, they innately understand the cause and effect of that action – let go of an object in mid-air, and the object will drop. While unfamiliar with the physical concept of gravity, they have an inherent ability as human children to grasp the causality. Machines cannot yet understand this concept. In reality, most AI is uniquely trained per task. Once trained in one pursuit, an AI system will need to be retrained and recalibrated to find and apply patterns in a new context, lacking versatility of applications – a difficulty called generalization. Without logical reasoning, effective few-shot learning, long and short-term memory and abstract thinking, AI will remain narrow (or weak) and limited in applications. At present, the field relies on statistics as the primary foundation to make computers act "smart," but building something better will require the introduction of new disciplines. Currently unknown approaches – perhaps based on neuronal hardware – are needed to push today's narrow AI into new dimensions. Regardless of the underlying technology, AI must move beyond models that augment correlation with probabilistic theory in search of something that approximates humans' innate understanding of causation. The common concept of learning in humans and machines – reward and consequence – appears to be reaching its limits in current computer science. Instead, we need a model that grasps the basic truths of our world – a system that doesn't predict based on experience but that, at its core, understands why and how our bodies, thoughts and environment operate. Without such a technological leap, machine learning based on probabilistic models can only solve problems that we can define in a pre-ordained space.

These limitations help to explain the stall in autonomous driving. Although experts have developed vast capabilities for autonomous vehicles, a driverless car needs to adapt to and handle an endless number of scenarios. Detecting a person on a street is easy. Detecting a person, pushing a shopping cart and shielding under an umbrella in the rain is another story. If a car can only recognize a shopping cart and an umbrella, it must understand by causal relation that a person might be standing underneath, even if not visible. Data scientists have tried an array of methods to elevate AI into more sophisticated spheres, but they remain restricted to the mathematical realm of patterns or trial and error, working with matter that understands neither causality, context nor emotions (Chapter 3.4). While those restrictions have limited progress in AI, new machine learning models are starting to push the boundaries of what had previously been impossible (although still relying on probabilistic models). "Emerging transfer-learning" and "few-shot learning" models can complement the three main machine learning models in place today – supervised, unsupervised, and reinforcement learning. While these models will advance efforts to crack the code of causality and enable more human-like learning, they remain probabilistic models that can only augment narrow AI rather than solving the challenge of AGI.

The US DARPA is one of the primary forces behind the push to expand AI capabilities. The agency articulates areas of targeted research that align with the aforementioned obstacles, including: new capabilities (better understanding and easier accreditation of AI systems); robust AI (strengthening models against incorrect predictions or labelling to increase reliability in tactical situations); adversarial AI (protecting AI against attacks driven by manipulated training data and/or exploiting the inherent limitations of pattern recognition by purposefully exposing AI to rigged data); high performance AI (introducing AI that can run on smaller devices but handle less structured data); and its artificial intelligence exploration (AIE) program, which focuses on high risk, high yield research to develop the next-generation technology after machine learning.[112]

Recommendation 14 – Construct a European Center of Excellence atop leading French contextual AI institutes. The French research institutes CNRS and INRIA[113] are the EU leaders in contextual AI, investigating how to break into the next frontier.[114] Centralizing the ownership and guidance of this critical task under the ethical guidance of the AI HLEG would allow the EU to target research on commercially viable solutions (e. g. autonomous driving). This will create push mechanics from the industry to ensure market-focused research that translates into the strengthening of long-term European AI excellence. Beyond the commercial aspects, however, contextual AI as a framework needs to achieve international acceptance. Hence, the EU research center must collaborate with internationally diverse but similarly value-based research centers around the world, like the Alan Turing Institute (UK) and Carnegie Mellon University (US). Strengthening the progress of contextual AI while also defining its boundaries is a culturally sensitive and subjective challenge – one where the strengths of the AI HLEG are needed to complement the strong policy and governance focus of both the Alan Turing Institute and the Carnegie Endowment for International Peace (parent to the CMU). This will untap both the academic and economic potential needed to drive progress at the nexus of various technologies and establish the foundation needed to discover the as-yet-unknown “next big thing”.

Recommendations on Talent and Research (R2), (R4), (R14), (R15), (R16)

4.2 Explainable AI becoming a key research field

Despite still limited capabilities, AI has already become a large part of daily life, and we rely on algorithms every day to perform various tasks quickly and efficiently. Thus, it is imperative that we understand how these algorithms work. This is even more important in times of eroding trust in the digital economy. According to the Global Web Index, 24 percent of global internet users surveyed in 2019 said they do not understand computers and new technology, a rise of almost 15 percent increase on the previous year. Additionally, 74 percent of user across Europe said they think new technologies will do more harm than good, and only 25 percent support the use of AI as part of societal management.

However, explaining AI systems and how they reach conclusions remains a difficult task. When we use AI to tackle larger and more complicated problems, we inevitably encounter a “black box problem” – we can see the input and the output, but cannot fully understand how the system got from point A to point B. Currently, we cannot precisely explain the decisions made by AI applications, especially ones based on unsupervised and deep learning models, because the systems independently adapt their models without human interference. Even if a person could crack open the black box and observe the layers and layers of potentially millions of different nodes and connections, all of them calibrating and recalibrating in real time, the process would be far too complex for the human mind to grasp. As a result, we are left to rely on inherent trust in a largely unknowable system. Explainable artificial intelligence (XAI) has emerged to try to solve this problem. XAI describes a type of AI models that produce output that humans can easily understand. This understanding does not require all AI operators to understand how the model works, but it ensures understanding of the limitations of a result, why the model works and why it does not. XAI serves as an interface between the mechanics of a model and the recipient of its output. The field aims to establish greater trust in AI-powered applications by ensuring that such products comply with regulations, can be audited, are not biased, etc. Generally, XAI is divided into three stages:

1. pre-modelling explainability, which focuses on understanding the data used in the development of AI models;
2. explainable modelling, which involves models that are developed with the purpose of being explainable; and
3. post-modelling, which identifies explanations for previously developed models. In recent years, researchers have focused their studies heavily on the post-modelling explainability of AI.

The leading approaches to create XAI include the DARPA-XAI project, the Local Interpretable Model-Agnostic Explanations (LIME) initiative, and guidance from the UK’s Alan Turing Institute, which introduces processes and guides for AI engineers and providers to ensure the compliance and user centricity of their models (for both completed and new models).[115] Led by these and similar initiatives, research progress in XAI has accelerated rapidly. Google’s recent White Paper on AI Explainability highlights further key advancements. Likewise, researchers are exploring the psychology of explanation, as a successful XAI system must provide transparency and explanations to people that draw on lessons from philosophy, cognitive psychology, human-computer interaction and social sciences.[116]

ZOOM OUT – Beyond Algorithms: Emotional intelligence

Artificial Emotional Intelligence, dubbed as emotion AI or the third wave of AI, can be described as tools that facilitate a more natural interaction between machines and humans. It includes improved algorithms that can gain insights about emotions from analyzing large amounts of data. If a machine can identify emotions by analyzing various inputs, such as image or video feeds, then it is considered an emotionally intelligent machine. This new wave of AI has already been applied in diverse industries and fields, such as advertisement and recommendation engines, mostly to conduct customer research. Other applications have emerged in domains such as call centers, mental health, self-reporting, automotive, and assistive services.

