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Comparison of National Strategies to Promote Artificial Intelligence

Part 2

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Preface

Technologies can rarely be reduced to their mere commercial added value.
The history of the Industrial Revolution teaches us that nation states have always endeavored to build or maintain political supremacy through pioneering economic achievements. In the age of digital upheavals, multiple disruptions and immense acceleration, this dictum still applies.

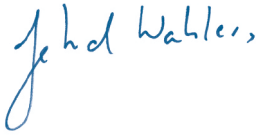
The topic of "artificial intelligence" plays a special role here – a technology that is currently being discussed worldwide and increasingly applied. As with any new technology, both the Cassandrian pessimists (such as Steven Hawking or Elon Musk) and the progress optimists (Mark Zuckerberg, Eric Schmidt or Bill Gates) contribute their theses on the future development of humanity. They widely vary from dark dystopia to paradisiacal future prospects.

Let us hope that the recently appointed Enquete Commission of the German Bundestag will counter an agitated and possibly overheated debate with sober stocktaking. Germany's AI strategy, which is expected by the end of the year, must define quantifiable goals and concrete measures, which will then be vigorously implemented. The political crash barriers necessary for the use of automated machine learning need to be established.

Other countries are well ahead in this respect. They have long since defined AI strategies, developed business models and subjected ground-breaking applications to initial practical tests. Therefore, it is worth taking a close look at how other economies are dealing with the digital revolution: What regulatory framework conditions have they defined? How do they implement policy strategies and programs to create new industrial policy facts?

With this two-part publication, the Konrad Adenauer Foundation intends to give a comparative overview of the AI strategies of major national economies in order to provide food for thought and inspire the German debate. We believe: "Tech is politics" – and politics and civil society should give this more attention and discuss this more vigorously.

I hope you find this publication an inspiring read.



Yours
Dr. Gerhard Wahlers

Dr. Gerhard Wahlers is Deputy Secretary General and Head of the Principal Department for European and International Cooperation of the Konrad-Adenauer-Stiftung.

Background and Definitions

Artificial intelligence: rapid developments and designs of the initial conceptual AI frameworks.

In July 2018, the German federal government published a key issues paper on the German strategy with regard to artificial intelligence (AI) and there they acknowledge: "Artificial intelligence has reached a new stage of maturity in recent years and is becoming a driver of digitization and autonomous systems in all spheres of life."[1] Therefore, the state, society, the economy, the government, and science are urged to consider artificial intelligence in depth and to deal with its chances and risks.

A comprehensive German AI strategy was presented at the Digital Summit in December 2018. The aim is to prominently embed the topic of AI in the digital policy of the federal government. In this way, Germany is catching up with a large number of countries which in recent years have seen extensive initiatives for AI strategy finding processes.[2]

These strategies are motivated by partly spectacular progress in research and application of AI systems, based on techniques of Machine Learning (ML) as well as its subdiscipline of Deep Learning (DL) and its large varieties of neuronal networks.

The global relevance of AI technologies is demonstrated by their prominent representation on this year's international agenda – from the Munich Security Conference in February, to the presentation of the EU Commission's[3] AI paper in April, to the joint AI declaration of the G7 states in Canada in June ("Charlevoix Common Vision for the Future of Artificial Intelligence").[4]

The role of Artificial Intelligence as a potential key technology of dystopian future concepts, social control, and autocratic world power fantasies is also increasingly finding its way into public debate.

This overview, however, focuses on the analysis of AI framework conceptss in six countries and how they deal with the revolutionary potential of Artificial Intelligence.

The following definition is used as a basis for the terminology:

"In the broadest sense, artificial intelligence is the ability of machines to learn, to think, to plan and to perceive; i. e. the primary qualities that we identify with human cognition. This ability is achieved by digital technologies or digital-physical hybrid technologies, which imitate the cognitive and physical functions of humans. For that purpose, AI systems do not only process data, they recognize patterns, draw conclusions, and become more intelligent over time. Their ability to adopt and refine newly developed skills has improved significantly since the turn of the century. This also means that what is referred to as AI changes with each major technological breakthrough, and the definition must therefore be periodically adjusted."

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1 Cf. German Federal Government, Key Points of the Federal Government for an Artificial Intelligence Strategy (July 2018), https://www.bmbf.de/files/180718%20 Eckpunkte_KI-Strategie%20final%20Layout.pdf.

2 To this end, see the OECD overviews, for example, http://www.oecd.org/going-digital/ai/initiatives-worldwide/, Future of Life Institute, https://futureoflife.org/ai-policy/, the Smart Data Forum, https://smartdataforum.de/ en/services/international-networking/international-ai-strategies/, Charlotte Stix, https://www.charlottestix.com/ai-policy-resources, und Tim Dutton, https://medium.com/politics-ai/an-overview-of-national-ai-strategies-2a70ec6edfd, all last retrieved on 17.9.2018.

3 Cf. European Commission, Artificial Intelligence for Europe (April 2018), http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=51625.

4 See Canadian G7 Presidency, Charlevoix Common Vision for the Future of Artificial Intelligence (June 2018), https://g7.gc.ca/wp-content/uploads/2018/06/FutureArtificialIntelligence.pdf.

Summary

The following summary describes the insights and assessments of the status quo of national strategies for the promotion of Artificial Intelligence (AI). The analysis of the six countries from part 1 of the study and the findings from the countries examined in this part (Canada, Japan, Israel, United Arab Emirates, India and Singapore) serve as a basis. Against the background of the results of the first two parts of the study, there is also a third part in preparation which focuses exclusively on the analysis of the recently published German AI strategy and the recommendations for action that follow it.

Policy fields for AI: In the European countries, the economic potential of AI is considered above all, while in Japan AI is seen as part of the inevitable next stage in human development, which will encompass all areas of life: *Society 5.0*. In Israel, the security policy dimension plays a central role; an aspect that other countries selectively or only rudimentarily address in their strategies. The USA, and China in particular, benefit from mutually open civil and military sectors. In India, the AI focus is on the promotion of social and societal aspects.

Ethics and human orientation as strategic strengths of the Europeans: Although ethical issues are discussed in different social forums in China and the USA, the topic is not given any high priority by the respective governments. This has left leeway for France's Emanuel Macron to take the lead on the topic of ethical AI. Although London took the initiative faster than Paris to develop an international AI governance *architecture*, it was weakened by the Brexit in its attempts to project and implement such initiative. Other countries, such as Finland, also lack the international significance for this.

The private sector as driver in AI development: In the leading AI countries, i. e. the USA and China, the development dynamics are largely determined by the private sector, in particular by young companies and globally operating Internet groups. These dynamics are enhanced by the deregulation tendencies that are common in the USA. In China, on the other hand, trends towards increased state control of the large technology companies become more and more evident. In Japan and South Korea, it is also the globally positioned hardware-oriented conglomerates that are driving AI forward. In the countries of continental Europe (including Germany), which focus on science and the protection of individuals, there is currently a lack of global technology companies. This is based in part on a general skepticism towards digital technologies and the resulting protective attitude of politics and society.

AI superpowers vs. "fortress countries": In comparison to the USA, where cooperation between business and science has grown over decades, Europeans, but also countries such as Canada, Singapore, Japan and India, have so far only been able to achieve this permeability to a very limited extent. Excellent research results remain in the ivory tower and its walls of debilitating regulation. Connecting AI research with the needs of the industry thus represents a major challenge in these countries.