Emotionally intelligent systems often overlap with and complement similar programs that identify very subtle, very human phenomena. For example, the US startup Woebot has developed an algorithmically enhanced application that provides interactive support for mental health patients and, when appropriate, prompts them to participate more deliberately in the cognitive behavioral therapies prescribed by their psychiatrists. Mindstrong Health takes this a step further for patients with severe mental illnesses, who often get caught in a vicious cycle of treatment, release and relapse. By analyzing about 1,000 often-imperceptible markers in how patients interact with their mobile phones, Mindstrong can alert them and their doctors when a relapse appears imminent.

By layering advanced emotional intelligence into these applications, these startups are opening doors for patients to live more fulfilling lives. However, they naturally raise ethical questions about possible abuses and manipulation. The broader use of these systems in new industries and fields has prompted calls for government and industry policies to properly guide users of these systems and ensure they do not harm people. Security and privacy concerns about emotional surveillance have become rampant among users. Combined with developments in the field of Brain Computer-Interfaces (BCI) – technologies that can directly record and stimulate brain activity in humans – artificial emotional intelligence systems could allow for the manipulation of people through personalized targeting (e. g. in the form of political propaganda or as a hacker technique to maliciously acquire personal information).

Therefore, policymakers need to wake up to the advent of the third wave of AI and create policies that effectively curb any potential exploitation. The EU's GDPR labelled biometrics data as personal data that cannot be accessed without first seeking permission. However, while emotions detected from facial images and voice synthesis are covered by this regulation because such data can be used to identify an individual, emotion-based data that does not provide unique identification is currently unregulated. The GDPR and similar regulations should be revised to include bio-sensed data in the definition of biometrics data.

Progress in this field is urgently needed. Many of the controversies that surround sensitive use cases of AI – such as recruitment, credit assessments or predictive policing – could be solved if the underlying AI system would be explainable and, hence, accountable. Solving the AI black box problem would, therefore, unleash substantial digital growth. The policy frameworks have already been put in place. A set of rights introduced through the GDPR relate directly to explainable AI, with an emphasis on oversight for opaque AI systems and protections for EU citizens who might suffer negative impacts from decisions made by such systems. While some companies have bristled against the GDPR, this aspect can help establish some of the primary drivers of widespread AI deployment – including ease of use, an understanding of the technology among the workforce and executives and users who trust AI's implications. Regarding of the technological advancement, the efficiency gains of AI applications will never be fully realized without a solid understanding of each AI-generated output. In this sense, XAI is by its very nature at the heart of the European governance effort to ensure human-centric AI. Indeed, humanized AI has been pioneered in Europe – not by enterprises, but by governance bodies – centering the development significantly deeper in the core of the European market than elsewhere in the world.

DRILL DOWN – What are Brain-Computer-Interfaces (BCI)?

BCI are both invasive and non-invasive tools to record and stimulate brain activity in humans to communicate information. Intersecting AI with edge devices but also interconnecting human communication with these technologies via brain recording and brain stimulation is likely to rearrange completely the technological playing field. The brain is becoming an edge computing device. It and other devices will be communicating with each other at bandwidths of 20 GB/s on a 5G network. Human-to-computer communication (i. e. typing, reading, watching a video) is currently stagnating at 0.63Mbits/s. Uncorking that bottleneck and elevating human-to-human as well as human-to-computer communication will unfold human cognition as the centerpiece of technology in ten years time and beyond. Near-term use cases are of a medical nature, i. e. enabling robotic limbs for patients suffering from cerebral palsy, certain strokes or injuries to the spinal cord. Longer term possibilities, linking to the vision of Elon Musk's BCI company Neuralink, including creating communication channels that allow humans to communicate with computers as fast as they do with each other, essentially allowing humans to up- and download thoughts or content to the and from the internet directly from their brain.

Recommendation 15 – An AI to disagree with – Lead the way toward a human AI symbiosis.
With ISO/IEC TR 24028:2020, the International Organization for Standardization and the International Electrotechnical Commission took a first stab at standardizing trustworthiness in AI. However, similar to the Alan Turing Institute's guide on trustworthy AI, the standard does not include fully scientific, actionable measures.[117] These shortcomings are significant. As long as XAI – which refers to methods and techniques in the application of AI such that the results of the solution can be understood by humans – remains a theoretical exercise, AI will not grow much beyond its current, rather passive form. The challenge of working with AI in real-time is knowing when to disagree. When we enable AI to bring forward results that humans can easily and quickly assess, comprehend and judge – then AI breaks the barrier to actionable functionality. Having realized that, DARPA is focusing on XAI to enable soldiers to judge model output and learn when to trust it. In

a similar sense, the EU must reap the benefits of XAI not only as an interface between a model and a human, but as an interface between theoretical data observations and industry application. Possible applications include assisting structural engineers in onsite assessments, screening terrain and assisting avalanche search parties, as well as bridging the gap between autonomy in driving and the liability and understanding of the in-control human driver. Where humans understand a recommendation, they can build on it – and will never be replaced. Incentivizing EU researchers in practical and industry oriented XAI competitions to build models that solve real world challenges by easing the interface between the model and humans would put the EU in the lead internationally with a practical pathway to explainable AI.

Recommendations on Talent and Research (R2), (R4), (R14), (R15), (R16)

4.3 Taming unfathomable AI through accountability

We have yet to see even the first-order impacts of XAI (e. g. increased commercial AI adoption in companies). The barriers to contextualization, causation and artificial general intelligence remain in place, at least for now. However, none of the breakthroughs in any of these fields will propel AI forward without an overarching framework for accountability. Especially as AI becomes increasingly integrated into human-centered industries, such as health care, people will have more and more urgent questions about the accountability for decisions made by or based on AI systems. Currently, AI models merely guide human doctors, who retain control of diagnoses or treatment decisions for their patients. However, the increasing strain on health care systems, currently exacerbated by COVID-19, underscores a critical need for humans to consider deeper AI integration into their systems. Given rising health care costs, aging societies and global health emergencies, people may need to rethink the luxury of human-to-human treatment. Similar needs arise in mobility, where autonomous systems lead to collisions caused by humans who place too much trust in the AI drive-navigation system, as well as in real estate, where poorly maintained AI systems caused a spike in mortgage prices.[118, 119]

These cases raise questions about accountability when AI-powered systems fail or lead to negative outcomes. Are developers culpable for the systems they create, even if those systems learn, adapt and change over time (as AI systems do)? Can individuals be held accountable for outcomes of the applications they use, even if the world's greatest AI experts can't explain how the system came to its decision? Currently, the acceptance of AI decision making is the responsibility of the respective users. But if users are increasingly passively affected (e. g. as patients receiving diagnosis and treatment plans largely out of their control), the accountability of AI developers – or even AI as an entity on its own – seems increasingly reasonable. However, it is not possible to punish computer systems or hold them accountable for their actions. As human-centered societies merging into a reality where we temporarily cede control over our decision-making to AI applications (e. g. following a navigation system's guidance or treatment recommendation), we face the challenge of an inherently unaccountable actor.

These issues go to the heart of AI's role in society and frame an outlook for the joint future of AI and society – a future shaped on one hand by XAI and a better understanding of AI decisions and their impact, and on the other hand by decision-making agents that by design cannot be held accountable. Thus, legislators need to derive a balance of accountability and responsibility between society, individuals, and the agent (AI) and codify this balance in laws and regulations that will inevitably shape AI's role in our societies and in our lives.

In science fiction and futurist writing one proposed solution to the twin challenges of accountability and contextualization is conscious AI – a system that knows it is a machine and that we are humans. This would require some kind of intellectual representation of the self in machines. However, humans have yet to solve the mystery of consciousness in themselves, let alone articulate it for scientific augmentation. However, reasoning AI, a system that abstractly connects causal relationships, is within the realm of our understanding. We simply have not yet found a language to formulate the questions and seek the answers. These questions and answers could become more apparent with a consolidation of the research sphere. None of the individual machine model types will independently break through to artificial general intelligence. The countries and regions that interconnect their research and applications – both in and adjacent to AI – will generate the critical step forward. We have seen numerous examples of this already. Neuromorphic computing and evolutionary algorithms emerged at the nexus of neuroscience and computer science. By intersecting neuroscience with hardware, brain-computer interfaces have allowed us to communicate directly with brain cells. We can see how, step by step, scientific discovery edges closer to replicating, adopting and eventually replacing human functions. Moonshot projects and million-dollar research programs may make great leaps forward and then suffer huge setbacks, but these are the costs that a society must be willing to pay if it seeks to drive true innovation in AI. For Europe, this is good news. While the US dominates efforts to develop the best tools to find answers to existing problems, European researchers continue their drive toward fundamentally new approaches. Publicly funded, historically proven research centers throughout Europe are well-positioned to search for the next big thing, whatever it might be.

Recommendation 16 – Create the cornerstone for reasoning AI – and scalable applications.
Owing to the high training costs and complexity of the models, AI is costly and therefore has grown to be a means for businesses to protect their markets. The discovery of the next milestones toward better, reasoning AI, edging toward more generally skilled systems, will eventually bring down these costs and thus enable widespread applications, resulting in a scalability of applications that potentially supersedes the soaring power of the current Silicon Valley empires – assuming they don't reach these milestones first. As the challenge concerns the multi-application of systems, the breakthroughs will certainly emerge from places where research spheres interweave. To tackle this ambitious task, the EU must expose researchers to a variety of industries and disciplines, including the medical, industrial, and legal fields, to train a new generation of experts who think holistically and possess a skill set that promotes cross-disciplinary excellence – a critical asset for the EU if it hopes to develop AI models that surpass current limitations. Fully funded residency programs that further interlink the vast but segmented European research space across domains will introduce academic researchers to each other and European industries (and thus increasing talent retention for academia and industry alike). This will align the EU's strong but often disagreeing stakeholders, and foster a generation of holistically and comprehensively educated academic and professionals in Europe, best equipped to build scalable AI.
Recommendations on Talent and Research (R2), (R4), (R14), (R15), (R16)

110 Cellan-Jones (2014): Stephan Hawking warns artificial intelligence could end mankind. BBC News, in: https://www.wired.com/story/ai-algorithms-need-drug-trials/ [2 Nov 2020].

111 Clifford (2018): Elon Musk: 'Mark my words- A.I. is far more dangerous than nukes'. CNBC, in: https://www.cnbc.com/2018/03/13/elon-musk-at-sxsw-a-i-is-more-dangerous-than-nuclear-weapons.html [2 Nov 2020].

112 DARPA (2020): AI next campaign, in: https://www.darpa.mil/work-with-us/ai-next-campaign [2 Nov 2020].

113 Centre national de la recherche scientifique (CNRS) and Institut national de recherche en informatique et en automatique (INRIA).

114 Atomico and Slush (2018): The state of European Tech: Chapter 6.3. Europe is home to the world's leading AI research community, in: https://2017.stateofeuropeantech.com/chapter/deep-tech/article/europes-engineering-engaging-data-science/ [2 Nov 2020].

115 ICO and The Alan Turing Institute (2020): Explaining decisions made with AI, in: https://ico.org.uk/media/for-organisations/guide-to-data-protection/key-data-protection-themes/explaining-decisions-made-with-artificial-intelligence-1-0.pdf [2 Nov 2020].

116 Google (2020): AI explanations whitepaper, in: https://storage.googleapis.com/cloud-ai-whitepapers/AI%20Explainability%20Whitepaper.pdf [2 Nov 2020].

117 Zielke (2020): Is Artificial Intelligence Ready for Standardization?, in: https://www.researchgate.net/publication/341616218_Is_Artificial_Intelligence_Ready_for_Standardization [2 Nov 2020].

118 Wolfe (2014): Driving into the ocean and 8 other spectacular fails as GPS turns 25. The World, in: https://www.pri.org/stories/2014-02-17/driving-ocean-and-8-other-spectacular-fails-gps-turns-25 [2 Nov 2020].

119 Sculley et. al. (2014): Machine learning: the high-interest credit card of technical debt. Google Research, in: https://storage.googleapis.com/pub-tools-public-publication-data/pdf/43146.pdf [2 Nov 2020].

5. Driving forces for the uptake of AI in the economy and society

AI promises benefits for the economy (as captured by the German concept "Industry 4.0") as well as benefits for society at large (as promoted through the Japanese vision of "Society 5.0").[120] However, leveraging AI's potential to drive economic and human growth will rely on active participation from citizens, businesses, investors, governments (as both regulators and users) and civil society. This chapter will focus on four distinct forces that will drive the adoption of AI:

1. the rise of corporate venture capital;
2. the underestimated role of Europe's strength in smart procurement;
3. the emergence of new business models; and
4. the growing potential of AI for public good.

5.1 The changing funding landscape of the cognitive age

Despite falling costs for cloud subscriptions, access to knowledge, semiconductors and almost every other component that goes into an AI system – talent being the chief exception – developing these cognitive machines remains an expensive pursuit. AI enterprise solutions are still largely bespoke, with very few turnkey solutions ready to integrate into any business' IT infrastructure and workflows. AI model creation and deployment is a laborious and costly process, especially when it needs to be tailor-made for each enterprise's needs.[121] For startups in particular, the scarcity of talent, the barriers that block access to sufficiently large data pools, and the uphill battles against cash- and data-rich digital platforms can prove too expensive to overcome (see Chapter 3.1). The same goes for the creation of the data warehouses and data lakes required to train and make AI systems work.[122] Having an engine without any fuel is no use.

Because of the cost hurdles, most non-tech companies focus their investments on low-hanging fruit and narrow use cases. While business leaders acknowledge that AI implementation is crucial for their company's success, few deploy it beyond a small handful of instances. In a 2019 survey, three-quarters of global business leaders said they believed AI had the potential to substantially transform their enterprises within the next three years,[123] but 58 percent of respondents said they had embedded AI functions in only one business unit or function (up from 47 percent the prior year). Less than a third of respondents said they integrated AI in multiple functions or business units.[124] In addition, companies overwhelmingly seek to improve their marketing efforts or supply chain management, rather than explore entirely new business models.[125]

Meanwhile, the funding ecosystem that provides venture capital to AI startups has rapidly expanded and diversified. In 2019, a record USD 26.6 billion was invested across more than 2,200 deals worldwide – up from roughly 580 deals and USD 4.2 billion in 2014.[126] While the EU lags the quantity and volume of funding in the US and China, trade tensions between the two powers could slow investment and innovation. In addition, recent US legal reforms, such as the Foreign Investment Risk Review Modernization Act of 2018 (FIRRMA)[127] and White House decisions that have limited the number of immigrants studying and researching in the US could slow AI innovation and investment there. These and other developments could shake up another maturing trend, albeit one that remains nascent in the EU – corporate venture capital (CVC). Similar to the growth of general CVC, which rose to USD 57.1 billion in 2019 from USD 17.9 billion in 2014, CVC funding specifically to AI startups increased to USD 10.6 billion in 2019, up 71 percent on 2018. While still accounting for the largest global share, CVC in the US and China slowed between 2018 and 2019, whereas in Europe there remains a clear growth trajectory. The number of CVC-backed deals to companies based in Europe grew by 19 percent in 2019, and the total value of these deals increased by 38 percent.[128] This development could be due to the fact that AI and predictive data analytics in Europe are driven more by a strong manufacturing sector with predominantly mid-size and large enterprises.