Ecosystems as a strategic asset: In order to develop better solutions and introduce them into the international dialogue, in addition to researchers, 2. talented developers, 3. data pools, 4. computing capacities and 5. strategic entrepreneurs, experienced investors (6.) and an agile (7.) are also required. While in the USA and China as well as partly in Israel these factors provide the breeding ground for the successful commercialisation of AI, within Europe this is only possible to some extent in the United Kingdom. In France or Finland, the small number of AI startups bears witness to the fact that such ecosystems are not yet actively

thought through and supported to the necessary extent. In Japan and South Korea, the majority of these factors is concentrated in large corporations, while local startup ecosystems remain small.

Lack of computing capacities as a strategic weakness: While availability of data and training of specialists are promoted by many strategies as a prerequisite for AI research and commercialisation, only in a few cases is there also a focus on the expansion of domestic computing capacities (except: South Korea, Japan and China). The current global trade conflicts reveal that availability of powerful chips or access to cloud-based computing power is a strategic necessity. Despite a technologically highly developed economy, there is only a small globally competitive semiconductors industry in Europe. At the moment, US companies dominate this sector.

Vague and inconsistent AI definitions: In the strategies compared, there are very different definitions of AI, or in some cases no definitions at all. The only thing that the strategies have in common is that they consider AI a driving force in the digital revolution, which harbours both potentials and risks in terms of social, economic and security policy. Accordingly, they often leave aside any existing sector or digital strategies. This is the theoretical foundation and basis for the divergence and convergence of different national AI strategies. Such divergence and convergence is both positive and problematic, since it leads to application diversity on the one hand, but at the same time increases the cost and time expenditure for political transition and implementation of global approaches for cooperation and regulation.

Lack of target systems: The strategies are predominantly formulated in general terms. Their partially vague objectives relate to different levels of impact. For example, China measures the economic strength of the AI industry, among others, while Great Britain and South Korea also set targets for the number of future PhD students. The Japanese government has established clear goals and time frames for AI applications.

The countries of the second part of the study at a glance:

Canada: Canada has developed a comprehensive strategy that involves all levels of economy, science and industry in order to strategically position the relevant players and support each other across disciplines. The aim is to strengthen the global presence and improve national prospects. The country also strives to take on an international leadership role in research and ethical practice. Canada's early involvement in AI research has made it possible for provincial, regional and federal governments to provide targeted support for educational and research institutions since the 1980s. The institutions are now well positioned, especially in terms of research and development. The government continues to play an important role in the development of advanced technologies by supporting communities with high-level strategic investments and transfers. The state collaborates closely with the private sector to improve financing, access and commercial applications. At the same time, the value of ethics is emphasized. By supporting academic and commercial recruiting and loyalty tactics through three major institutions, Canada aims to offer its economy a sustainable future and an open approach for the exchange of knowledge.

Japan: No government in any of the reviewed countries links the future of their country as closely to AI as Shinzō Abe in Japan. One of his two top goals is the realization of *Society 5.0*. In this next stage of human evolution, the physical and cyber worlds merge. Numerous government initiatives and an interministerial AI strategy have already resulted from the implementation work. The focus of research funding is on three institutes that perform research on specific AI applications for increased productivity, mobility, medicine and safety. So far, the private sector has been the main contributor to research spending. Public university research is underfunded and internationally isolated. The degree of permeability and exchange between research and industry is also rather low. In order to change this, the *cross-appointment system* allows researchers and developers from science and the private sector,

respectively to work part-time in the other area. Universities also receive incentives to do more research together with the private sector. Large companies such as Toyota, NEC or Toshiba have recognised that the future of machines lies in their intelligence. They can scale it globally if they catch up in software development and adopt the concept of open innovation. So far, there are only a few AI startups. With deregulation in *sandboxes* and geographically defined *Strategic Special Zones*, AI policy is linked to the development of structurally weak regions. The government wants to achieve global integration by adapting data protection legislation to the EU GDPR, establishing international standards for robotics and guidelines for ethical AI.

Israel: In the last two decades, the "startup nation" has created a dynamic high-tech sector with at least 360 AI start-ups through incentives and support programmes. In a highly developed network approach, national and international business and science cooperate closely with the state. Virtually all the major tech companies and corporations in the world operate research centres in Israel. They generate many jobs, but often transfer the added value of intellectual property abroad. Through the *Technology Transfer Companies* (TTC), the domestic universities and research clinics have established an effective instrument for the commercialisation of research. Startups can rely on funding running into billions by the innovation authority and *Venture Capital*, particularly for establishment and development of marketable technology products. The military considers AI to be "the key to survival in the modern world" and acts as a driving force of innovation through its selection and training programmes: Israel – a knight of the cognitive era Although there is still no independent AI strategy, yet, Prime Minister Benjamin Netanyahu sees great export potential for AI in the fields of *cyber security*, digital medicine and mobility. However, the transformative force of AI has so far been little reflected in society of the country.

United Arab Emirates: Small data pools, no supercomputers, very low scientific performance, and practically no AI patents. In contrast to that, there is an urgent need to reduce dependence on oil revenues and to diversify the economy, in combination with the government's high political capacity to act. As part of a cabinet reshuffle in October 2017, the government systematically focused on the vision of making the UAE the "best country in the world" by 2071. Technology, and particularly AI and innovation, plays a central role in this. These ambitions are reflected in the newly established State Ministry for AI and in many ambitious and concisely formulated technology strategies. Their goal is clear: a leading position for the UAE in the application of AI. For implementation, the country relies above all on the creative power and demands of the authorities and on partnerships with countries such as India. It is not yet clear which concrete capacities are to be built up and how they will fit into the global AI landscape.

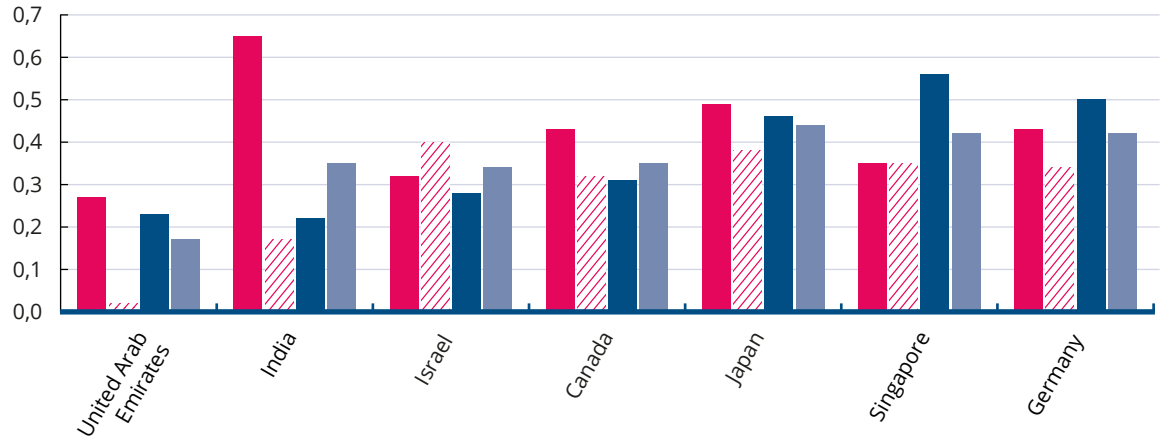
India: India has a unique focus on the application of AI to improve welfare and social problems and seeks leadership in this area. Before this can be achieved, however, India must overcome a multitude of challenges. There is a particular lack of institutional and coordinating capacities, which the Indian AI Strategy of 2018 aims to remedy with institutions at two levels: to promote the basic AI research and to advance AI commercialisation. Other obstacles include a low level of data processing capabilities, a weak intellectual property system and relatively low Internet penetration. India's approach will bear fruit only if and when these factors show progress. However, important findings on institution establishment can be derived from the Indian AI strategy, such as the strategically positioned two-stage institutions at the level of basic AI research and AI commercialisation policy. Both aim to build partnerships with relevant stakeholders to found and expand networks and accelerate AI development.

Singapore: The country is seeking a co-operative AI ecosystem between industry and science and intends to provide an environment with appropriate resources to foster innovative development. In the absence of mineral resources and geopolitical relevance, the promotion of digitisation and AI has become one of the government's priorities, with the aim of becoming known worldwide as the AI hub. To this end, the five-year initiative *AI Singapore* was developed in 2017. Within the *100Experiments* scheme, companies can submit problems for which there is no standardised AI solution yet, but for which a solution could easily be worked out. These companies and their problems are then placed with AI developers. Through *Fundamental Research*, Singapore supports basic research and addresses research gaps, with a view to both technical and ethical societal issues. Understanding and acceptance of AI among the population is promoted by the *AI for Everyone* scheme, which offers specific learning formats on AI. The *Accreditation@ SGD* initiative supports young companies in their early growth phases by means of customised consulting services, particularly in the areas of technical applications. In addition to its efforts to create an AI-friendly environment among relevant players and in terms of legislation, the government also intends to promote, through various initiatives, the responsible use of data and the ethical use of AI solutions.

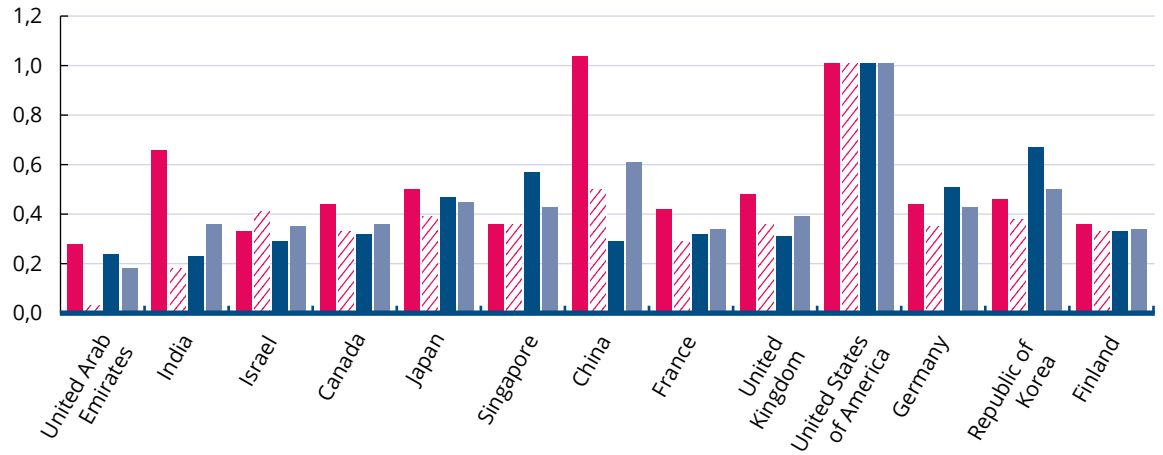
Cambrian AI Index ©

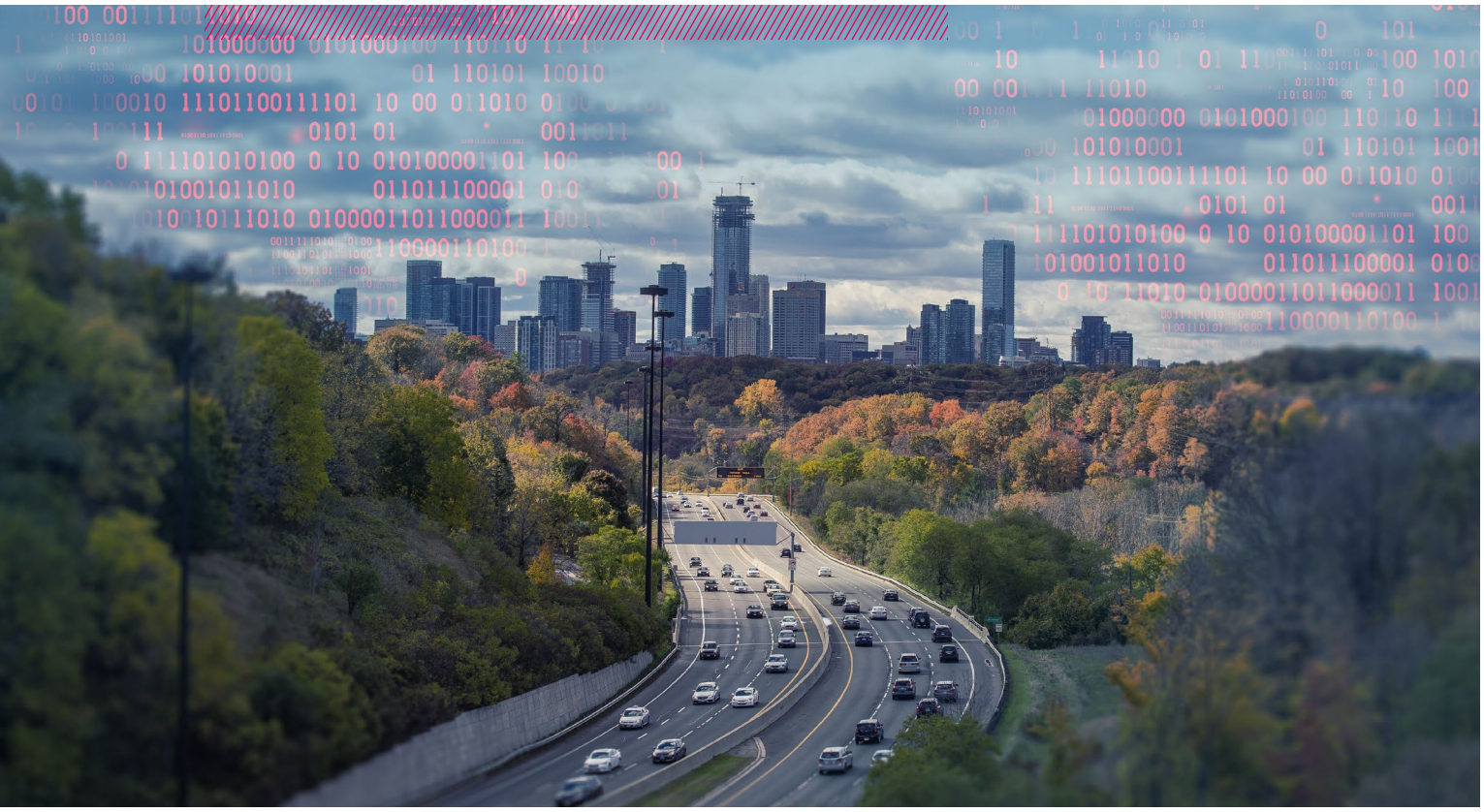
The analysis assessed the countries on the basis indicators that incorporate the countries' preconditions, the research and development situation and the degree of commercialisation of AI. To integrate these indicators and determine the AI position of a country, the *Cambrian AI Index* © was developed. The index is limited by proxy measurements for which reliable and comparable data are available at this early stage of the AI application. There was no weighting of the data. The reference country for the index is the United States, the world's leading AI nation.