It has yet to be seen how COVID-19 will impact the availability of CVC. However, it is already evident that the crisis should drive collaboration between larger, well-established companies and smaller, younger firms, especially in the field of AI. As the pandemic recedes, Europe's economies, firms and citizens will urgently need the economic growth that flows from increased regional competitiveness. Looking forward, we believe this need and the upward trend in CVC will merge to propel a concept called "collaborative innovation", which reflects that large incumbent firms can drive growth by investing time, energy and capital in overcoming the limitations of their in-house, captive R&D models. While these internal R&D operations are extremely good at delivering incremental advancement, they struggle to create disruptive products or entirely new markets. Meanwhile, these large firms can help young companies to overcome the constraints of scaling across fragmented markets and accessing venture capital.[129] Considering the economic structure in Europe – with its world-leading SMEs urgently in need of a technological upgrade – the potential of these partnerships to contribute to innovation and growth is particularly high.

Recommendation 17 – Promote "Creative Upgrading" rather than "Creative Destruction."
While traditional venture capital (VC) has a track record in exerting pressure on industries through investments in disruptive startups, CVC aims to upgrade industries internally, without destroying their core businesses. The skills and incentives of both VC and CVC are necessary to overhaul Europe's economies, so policymakers need to look for ways to effectively pair them. This can be achieved through a variety of measures – for example, through tax incentives, publicly backed fund-of-funds structures, or an incentive scheme that encourages partnerships by providing a contingent indemnity for losses from joint investments.
Recommendations on Commercialization (R5), (R11), (R12), (R17), (R19)

5.2 The underestimated role of smart procurement

While CVC allows companies to complement their R&D department's efforts to drive innovation, smart procurement can help foster innovation along their supply chain. However, despite a variety of AI applications designed to optimize various supply chain operations, the impact and implementation potential of AI-powered smart procurement remains vastly underestimated. While most digitization projects start with the upgrading or development of new products and services for customers, purchasing generally plays a minor role, if any. Digital transformation of procurement processes is still stuck in its infancy, despite its enormous potential. It is estimated that fully automated procurement processes could save the 5,000 largest companies up to USD 86 billion annually, but as of 2018, fewer than 10 percent of companies used key technologies in procurement.[130] Considering that the post-COVID era will put Chief Procurement Officers under further pressure to "do more with less", we expect the demand for smart procurement to accelerate.

Compared to other areas, Europe is well positioned to provide solutions in relation to smart procurement. For example, SAP Ariba – which has three times the global transaction count of Amazon and Alibaba combined – offers a Procure-to-Pay suite that supports procurement and supply chain collaboration. In 2019, SAP Ariba was recognized by Gartner as the leader in smart procurement, based on what the research firm described as strong innovation and deep market understanding.[131] European startups have also recognized procurement as a growing market. While it produced less than half the number of North American procurement startups between 2001 and 2017 (172 versus 400), Europe accounted for twice as many procurement startups as China during this period.[132] While the industry is consolidating through incumbents such as SAP Ariba, the number of procurement startups allows companies to explore a wealth of innovation opportunities to improve their performance. Focused startup facilitation within Europe, together with innovation partnerships with and acquisitions of startups around the world by European software and manufacturing companies, could further bolster the continent's competitiveness in this area.

Recommendation 18 – Proliferate smart procurement: Encourage European companies, including the leader SAP Ariba, to create a smart procurement ecosystem of startups that can deliver unique functionality in this space. This work needs to be complemented by efforts from the German Research Center for Artificial Intelligence (DFKI) and its European counterparts to coordinate joint research streams and virtual smart supply chain designs and trials. Also, making smart supplier information as well as financial market trading data (e. g. of future trades) accessible in aggregate will be very useful, not only for training supply chain management AI but also for think tanks and government agencies to understand economic shifts and trends.

Recommendations on Governance (R1), (R8), (R13), (R18)

5.3 Data-driven business model innovation

Most businesses focus on AI deployments that create efficiency gains (see Chapter 5.1 The changing funding landscape), an approach that arises from a mindset of loss-avoidance or cost reduction. Too few companies consider AI as part of a revenue-generating strategy, which is where most business value derives. As this understanding has started to trickle down, we have seen new data-driven business models rather than mere process or product upgrades. These models go beyond the classical business-to-customer (B2C) and business-to-business (B2B) business models in traditional economic sectors. Whether in e-commerce, insurance,[133] marketing or after-market sales in the auto industry,[134] new models have emerged that serve both businesses and consumers simultaneously (B2B2C). At the same time, the growing deployment of blockchains facilitates privacy assured peer-to-peer (P2P) value creation and, in some cases, allows companies to address the innovation needs of governments (B2G). While these acronyms may appear as little more than helpful labels to describe business setups, they indicate a trend toward more dynamic web-based value creation models that supplement the linear models of traditional economies.

The shift toward data-driven business models is already happening, though their success depends heavily on their ability to compete with established tech platforms. While the revision of antitrust regulations (see DSA in Chapter 2.2) and data sharing mechanisms (see Chapter 3.1) could level the playing field, trends in business model innovation support innovators' efforts to reach scale. Traditional B2B or B2C models are inherently linear, with information and physical goods naturally flowing from one entity to another. With the IoT and advanced data analytics as a technological base for exchange, such barriers are broken down in a business model we expect to continue to proliferate: B2B2C. In B2BC settings, company A sells a product or service to a business, gaining customers and/or data from Company b. In turn, company A can keep those customers and/or use that data. The car industry has started to embrace B2B2C setups, which allow original equipment manufacturers to stay in touch with their customers and assets and learn from their data while maintaining their B2B relationships (e. g. with their distribution networks). The same business rationale is easily applicable to a range of other linear industries, including agriculture and medical equipment manufacturing. Thus, done right, B2B2C can be one of the most effective ways to acquire customers and contruct a powerful data moat.[135] As such, it offers a tangible way for EU-based startups to tap into the landscape of established and respected companies across the region.

Until a few years ago, the other key business model innovation, peer-to-peer (P2P) models, only played a niche role. A P2P business employs a decentralized model, whereby individuals interact directly with each other – for example, individuals lending money to one another. Increasingly facilitated by the slow but steady rise in the adoption of blockchain, these business models will not necessarily rely on central stores of data. Although not based on blockchain, one example of a P2P model is embodied in the COVID-19 tracing apps, especially the German Corona-Warn-App, which does not save any user data in a centralized data center. While this model naturally constrains the value that companies can derive from user data, P2P business owners can tap into the growing awareness of customers around data protection and privacy, opening new revenue streams that do not need to rely on the monetization of user data in the first place.

Finally, governments are racing to respond and open themselves up for business with entrepreneurs and innovators, paving the way for B2G and G2B business models that can bring together the speed and ingenuity of startups with public resources and funding.