Cambrian AI Index © of countries from part 2 of the study



Cambrian AI Index © of countries from part 1 and 2 of the study





Canada

AI research location with a long history

- AI research for decades
- A pan-Canadian network of university laboratories focusing on AI core research
- Location of AI research labs of many tech giants including Microsoft, Google, Facebook and Samsung
- Favourable immigration policies, grants and tax incentives; as well as special regulatory zones to encourage local and international companies to commercialise AI

I.) Introduction

In November 2017, Canada's Prime Minister Justin Trudeau stood on stage with Eric Schmidt, CEO of Alphabet, discussing the importance of AI as a driver of economic growth.[5] Looking at the text of the Canadian AI strategy paper, it is striking that social sectors, such as healthcare and social welfare are not explicitly mentioned – unlike many other national AI-related strategies. Rather, the declared objectives are: 1) to prevent AI talent from migrating to the USA, 2) to create favourable conditions for the commercialisation and economic growth of the country. In order to achieve these goals, the various administrative and governmental levels in the country have allocated a total of approximately 430 million Euros[6] provided by various schemes, either directly or very closely linked to R&D in AI, talent delivery and commercialisation.

II.) Requirements for AI

Canada has about 36 million inhabitants (about one tenth of the United States), 32 million of whom used the Internet in 2016.[7] The source of potential data for AI is correspondingly small.

The public sector, on the other hand (also a relevant data source for AI) makes its data freely available in high quality (among the countries compared, the availability and quality of public sector data is better only in the UK).[8] In relation to Canada's small population, about as many Master's students are trained in AI-related fields as in the USA. This puts Canada ahead of Great Britain and France and behind Singapore and Israel. In absolute figures, however, it is estimated that there are currently only 860 Master's students, which means that the country still lags significantly behind the USA.[9] In addition, Canada only operates six of the world's 500 best supercomputers.[10]

III.) Institutional framework

Canada has a strong institutional framework to implement AI R&D funds for a network of established top research institutions. A central pillar in this framework is the *Canadian Institute For Advancement and Research* (CIFAR), founded in 1982, which currently runs twelve different R&D programmes in 16 provinces, which in turn provide orientation for the *Pan-Canadian AI Strategy,* and whigh governs the recently established Federal Fund with 83 million Euro. CIFAR is currently forwarding the majority of this fund to the three main AI R&D centres in Canada: the *Montreal Institute for Learning Algorithms* (MILA) in Montreal, the *Vector Institute* in Toronto and the *Alberta Machine Intelligence Institute* (AMII) in Edmonton. All three centres are associated with universities that strictly focus on AI R&D and not on commercialisation.

Ethics – "top down" and "bottom up": The discourse on AI ethics and the impact of AI progress on society in Canada takes place at several levels On the one side, CIFAR manages an independent program (with its own fund and team) called *"AI & Society"*. It is focused on future national economic, ethical and legal policies which take into account the concerns about the impact of AI on the labour market or on the health sector.[11] To this end, the *AI & Society* team runs nationwide workshops, conducts surveys with experts and cooperates with the UK and France. In addition to this *"top down"*-Initiative, the Montreal AI players have compiled the Montreal Declaration for Responsible AI, which aims to stimulate the discussion between the public, the private sector and the state.[12] It proposes a framework and a set of values, such as well-being, autonomy, justice and privacy, which must be assessed and observed in the development or implementation of AI technologies.

IV.) Research and Development

In Canada, total R&D spending in 2016 was at around 22 billion Euro.[13] Around 200 million Euro have been allocated for AI research; 83 million via the *Pan-Canadian AI Strategy*[14] and 118 million are forwarded to the universities of Montreal and McGill through the *Canada First Research Excellence Fund*.[15] In addition the provincial governments of Quebec and Ontario recently allocated a further 100 million Euro exclusively for R&D in AI.[16] According to the CSRanking, about 120 teachers (about 1,060 in the USA) have been engaged in research on AI in the country since 2016,[17] which represents a similar relation relative to the overall population as in the United States.[18] These teachers are estimated to supervise 370 doctoral students per year.[19] The AI-relevant scientific production is 1,200 citable documents,[20] which puts Canada in eighth place among the twelve countries compared. Interestingly, however, Canada ranks fourth in the H index, which measures the influence of these publications (after the US, UK and China),[21] which emphasises the high quality of Canadian AI publications.

Research areas and instruments

The most important instrument for AI R&D is the *Pan-Canadian AI Strategy* managed by CIFAR (see above), which coordinates research at the three major AI hubs. These three centres, located in Montreal, Toronto and Edmonton, are all associ-

ated to local universities and focus almost exclusively on AI research and development. These centres, each led by one of the three famous AI researchers Dr. Yoshua Bengio, Geoffrey Hinton and Richard Sutton, are pioneers in the development of *Deep Learning*, neural networks and reinforcement learning. It is worth noting that they continued to operate during the last "AI hibernation" of the 1990s and 2000s, financed by a sister AI programme also managed by CIFAR ("*Learnings in Machines & Brains*").[22] Today, with renewed interest in AI research, all three centres benefit from the basic funding provided by the federal programmes. The *Vector Institute* hub in Toronto is currently the best funded. In addition to the 14 million Euro it received from CIFAR, a further 86 million Euro came from the provincial government and the private sector, in particular Google.[23] It's not uncommon in Canada for private investments to be made following public funds. With the additional funding from the private sector and the provincial governments, all three centres have expanded their basic research and are now actively participating in the development of the following key technologies: *Deep learning,* neural networks, reinforcement learning, *Pattern Recognition, Computer Vision*, unattended learning, *Natural language processing*, *Deep Networks,* learning theory and optimisation of *Deep learning*, statistical theory and algorithmic gaming theory. All in all, the centres directly or indirectly support a large network of researchers, with the MILA Montreal Centre taking the lead and directly supporting 234 AI researchers.[24]

Canadian companies are also offered 15 to 35 percent tax benefit for basic and applied research in the field of science and technology through the *Scientific Research and Expert Development* (SR&ED) program.[25] In addition, the *Global Talent Stream program*[26] simplifies immigration requirements for AI researchers, and other specialists and talents. According to Navdeep Bains, Canada's Minister of Innovation, Science and Economic Development it only takes "two weeks" until a work permit for these researchers is applied for and issued.[27] Other countries can learn from this as the battle for AI talent intensifies.

V.) Commercialisation

Commercialisation of AI research is the weak point of the country. While a study by Asgard and Roland Berger in 2018 recorded 131 AI startups (just under 1,400 in the USA),[28] another mapping of the Canadian startup scene revealed 650 AI-focused startups scattered across the country in 2018.[29] In 2016, however, only 2.7 percent of all global investments in AI startups were made in Canada (USA 62 percent in the same period).[30] Also, only a small proportion of relevant AI patents originate in the country (between 2015 and 2017, an average of 1.43 percent of all internationally enforceable AI patents worldwide).[31] At the level of automation of the economy, measured by the number of robots per 10,000 employees in the manufacturing industry, the country is ranked in the back midfield (145 robots in comparison to 631 in South Korea and 71 in Great Britain).[32] Among the countries compared, the public sector exerts the least influence as a possible driver of innovation through its demand[33] and does not play a role in the strategy as a possible user of AI, either.