Recommendation 19 – Facilitate the emergence of B2B2C and P2P business models:
Focus startup support not on the product innovation and application of advanced technology, but more on the changing nature of underlying business models, particularly B2B2C and P2P. Both models address Europe's problem with data access, while also aligning with its emphasis on the protection of the individual. The creation of a White Book by a working group of US and UK business school professors, entrepreneurs and VCs describing best-in-class examples and case studies of successful and unsuccessful models and the subsequent distribution of this White Book to European entrepreneurs could support this trend.
Recommendations on Commercialization (R5), (R11), (R12), (R17), (R19)

5.4 AI for Public Good and the roles of the public sector and civil society

Although AI has existed in some form for several decades, many governments and civil society actors have only paid lip service to the promotion and use of responsible AI for the public good. In that void, for-profit companies became the overwhelming influence on the development and deployment of these technologies, including in the sphere of public goods. Today, the direction of AI advancement for the benefit of societies is driven almost entirely by private-sector firms, including Google's AI for Good Program,[136] SAP's Billion Lives Initiative[137] and Microsoft's portfolio of initiatives (e. g. the AI for Accessibility grant program aimed at empowering people with disabilities[138] and the AI for Health program that supports non-profits, researchers and organizations in healthcare[139]). Only recently has the global "tech for good" actor landscape become more diverse, adding more social entrepreneurs (e. g. the Global Innovation Gathering), organizations that match nonprofits with data scientists (e. g. Data Science for Social Good[140] and DataKind[141]) and forums that convene public- and private-sector actors from across the globe (e. g. the ITU Global Summit AI for Good).[142]

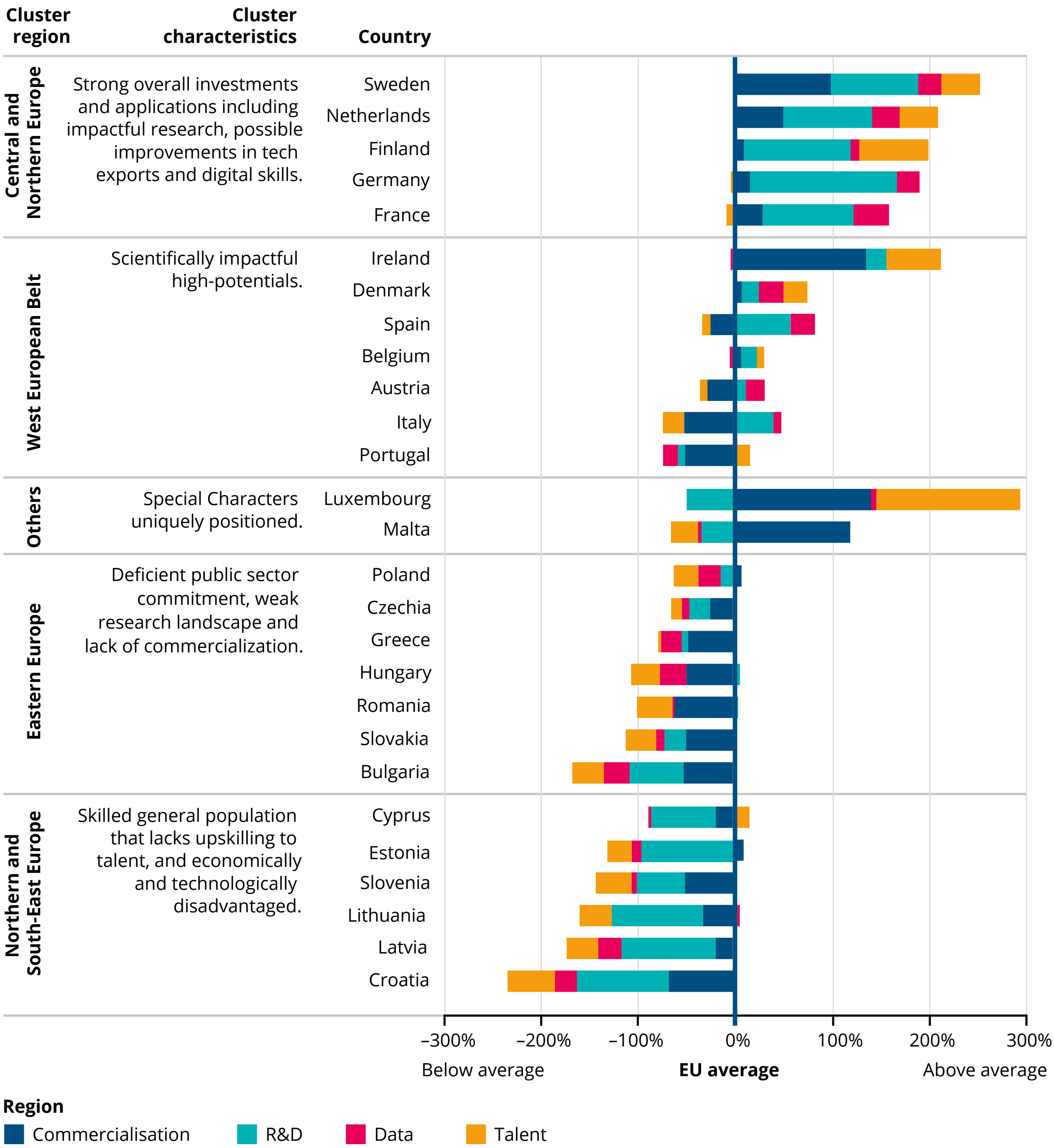
Nevertheless, governments and traditional civil society actors continue to play, at best, a marginal role in developing and applying AI powered solutions for the public good. Key bottlenecks to the digitalization of the public sector include entrenched legacy systems, especially at institutions in advanced economies like the EU, as well as a narrow mindset that sees digitization as a compartmentalized IT function rather than a cross-departmental process. More often than not, projects outsourced to large technology companies fail to comprehend the role of the user (i. e. citizens), underestimate the organizational change required for digitization, don't have sufficient data literacy to apply AI correctly, or are overly ambitious in scope. Public-sector entities can no longer outsource their responsibility to change internal operations. But shifting the onus for this work will require a shift in mindset as well. This means the public sector will need to play a "multifaceted role in the emergent ecosystem – as a client, but also as a skilled procurer, project overseer, and an enabler of genuine competition."[143] More than any other sector, succeeding in this transformation will require public-sector entities to transform their organizational structures and increase their attractiveness to tech experts. In particular, processes will need to be renewed or redesigned before they are digitized. This requires the introduction of human-centered service design methods, such as design thinking, and the transition of administrative emphasis from the duties of citizens to the needs of citizens.[144] Unlike commercial operations, public bodies need to serve all users, including marginalized groups and the "extreme users" at the far ends of the spectrum of product and service requirements, increasing the need for effective AI governance mechanisms (see Chapter 3.3).