Regulation: The Canadian federal government sets the guidelines for provincial regulation. Of the ten provinces, the following are the most economically important: Ontario, Quebec, Alberta and British Columbia. The existing rules and regulations are not sufficient to promote the use and application of AI, in particular with regard to intellectual property, copyright and ownership of both inputs (data) and outputs (decisions or actions of robots) and thinking machines that use AI).[34] CIFAR, with its "*AI & Society*"programme, is working hard tochange this. They focus on cross-company and cross-industry collaboration, data privacy and ethics. PIPEDA, the law on the protection of personal data and electronic documents, which in many respects is similar to the EU GDPR, regulates the use of data (the input) as well as the actions in case of data protection violations, as stipulated by the latest amendment (November 2018).[35] The regulations also include how Canadian startups and companies can use data in their AI models.

The *Canadian Securities Authority* (CSA), the governing body of the Canadian capital market, has established a special regulatory zone (*sandbox*) to explore new business models with innovative products in the capital markets, such as the use of AI for trading.[36] Similar special zones are also being developed by *Transport Canada* for the development of self-propelled vehicles, after the institution has specified "Guidelines for Testing of Highly Automated Vehicles".[37] *Health Canada* also promotes the research and testing of technologically advanced (and possibly AI-controlled) medical devices.[38]

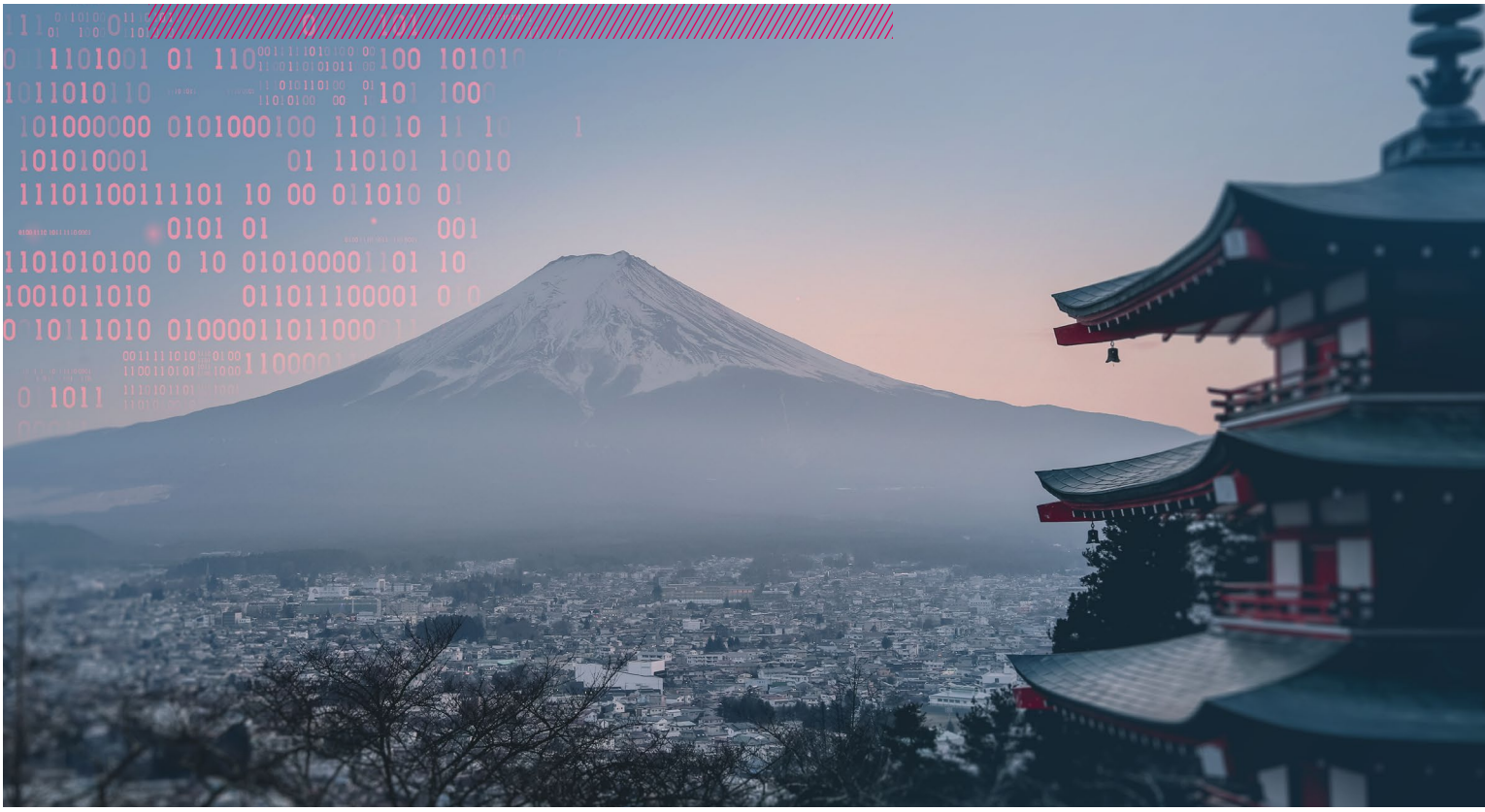
Generally speaking, while Canada's current regulations remain insufficient and overall cautious with regard to AI applications, they are not too strict to discourage companies. On the contrary: Companies and startups are familiar with what is allowed and what is not (e. g. through PIPEDA), they are given the opportunity to participate in the discussions on future regulations (e. g. through CIFAR and the CSA Special Regulatory Zone) and have a good understanding of which industries will be better regulated next.

Promotion of startups and companies: The Canadian federal government is focusing its direct support of commercialisation of technology and innovation on larger projects and companies. However, smaller companies and startups, are not left alone and well supported by private venture capital.

The *Strategic Innovation Fund of Canada* (SIF), a program designed to accelerate technology transfer and the commercialisation of innovative products, is intended to provide grants for companies and their projects, which will cover up to 50 percent of the expenditure.[39] This fund is also available to foreign companies intending to do business in Canada. With the 2018 budget, this fund was replenished with 840 million Euro for a period of five years.[40] Although the SIF is more traditional in its operation (i. e. 'grant application'), it is quite flexible and often changes its parameters. In February 2018, for example, the fund announced that it would adapt to the economic situation and general access to capital by providing 6.7 million Euro to support larger projects.

At the beginning of 2018, the federal government announced a new commercialisation instrument, the "Supercluster" initiative, which will be financed with around 635 million Euro over five years.[41] The Superclusters were created specifically to promote economic growth and to encourage the private sector to collaborate with education and research institutions to create regional innovation ecosystems comparable to Silicon Valley. Three of these superclusters are specifically oriented towards applied research and the use of AI technologies for commercialisation. The *Advanced Manufacturing Supercluster* in Ontario focuses on the next generation of manufacturing and robotics.[42] With 270 participants, the largest "*Digital Technology Supercluster*" in British Columbia concentrates on the use of larger data records and *machine learning* to improve service delivery in the fields of natural resources, precision health care and manufacturing.[43] The "*AI-Powered Supply Chains Supercluster (SCALE.AI)*", headquartered in Quebec, focuses on harmonising the sectors of manufacturing, transport, IT and retail as well as on developing intelligent supply chains using AI and robotics.[44]

5 The New York Times, 2017.
6 For standardisation purposes, all amounts in foreign currencies were converted into Euro and rounded at the exchange rate of November 12, 2018.
7 World Bank, 2016 (cf. Methodology of the Cambrian AI Index).
8 Open Data Barometer, 2016 (cf. Methodology of the Cambrian AI Index).
9 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
10 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index).
11 CIFAR, k. D.
12 Université de Montréal, 2017a.
13 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index).
14 CIFAR, 2017.
15 Government of Canada, k. D.a.
16 Université de Montréal, 2017b; Government of Ontario, 2017.
17 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
18 Ibidem.
19 Ibidem.
20 SJR, 2017 (cf. Methodology of the Cambrian AI Index).
21 Ibidem.
22 CIFAR, k. D.
23 Shead, 2017.
24 MILA, k. D.
25 Ernst & Young, 2018: 45.
26 Government of Canada, k. D.b.
27 Smith, 2018.
28 Asgard Human Venture Capital/Roland Berger, 2018 (cf. Methodology of the Cambrian AI Index).
29 Gagné, 2018.
30 CB Insights, 2017a (cf. Methodology of the Cambrian AI Index).
31 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index).
32 IFR, 2017 (cf. Methodology of the Cambrian AI Index).
33 World Economic Forum, 2017: 82–83 (cf. Methodology of the Cambrian AI Index).
34 Aubin, Freedin, 2017.
35 CanLII, 2015.
36 CSA, 2017.
37 Government of Canada, 2018a.
38 Government of Canada, 2017.
39 Government of Canada, k. D.c.
40 Ibidem.
41 Government of Canada, 2018b.
42 Ibidem.
43 Ibidem.
44 Ibidem.



Japan
On the way to “Society 5.0” with AI

- Interministerial AI strategy and numerous government initiatives for attainment of *Society 5.0*
- Three research institutes researching specific AI application areas
- *Cross-appointment system* and reforms for increased permeability between research and industry
- Adapted copyright law for *text and data mining* and adaptation to EU GDPR
- Deregulation in special regulatory zones *(sandboxes)* and geographically defined *strategic special zones*
- But: Hardware focus of large corporations (IoT) and only a few AI startups

I.) Introduction

“Abenomics”, Premier Shinzō Abe’s ambitious economic programme, has two key objectives. One is sustainable growth. The other is nothing less than mankind’s evolutionary move towards the “super-smart society 5.0.”[45] “Society 5.0 is a human-centred society that reconciles economic progress with the solution of social problems through a system that integrates cyberspace and physical space to a very high degree.”[46] The fact that machines are increasingly taking over people’s jobs is less cause for concern in Japan than for hope. For the population is aging and shrinking, especially in rural areas. Since immigration is very limited for various reasons (less than two percent of foreigners in 2016),[47] AI is intended to help compensate for a shrinking working population. Consequently, the focus is on practical fields of application which fundamental research is intended to serve: 1) productivity, 2) health, care and wellbeing, 3) mobility and 4) security.[48]

AI-supported robots are to be used primarily in geriatric care,[49] which is also based on a cultural openness to non-human forms of intelligence.[50] AI technology should be understood as a service *(AIaaS)* based on large amounts of data from the Internet of Things (IoT), as the strategy presented in March 2017 explains.[51]

For the 2018 financial year alone, the government has planned total investments of around 580 million Euro in the AI sector, which represents an increase of 30 percent over the previous year, but which the Japanese press still considers to be too low.[52]

The globally operating Japanese corporations are strong in the hardware sector, but lack software innovations. They try to buy these abroad, as there are hardly any AI startups operating in the country at the moment. There is also a lack of training for AI talents, but research is internationally isolated. If, however, AI research support is successful, the country catches up in terms of software development and the state regulation measures become effective, Japan has the potential to become a world leader in AI in the areas of industrial production, medicine and mobility.

II.) Requirements for AI

With around 118 million, Japan has comparatively many Internet users (fourth place after China, India and the USA),[53] however, due to the continuing negative demographic trend, the population is ageing and shrinking. The country ranges more in the midfield in terms of access to and quality of public data (sixth among the twelve countries surveyed).[54] Of the 500 strongest computers worldwide, 36 are in Japan (third place after China and the USA). One of them (ABCI) currently ranks fifth in the top 500.[55] In the strategically important semiconductor industry, four companies[56] generated sales of around 30 billion Euro in 2017, which represented around 17 percent of the sales of US companies.[57] The 2018 budget therefore foresees investments for "R&D in AI chips of high efficiency and speed through industry-government-science cooperation" at an amount of 77 million Euro. In turn, investments of 17 million Euro are planned for research into quantum computers and chips, and around 15 million Euro for the establishment of an "open platform for nanotechnology and materials research".[58]

The talent pool for AI is valued at 210 Master students who graduate annually at computer science institutes, and rather small compared to South Korea.[59]

III.) Institutional framework

Shinzō Abe and his party have a comfortable majority in both houses of parliament with regard to implementation of *Society 5.0*. The strategies of most ministries include references to AI, such as the *Integrated Innovation Strategy* and the *Japan Revitalization Roadmap*.[60]

The framework conditions for research and development of innovations as well as the allocation of budget and personnel are set by the "Council for Science and Technology and Innovation" (CSTI). The CSTI is chaired by the Prime Minister and the individual sector ministries follow the guidelines of the CSTI.[61] Already in April 2016, the "Strategic Council for AI Technology" was founded on the instructions of Shinzō Abe, which presented an AI strategy in March 2017. The Council considers itself a "control tower"[62] that coordinates the efforts of various ministries. The coordinated ministries are: 1) Ministry of Internal Affairs and Communications, 2) Ministry of Education, Culture, Sport, Science and Technology, 3) Ministry of Economy, Trade and Industry. Coordination includes the research centres subordinated to the ministries as well as the "Japan Science and Technology Agency" (JST) and the "New Energy and Industrial Technology Development Organization" (NEDO).[63] The CSTI also includes representatives of the Ministries of Health and Labour, Land, Infrastructure, Transport and Tourism, as well as Agriculture and Fisheries, which have large amounts of data at their disposal,[64] as well as representatives of universities and the industry association *Keidanren*. The Ministry of Defence has so far only played a minor role.

In addition to promoting R&D, the Council coordinates with the industries that use AI *(exit industries*) and promotes the social fields of application for AI within an industry coordination body. The AI strategy also calls for an ambitious industrial strategy (*Industrialization Roadmap*), which combines the "wisdom of industry, science and government" to arrive at "consistent approaches" in terms of research, commercialisation and social implementation of AI.[65]

Numerous proposals and initiatives for ethical AI with positive basic tenor: Already in May 2016, the Advisory Council for AI and Human Society was established on the initiative of the CSTI. It consists of twelve members from the fields of engineering, philosophy, law, economics and social sciences. Its report of March 2017 takes a critical look at ethical, legal, social and economic considerations, as well as the influence of AI on education and research, but comes to the conclusion that the positive aspects clearly predominate. New forms of interaction between man and machine are an opportunity to rethink the concept of humanity.[66] The Council also proposes that an *Institutional Review Board (IRB) on AI* be established at all universities.[67] International rules and standards for AI were adopted by the Ministry of Internal Affairs and Communications (MIC) in 2016 at the G7 meeting of ICT ministers.[68] In addition, the *Japan Society for Artificial Intelligence* has developed principles for ethical AI.[69] The lack of diversity (gender, age, origin, language) within the research and development teams in Japan could become a problem for development of neutral *(unbiased)* algorithms.