Given the ability of civil society to illuminate areas in which AI can benefit all parts of society and to recognize hazards that might otherwise go overlooked, these individuals and entities bring a crucial perspective to both the development and the deployment stages. The civil society also stands to benefit from AI systems and should seek to extend new technological benefits to the people it represents and the issues it addresses. However, civil society still remains focused more on questions around the regulation of AI. (In the US, these discussions center on normative ethical frameworks and responses to challenges, particularly those resulting from excessive government power at local and state levels. In Europe, the debate focuses more on the role of governments and regulation as counters to the impact of corporations.) However, a number of academic institutions and NGOs have started to fill the gaps, including a group of organizations that comprise a transatlantic digital rights ecosystem. This includes worldwide professional entities, such as Institute of Electrical and Electronics Engineers (IEEE),[145] the Partnership on AI for the Benefit of People and Society (PAI),[146] and the OpenAI Institute.[147] It includes more traditional NGOs, including the Electronic Frontier Foundation (EFF), the American Civil Liberties Union (ACLU), Bits of Freedom (the Netherlands),[148] the Open Rights Group (UK),[149] the Association for Technology and Internet (ApTI, Romania),[150] the Chaos Computer Club[151] and NetzPolitik[152] (Germany), and DFRI (Sweden).[153] It also includes academic institutions, such as the Markkula Center.[154] Many of these organizations are members of European Digital Rights (EDRi),[155] a Brussels-based association of civil and human rights organizations that, since its founding in 2002, has advocated for digital rights and freedoms at a supranational level. Most of the European organizations have had little to say about AI ethics in comparison with their American peers, but they have been much more effective in holding companies accountable for their use of personal data. For example, the Austrian activist Max Schrems filed a lawsuit against Facebook in 2013 that upended the transatlantic data-sharing agreement Safe Harbor. The focus of civil society on the regulation of AI, however, seems to have come at the expense of efforts to promote the potentially powerful benefits that applications of this technology could provide. This is a crucial missed opportunity – one made worse by the scarcity of AI and data science talent, most of whom are drawn to high-paying jobs in the private sector, rather than to the public sector and civil society efforts.

Recommendation 20 – Champion AI for Public Good. Whether in the health, climate change, education or environmental protection and natural resources or in areas underserved by the private sector, AI can play an important role in protecting or improving public goods. Dialogue around AI for public good should be facilitated through alliances between the EU, Canada and US "AI for good" initiatives that are already flowing into the G7 / GPAI (Global Partnership on Artificial Intelligence) dialogue. Developing AI-based solutions for public goods requires public sector and civil society actors to have the capability to identify use cases in which AI can be applied, formulate the requirements for designing solutions (e. g. data, computing power, last mile support, etc.), and develop their own governance systems in order to avoid harmful side effects. In doing so, the quantifiable benefits of such undertakings will need to be studied and stated clearly, lest they will be misunderstood as frivolous spending in times when recovery and stimulus funds are becoming scarce. Quite to the contrary, AI for public good can help bring about efficiencies across different sectors in society, conserve scarce resources, and allocate them to where they are needed most in these challenging times. To achieve this, civil society and the public sector need to take on new roles. In addition to being watchdogs, advocates, or service providers, they need to better understand AI and its positive and negative potential, particularly with regard to the interplay of data, models and algorithms. This requires AI-specific expertise as well as the political will to develop both innovative technologies and processes. It also requires bringing in other actors that can contribute complementary skills and tools through a platform that connects AI experts in academia and global platforms and strategy and policy experts in think tanks with data analytics providers and their data pools, as well as representatives from vulnerable stakeholder groups who need AI-powered solutions for social good. We suggest first focusing on climate health or infrastructure problem sets, for which consensus across Europe is the greatest.

Recommendations on Partnerships (R3), (R6), (R7), (R9), (R10), (R20)

Relative deflection of EU countries to EU average in select AI priority by country clusters
shows in percent how far above or below the EU average (0%) each EU country is positioned, in respect to four selected AI priority segments (color coded)



120 Cabinet Office (2020): Society 5.0, in: https://www8.cao.go.jp/cstp/english/society5_0/index.html [2 Nov 2020].

121 Tse (2019): Four reasons why your business isn't using AI. California Review Management, in: https://www8.cao.go.jp/cstp/english/society5_0/index.html [2 Nov 2020].

122 The Economist (2020): A deluge of data is giving rise to a new economy, in: https://www.economist.com/special-report/2020/02/20/a-deluge-of-data-is-giving-rise-to-a-new-economy [2 Nov 2020].

123 Davenport and Ronanki (2018): Artificial Intelligence for the real world. Harvard Business Review, in: https://hbr.org/2018/01/artificial-intelligence-for-the-real-world [2 Nov 2020].

124 Chui, Henke, Miremadi (2019): Most of AI's businesses uses will be in two areas. Harvard Business Review. McKinsey & Company, in: https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/most-of-ais-business-uses-will-be-in-two-areas [2 Nov 2020].

125 Chui, Henke, Miremadi (2019): Most of AI's businesses uses will be in two areas. Harvard Business Review. McKinsey & Company, in: https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/most-of-ais-business-uses-will-be-in-two-areas [2 Nov 2020].

126 Analysis based on data from CB Insights.

127 FIRRMA's objective is to restrict the ability of foreign investors to invest, even with only a minority stake, in US businesses relevant to critical technology that relates to national security. Relevant investments and sales are reviewed by the Committee on Foreign Investment. The investment risk review is extended to include non-controlling investments in emerging and foundational technologies that, again, relate to national security. It seems likely that AI and robotics businesses may fall within this latter category in individual cases. This driver of investment in and adoption of AI could have negative consequences in slowing down Chinese investments in the US, or it could have a positive risk-mitigation effect on safeguarding adoption, which remains to be seen.

128 CB Insights (2020): The 2019 Global CVC Report.

129 World Economic Forum (2015): Collaborative innovation: Transforming business, driving growth, in: www3.weforum.org/docs/WEF_Collaborative_Innovation_report_2015.pdf [2 Nov 2020].

130 Bain and Company (2018): How digital tools are transforming procurement, in: https://www.bain.com/insights/digital-procurement-infographic/ [2 Nov 2020].

131 In: https://www.ariba.com/resources/gartner-2019-magic-quadrant-for-procure-to-pay-suites [2 Nov 2020].

132 Nougues and Rousselle (2018): Innovative start-ups are shaping the future of procurement. Oliver Wyman, in: https://www.oliverwyman.com/our-expertise/insights/2018/jul/innovative-start-ups-are-shaping-the-future-of-procurement.html [2 Nov 2020].

133 Fell, Kottmann, Renaudeau (2016): Insurance inside: The new era of B2B2C insurance. Oliver Wyman, in: https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2016/nov/Oliver-Wyman-Insurance-Inside-The-New-Era-of-B2B2C-Insurance.pdf [2 Nov 2020].

134 Lomate and Ramachandran (2019): B2B2C: The future of customer engagement. Infosys, in: https://www.infosys.com/about/knowledge-institute/insights/Documents/future-customer-engagement.pdf [2 Nov 2020].

135 Rampell (2020): On B2B2C business models. Andreessen Horowitz, in: https://a16z.com/2018/05/17/b2b2c-business-models-rampell/ [2 Nov 2020].

136 Google (n.d.). AI for Social Good, in: https://ai.google/social-good/ [2 Nov 2020].

137 SAP (n.d.): One Billion Lives, in: https://www.sap.com/corporate/en/company/innovation/one-billion-lives.html [2 Nov 2020].

138 Microsoft (n. d.): AI for accessibility, in: https://www.microsoft.com/en-us/ai/ai-for-accessibility [2 Nov 2020].

139 Microsoft (n.d.): AI for health, in: https://www.microsoft.com/en-us/ai/ai-for-health [2 Nov 2020].

140 Data Science for Social Good, in: https://dssg-berlin.org/ [2 Nov 2020].

141 DataKind, in: https://www.datakind.org/ [2 Nov 2020].

142 ITU AI for Good Global Summit, in: https://aiforgood.itu.int/ [2 Nov 2020].

143 Filer (2019): Why the 'government' in govtech must be more than just a client. NS Tech, in: https://tech.newstatesman.com/guest-opinion/govtech-definition-government-client [2 Nov 2020].

144 Straube, Gimpel, Carrier (2017): Bürgernähe als Chance. Public Service Lab, in: https://medium.com/public-service-lab/b%C3%BCrgern%C3%A4he-als-chance-68383480aec [2 Nov 2020].

145 IEEE (2020): A statement from the President, Past-President and President-Elect of IEEE, in: https://www.ieee.org/ [2 Nov 2020].

146 Partnership on AI (2020): Research, publications & initiatives, in: https://www.partnershiponai.org/ [2 Nov 2020].

147 Open AI (2020): Discovering and enacting the path to safe artificial general intelligence, in: https://openai.com/ [2 Nov 2020].

148 Bits of Freedom (2020): About Bits of Freedom, in: https://www.bitsoffreedom.nl/english/ [2 Nov 2020].

149 Open Rights Group (2020): Join ORG, in: https://www.openrightsgroup.org/ [2 Nov 2020].

150 ApTI (2020): About ApTI, in: https://www.apti.ro/apti-english [2 Nov 2020].

151 Chaos Computer Club (2020): Home, in: https://www.ccc.de/en/home

152 Netzpolitik (2020). Home, in: https://netzpolitik.org/ [2 Nov 2020].

153 DFRI (2020): About DFRI, in: https://www.dfri.se/dfri/?lang=en [2 Nov 2020].

154 Markkula Center for Applied Ethics (2020): Voting for ethics, in: https://www.scu.edu/ethics/ [2 Nov 2020].

155 EDRi (2020): Who we are, in: https://edri.org/about-us/who-we-are/ [2 Nov 2020].

6. Methodology and comments on the analysis

This report includes analysis into the data collected and the clustering techniques used in the analysis of the countries of the EU in the sub-chapter "ZOOM OUT: AI in EU member states – an incoherent landscape" and throughout the report. EU countries are defined as official member countries of the EU as of July 2020, i. e. without the United Kingdom. The dataset consists of various kinds of data: indexes, counts, data per capita, currency, and field weighted averages. The composed data is a meaningful selection of a broader dataset, excluding data types which were including missing values. The graph "Reflective Deflection of EU Countries to EU Average in Select AI Priority Segments by Country Clusters" visualizes how far above or below each EU country is positioned relative to the EU average. The chosen priority segments are talent, data, research and development (R&D), and commercialization. The talent segment includes the following variables: "Digital Skills" and "Future Work Skills". The R&D segment includes "Number of AI Research Publications per Researcher" and "H-Index". The data segment includes "Internet User Density". The commercialization segment includes "AI Funding Density", "Tech Investments by Companies", and "High Tech Export". To preserve the interpretability of the visualizations while accounting for various scales, each variable has been computed to show the relative deflection in respect to the average of all EU countries, and has been computed as the percentage change to the average. Computation: *(value – average)/average)*. The segments talent, data, R&D, and commercialization represent the mean value of the percentage changes of the included variables to the EU average.

For the clustering of the EU countries in the sub-chapter "ZOOM OUT: AI in EU member states – an incoherent landscape", the respective countries have been clustered into categories to create a comprehensive yet understandable overview of the status quo of the European Union. To create meaningful insights, the data was normalized to create comparability among values on various scales. All scales are positive, as they increase with "better" values. Computation of normalization: *((value – min)/(max –min)) * 100*

The clusters have been created based on the observations' nearest means to the cluster centers, a methodology called k-means clustering, a method of vector quantization. To interpret the clusters, the observations have been reduced in dimensions into arising principal components. To derive the characteristics of each cluster, the variable vectors contributing to the principal components have been mapped. Subsequently, the impact that each variable vector brings onto the principal component can be identified.

This report includes further graphs. These graphs show the total, unprocessed value of each metric respective to a country, as defined below.

6.1 Definition and sources

For this report, only publicly available, secondary data was collected.

ICT Regulation

Composite index on a scale of 0 (min) to 100 (max) based on the ICT Regulatory Tracker by the International Telecommunications Union. Standardized on 0-2.
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 in: https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf [02 Nov 2020] based on data provided by International Telecommunication Union (ITU), ICT Regulatory Tracker, 2018 in: https://www.itu.int/net4/itu-d/irt/#/tracker-by-country/regulatory-tracker/2018 [02 Nov 2020].

Cybersecurity

Composite index on a scale of 0 (min) to 100 (max) based on the Global Security Index (GCI) by the International Telecommunications Unions. Standardized on 0-1.
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 in: https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf [02 Nov 2020] based on data provided by International Telecommunications Union (ITU), Global Cybersecurity Index, 2018 in: https://www.itu.int/dms_pub/itu-d/opb/str/D-STRGCI.01-2018-PDF-E.pdf [02 Nov 2020].

Legal Framework Digital Businesses

Weighted average to Executive Opinion Survey on a scale of 0 (min) to 100 (max) by the World Economic Forum. Response to the survey question "In your country, how fast is the legal framework of your country adapting to digital business models (e. g. e-commerce, sharing economy, fintech, etc.)?" [1 = not fast at all; 7 = very fast]
Source: World Economic Forum, The Global Competitiveness Report, 2019 in: http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf [02 Nov 2020].

Internet User Density

Internet Users per Capita. Computation:
InternetUserDensity = InternetUsers/Population.
Both population per country and count of internet users per country provided by Internet World Stats.
Source: Internet World Stats, Internet Usage in European Union, 2019 in: https://www.internetworldstats.com/stats9.htm#eu [02 Nov 2020].

Supercomputer

Count of supercomputers per country as identified by Top500. Minimum capacity computing power of 1.14 petaflops required to be identified – that is 1.14 quadrillion floating point operations per second.
Source: Top500, 2019 (https://www.top500.org/lists/top500/2019/11/)

R&D Top 1000 Companies in IT

Expenses for R&D in billion USD of global 1000 publicly held companies.
Source: Strategy&, The Global Innovation 1000 study, 2018. in: https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html [02 Nov 2020].

AI Researcher Density

AI researchers per Capita. Computation
AIResearcherDensity = AIResearchers/Population.
AI researcher defined as an individual who presented at a selection of 21 AI conferences in 2018. Total number of individuals accounted for is 22,400 as provided by Gagne, J in 2019. Population provided from Internet World Stats, 2019.
Sources: Gagne, J, Global AI Talent Report, 2019 in: https://jfgagne.ai/talent-2019/ [02 Nov 2020], Internet World Stats, 2019 in: https://www.internetworldstats.com/stats9.htm#eu [02 Nov 2020].

Number of AI Research Papers

Number of research papers as listed in the SCOPUS database hosted by Elsevier and provided in the SCImago Journal & Country Rank. Sum of publications categorized within the subject of “Artificial Intelligence” across 1966 to 2018.
Source: SCImago Journal Rank, 2018 in: https://www.scimagojr.com/countryrank.php?category=1702 [02 Nov 2020].

Number of AI Research Publications per Researcher

Number of AI Research Publications (see 6.1.8.) per AI researchers. Computation: *No. AIResearchPublicationsperResearcher = No. of AIResearchPublications/No. of AIResearcher.* AI researcher defined as an individual who presented at an AI conference in 2018. Total number of individuals accounted for is 5,400 as provided by Gagne, J in 2019.
Source: SCImago Journal Rank, 2018 in: https://www.scimagojr.com/countryrank.php?category=1702) [02 Nov 2020]. Gagne, J, Global AI Talent Report, 2019 in: (https://jfgagne.ai/talent-2019/ [02 Nov 2020].