IV.) Research and Development

In absolute figures, total R&D spending in 2016 amounted to around 140 billion Euro (third place among the twelve countries surveyed). The public sector contributed only around 22 percent of this sum, the lowest of all the countries surveyed. CSRankings rates the Computer Science Institute at the University of Tokyo as the only Japanese university AI institute in the country.[70] Since 2016, 30 faculty members have been actively researching in AI areas at this institute[71] and supervising approximately 90 doctoral candidates in this field every year.

The three non-university AI research centres AIST, RIKEN and NICT are "*integrated administrative institutes*" subordinated to various ministries. They employ numerous researchers, but do not offer any training or educational courses. Moreover, there are more than 70 robotics laboratories nationwide,[72] some of which also deal with AI applications.[73] Elderly gentlemen dominate the management of these research labs, which in turn hardly cooperate with each other. Moreover, the higher education system is underfunded and becomes less and less efficient.[74] In 2017, researchers in various fields have been able to issue 2.800 citable AI publications (fourth place among the twelve countries surveyed). However, their overall influence was rather small (sixth place out of twelve).[75] Only publications on *Computer Vision* and *Pattern Recognition* (fourth place worldwide) and Human-Computer Interaction (fifth place worldwide) had a noteworthy worldwide influence.[76]

In order to implement *Society 5.0,* Prime Minister Abe's government intends to increase total R&D spending to one percent of GDP,[77] to fund three research centres for concrete AI applications in four areas of activity, train AI talents, increase permeability between business and science and overcome the international isolation of the research sector.

Research areas and instruments

In the centre of state funding of AI research are three research centers,[78] that work interdisciplinary and collaborate with each other. These research centres are also planned to be used as "research hubs" for "open innovation" created by cooperation between industry, government and science (by other universities).[79] According to the *Industrialization Road Map*, there are clear planning guidelines for roles, timelines and expected results of these centers.[80] They will focus on

research in four strategic application fields (productivity, mobility, health, safety). This involves approaches that must be consistently pursued from fundamental research through to social implementation. On the other hand, there are approaches for which a short-term monetarisation and thus a commitment of the private sector is not expected, or approaches in cooperative areas, such as international standardisation and common infrastructure technology.[81] From 2020, the results of the individual centres are to be combined in cooperation with companies and ministries to form "integrated systems".

The *Artificial Intelligence Research Center* (AIRC) at the AIST Institute considers itself a "central contact point for the promotion of large-scale research"[82] and has at its disposal 123 million Euro (2016), the largest budget among the three centres mentioned above. This is expected to almost double in 2019 to around 212 million Euro.[83] On the basis of *Deep learning* and neural networks twelve teams are performing research on the interaction of AI and IoT, among others, as well as pattern and image recognition (for medicine or security). According to AIST information, the world's largest open AI computing infrastructure (ABCI) is available to AIST.[84] AIST also maintains a joint AI laboratory with NEC and partnerships with foreign institutes such as the DFKI in Germany.

The *Center for AI Development* (AIP) is part of the RIKEN Institute for Physics and Chemistry governed by the Ministry of Education (MEXT). More than 50 teams do research on fundamentals, "goal-oriented technology research" and "AI in society".[85] The AIP will have an important role to play, especially in the development of AI-supporting "all-purpose infrastructure technology" for the purpose of "revolutionising industrial production", for medical diagnostics and damage limitation in the event of natural disasters.[86] In 2016, around 56 million Euro were available for these areas.[87] The AIP cooperates with NEC, Toshiba, Fujitsu and Fujifilm through separate, respective AI centres. Also under the authority of the Ministry of Education (MEXT) is the *Japan Science and Technology Agency* (JST), which in turn runs programmes for the promotion of "strategic fundamental research" related to AI. A laboratory for interlinking of various AI projects both of the research institutes and the universities (*AIP Network Lab*, *PRISM*)[88] is a particularly noteworthy project in this context.

The *National Institute of Information and Communication Technology* (NICT) reports to the Ministry of the Internal Affairs and Communications (MIC) and was endowed with around 17 million Euro in 2016. On the one hand, research is being carried out there on the development of "universal communication technology".[89] On the other hand, CiNet is also located there and engages in applications of neurosciences in computer science, interfaces between brain and machine, and robotics for medical applications, which "helps us understand how humans and robots can best coexist in future."[90]

Counteracting the lack of AI talents is one of the most urgent challenges because by 2020 the METI Ministry of Economics expects a shortfall of about 48,000 people in "leading IT human resources".[91] These are divided into three groups: those that 1) solve basic AI problems (especially in the fields of information technology, robotics, *Natural Language Recognition*, neurosciences), 2) translate AI fundamentals (e. g. in algorithms, database architectures and programs), 3) are able to apply and use AI practically in industries and services.[92]

The first two groups are to be expanded through attractive salaries, favourable research conditions and contents for domestic and foreign researchers. Young AI researchers, in particular, are intended to benefit from this and to access funds, for example through JST programmes.[93] The third group needs AI further training and overall improved training and education in mathematics and IT subjects. The exact needs and strategies for this are to be clarified in a discourse between industry and science under the auspices of the METI Ministry of Economics.[94]

To date, the degree of cooperation between universities and industry has been rather low (sixth place among the twelve countries surveyed).[95] An important instrument to improve this is the *cross appointment system,*[96] which allows research-

ers from universities to also work part-time at national research institutes or in the private sector. In return, researchers from the private sector are allowed to work part-time at universities. New subsidy mechanisms are also intended to benefit universities that implement "management reforms" and seek funding from the private sector. At the same time, companies are to be encouraged to invest more in long-term research projects at and in cooperation with universities[97] and establish so-called *Moonshot initiatives*.[98]

Moreover, in 2016, the Ministry of Economics (METI) stated that Japan was isolated from the global flow of researchers and research funds.[99] Therefore, the immigration requirements for highly qualified foreigners and the underlying points system were revised and updated in 2017.[100] Now, researchers are permitted to take on multiple employment, obtain permanent stay permits much faster, initiate family reunion and obtain work permits for their partners. In the field of AI, research partnerships have also been agreed, for example with Israel[101] and Germany[102]

V.) Commercialisation

In addition to cooperation with the aforementioned centres, many of the globally operating corporations (Toshiba, NEC, Hitachi, Sony, Mitsubishi Electrics, Fujitsu, Canon, etc.) conduct their own application-oriented research programmes on AI.[103] According to government information, the private sector invests around 4.5 billion Euro in technology per year.[104] On average, between 2015 and 2017, 5.17 percent of internationally enforceable patents came from Japan,[105] which puts the country in second place in the world. Despite this ranking, the gap to the USA, who are at first place, is still enormous, since around three quarters of the mentionend AI patents in the same period came from the USA.