H-Index

Index describing the equilibria of the number of citations of an author’s publications corresponding to an author’s single publications number of citations as provided by SCImago Journal based on publications across 1966 to 2018.
Source: SCImago Journal Rank, 2018 (https://www.scimagojr.com/countryrank.php?category=1702)

Citation Impact

Field weighted citation impact calculated by comparing the number of received citations actually to the number of expected citations for a publication of the same type, publication year, and subject as provided in the SCImago Journal.
Source: SCImago Journal Rank, 2018 in: https://www.scimagojr.com/countryrank.php?category=1702 [02 Nov 2020].

Digital Skills

Weighted average to Executive Opinion Survey on a scale of 0 (min) to 100 (max) by the World Economic Forum. Response to the survey question “In your country, to what extent does the active population possess sufficient digital skills (e. g. computer skills, basic coding, digital reading)?” [1 = not all; 7 = to a great extent]
Source: World Economic Forum, The Global Competitiveness Report, 2019 in: (http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf [02 Nov 2020].

Future Work Skills

Weighted average to the Executive Opinion Survey on a scale of 0 (min) to 100 (max) by the World Economic Forum. Response to the survey question “In your country, how do you assess the style of teaching?” [1 = frontal, teacher based, and focused on memorizing; 7 = encourages creative and critical individual thinking]
Source: World Economic Forum, The Global Competitiveness Report, 2019 in: http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf [02 Nov 2020].

AI Professional Density

AI professionals per capita. Computation: *AIProfessionalDensity = AIProfessional/Population.* AI professional defined as a self-identified professional individual, holding a PhD with the self-described job title “data scientist”, “research scientist”, ”machine learning engineer”, ”machine learning researcher” and “data analyst” on the global professional network LinkedIn. Total number of individuals accounted for is 36,524 as provided by Gagne, J in 2019. Population provided from Internet World Stats, 2019.
Sources: Gagne, J, Global AI Talent Report, 2019 in: https://jfgagne.ai/talent-2019/ [02 Nov 2020], Internet World Stats, 2019 in: https://www.internetworldstats.com/stats9.htm#eu [02 Nov 2020].

AI Funding Density

USD in funding for all private AI start-ups from 2016 to 2020 per capita. Computation *AIFundingDensity = Sumo f funding from2016to2020/Population* . AI start-ups as identified by CB Insights across market sectors and industries. Only closed funding for private companies, no debt or loans and no government funding.
Source: CB Insights, The 2019 Global CVC Report, 2019 in: https://www.cbinsights.com/research/report/corporate-venture-capital-trends-2019/ [02 Nov 2020].

Tech Investments by Companies
Weighted average to Executive Opinion Survey on a scale of 0 (min) to 100 (max) by the World Economic Forum. Response to the survey question: "In your country, to what extent do companies invest in emerging technologies (e. g. Internet of Things, advanced analytics and artificial intelligence, augmented virtual reality and wearables, advanced robotics, 3D printing)?" [1 = not at all; 7 = to a great extent]
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 in: https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf [02 Nov 2020] on data provided by the World Economic Forum, Executive Opinion Survey 2016–2017 in: http://reports.weforum.org [02 Nov 2020].

High Tech Export
High technology manufacturing exports as a percent of total manufactured goods in 2018.
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 in: https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf [02 Nov 2020] on data provided by World Bank, World Development Indicators in: http://data.worldbank.org/data-catalog/worlddevelopment-indicators [02 Nov 2020].

Software Spending
Total computer software spending as a percent of GDP in 2018.
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 (https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf) on data provided by the IHS Markit, Information and Communication Technology Database in: https://www.ihs.com/index.html [02 Nov 2020], sourced from INSEAD, Cornell University, and World Intellectual Property Organization, The Global Innovation Index 2019 in: https://www.globalinnovationindex.org [02 Nov 2020].

Robot Density
Number of robots in operation per 10,000 employees in the manufacturing industry.
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 in: (https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf [02 Nov 2020] based on data provided by the International Federation of Robotics in: IFR, https://ifr.org [02 Nov 2020]. Missing values were sourced from the International Labour Organization, ILOSTAT in: https://ilostat.ilo.org/ [02 Nov 2020].

Government Procurement of Advanced Tech in 2019.
Weighted average to the Executive Opinion Survey on a scale of 0 (min) to 100 (max) by the World Economic Forum. Response to the survey question: "In your country, to what extent do government purchasing decisions foster innovation?" [1 = not at all; 7 = to a great extent]
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 in: https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf [02 Nov 2020] on data provided by the World Economic Forum, Executive Opinion Survey 2016–2017 in: http://reports.weforum.org [02 Nov 2020].

ICT Use and Efficiency
Weighted average to the Executive Opinion Survey on a scale of 0 (min) to 100 (max) by the World Economic Forum. Response to the survey question: "In your country, to what extent does the use of ICTs by the government improve the quality of government services to the population?" [1 = not at all; 7 = to a great extent]
Source: Portulans Institute, World Information Technology and Services Alliance; The Network Readiness Index, 2019 (https://networkreadinessindex.org/wp-content/uploads/2020/03/The-Network-Readiness-Index-2019-New-version-March-2020.pdf) on data provided by the World Economic Forum, Executive Opinion Survey 2016–2017 in: http://reports.weforum.org [02 Nov 2020].

Imprint

Editor
Konrad-Adenauer-Stiftung e. V. 2020, Berlin

Authors
Olaf Groth, Founder and Managing Partner of Cambrian Group
Tobias Straube, Principal at Cambrian Group

Cambrian Futures LLC, Eunice Street, Berkeley CA-94708-1644, United States
https://cambrian.ai, Twitter: @AICambrian

Editorial team and contact at the Konrad-Adenauer-Stiftung e. V.
Sebastian Weise
Advisor for Global Innovation Policy
Klingelhöfer Strasse 23
10785 Berlin
T +49 30 / 269 96-3732

Jason Chumtong
Advisor for Artificial Intelligence
Klingelhöfer Strasse 23
10785 Berlin
T +49 30 / 269 96-3989

Cover image: © NASA Earth Observatory images by Joshua Stevens, using Suomi NPP VIIRS data from Miguel Román, NASA's Goddard Space Flight Center; Kirsty Pargeter/ Vecteezy.com
Images: © S. 7 © iStock by jamesteohart/getty images; Alexrk2/Wikimedia Commons, S. 22 © iStock by DKosig/getty images; Alexrk2/Wikimedia Commons, S.30 © iStock by piranka/getty images; Alexrk2/Wikimedia Commons, S. 41 © Quardia/shutterstock; Alexrk2/Wikimedia Commons, S. 49 © DamienArt/shutterstock; Alexrk2/Wikimedia Commons, S. 57 © your123/Adobe Stock; Alexrk2/Wikimedia Commons
Design and typesetting: yellow too Pasiek Horntrich GbR

ISBN 978-3-95721-807-0

In 2017, Finland was the first European country to present its own artificial intelligence (AI) strategy. Since then, a total of 22 countries and the EU itself have done so. The direction of travel is clear: Europe wants to use the economic and societal potential of AI, and to become an AI-leader internationally. In consideration of this ambition, this study analyses in detail the European AI innovation ecosystem and develops recommendations for action to strengthen it.

Konrad-Adenauer-Stiftung e. V.