Although Japanese companies continue to be leading in the production and export of robots, this position is threatened because manufacturers have invested too little in software development.[106] The concept of *open innovation* has not yet been sufficiently adopted by the corporations.[107] At the same time, only few impulses are generated by the domestic innovation ecosystem. Asgard and Roland Berger only count 113 AI startups (USA: 1,393, China: 383),[108] of which CB Insights considers at least two to be among the most influential AI startups in the world, i. e. "Preferred Networks" and "LeapMind".[109] Similar to South Korean conglomerates, Japanese corporations buy innovation abroad, such as Toyota in Silicon Valley.

The Abe government supports AI commercialisation alongside its commitment to global industry standards for industrial robots under the *New Robot Strategy*,[110] through adjustments in copyright law, an EU-compatible data protection law, accelerated or suspended approval procedures, startup support and tax relief for modern IT procurement.

Regulation: From January 2019[111] an already resolved extension of copyright law will apply, which through three new articles permits the use and further processing *(text and data mining*) of protected contents by commercial and non-commercial AIs even without the consent of the authors (*fair-use* principle).[112] Access to large amounts of data is important to improve the self-learning capabilities of machines. A similar regulation is currently initiated in Singapore and Canada. The legal framework is also to be extended for copyright of products created by AI (e. g. texts, music).[113]

In May 2017, the *Act on the Protection of Personal Information* was also revised in order to promote the collection and sharing of data while at the same time decoupling them from personal data and processing them anonymously. The revised version has many similarities with the EU GDPR. Against this background, the EU has put Japan on a "white list" of countries with data protection standards comparable to the high standards of the EU.[114] This promotes global integration of the country, as Japan, unlike China, allows its AI products to be exported to the EU.

A law adopted in June 2018 allows companies to develop innovative pilot projects within previously

approved and clearly defined boundaries *(sandboxes*). Within these deregulated test environments, companies can try out new technologies and business models and generate data. If the pilots are successful, the government can extend the same (de-)regulation to the entire country. For this purpose, an office was specifically established to coordinate the application process.[115] The establishment of geographically defined *National Strategic Special Zones* is aiming in a similar direction.[116] At ten locations in the country tax relief is granted for new companies settling there and regulations are relaxed or repealed – for example in the field of mobility or medical research – in order to strengthen regions outside Tokyo and develop interesting "test cases" for the country. In 2016, for example, the city of Senbocu created such a test case for driverless buses.[117] In terms of regulation of autonomous driving (up to level 4), a strategy already worked out in 2016 is currently being specified[118] and the world's first functional system of driverless taxis will probably be operating in Tokyo by the 2020 Olympic Games.[119]

In order to make the country the central "hub" for regenerative medicine, allocation of *National Strategic Special Zones* as well as the approval procedures for medications and medical devices have been revised. As a result, Japan has the fastest approval procedures in the world.[120]

Support of startups and companies: The low number of AI startups is due to the generally small startup scene. Traditionally, society has a rather high risk aversity, is self-regarding and many of the existing skilled workers are absorbed by the large technology groups.[121] This in combination with a restrictive immigration policy makes it difficult for startups that were founded despite these unfavourable conditions to find good staff. To make matters worse, startups have virtually no private startup capital and an exit by purchase is the exception (rule: IPO).[122] However, due to the number of founders returning from abroad and the increase in *corporate venture capital*[123] the number of startups is rising, nevertheless. In order to promote this trend further, the government is paying into the "500 Startups" fund. Furthermore, in 2018, the Ministry of Economics approved a new incubator programme that was launched to found a total of 20 companies with a market value of more than one billion US dollars *(unicorn companies*) by 2023.

In addition, since May 2018, the government has reduced property tax rates for small and medium-sized companies investing in "*ICT*, *robotics* and *cloud tools*".[124] Apart from that, companies of all sizes are going to receive tax relief if they procure "advanced IT."[125]

The state as user: In terms of procurement of advanced technology, the public sector is in the midfield compared to other countries (together with Finland, it ranks eighth among the twelve countries surveyed).[126] Nonetheless, the country strives for becoming the most advanced IT nation in the world, based on the *Basic Act for the Advancement of Public and Private Sector Data Utilization*. In accordance with the aforementioned law, the entire administration is to be digitised and public and private data made available for use to the private sector. The concept of "Society 5.0", in which AI will permeate all areas of life, is superior to the law, so that this concept will certainly bring along further demand from the state. The results in the "Security" research field serve the disaster control authorities in forecasting, limiting damage and initiating rapid reconstruction.[127] There are further AI projects carried out by the military (AI-based archive management as a pilot project for the entire administration)[128] and the police (image recognition, detection of financial fraud).[129]

45 Cf. Government of Japan, 2018a, b.
46 Cabinet Office, k. D.
47 Migration Policy, 2017.
48 Strategic Council for AI Technology 2017: 4.
49 Government of Japan, 2018b: 5.
50 Ito, 2018; Newsweek, 2017.
51 Strategic Council for AI Technology 2017: 4.
52 Japan Times, 2018a.
53 World Bank, 2016 (cf. Methodology of the Cambrian AI Index).
54 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index).
55 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index).
56 Toshiba, Sony, Renesas Electronics, ROHM Semiconductors.
57 Statista, 2018 (cf. Methodology of the Cambrian AI Index).
58 MOF, 2018: 7.
59 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
60 See also Waldenberger, 2018 for an in-depth overview of *Society 5.0* initiatives.
61 Cf. Harayama, 2017: 2.
62 Strategic Council for AI Technology 2017: 3.
63 Cf. governance structure of the Council in: NEDO, 2017: 12.
64 Strategic Council for AI Technology 2017: 4.
65 Ibidem.
66 Advisory Board on Artificial Intelligence and Human Society, 2017: 18.
67 Ibidem: 23.
68 These are: Transparency, user support, controllability, security, data privacy, ethics and responsibility. Cf. MIC, 2017.
69 Cf. AI-ELSI.
70 Next Generation Artificial Intelligence Research Center. Cf. Tokio University, k. D.
71 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
72 The Robot Society of Japan, k. D.
73 See, for example, University of Tsukuba, k. D. or the well-known director of the Intelligent Robotics Lab at Osaka University, Prof. Hiroshi Ishiguro.
74 Harayama, 2017: 8 ; Nippon, 2017.
75 SJR, 2017 (cf. Methodology of the Cambrian AI Index).
76 Ibidem.
77 Harayama, 2017: 19.
78 See Annex 1 for an overview of the research areas and equipment as well as institutional allocation of the AI research centers.
79 Ibidem.
80 Strategic Council for AI Technology, 2017: 21 f.
81 Ibidem: 8.
82 AIST, 2017: 4.
83 Japan Times, 2018b.
84 AI Bridging Cloud Infrastructure, https://abci.ai/.
85 See Annex 1 for an overview of the research areas
86 Strategic Council for AI Technology, 2017: 21f. See also RIKEN, k. D.
87 Harayama, 2017: 17.
88 JST, k. D.
89 NICT, UCRI, k. D.
90 NICT CiNET, k. D.
91 Strategic Council on AI Technology, 2017: 10.
92 Ibidem: 22.
93 JST, 2018.
94 METI, 2018c.
95 World Economic Forum, 2018: 160–161 (cf. Methodology of the Cambrian AI Index).
96 Cf. METI, k. D.
97 Cf. METI, 2016.
98 Prime Minister's Office, 2018.
99 METI, 2016: 1.
100 Immigration Bureau of Japan, 2017.
101 METI, MoEI, 2017: 3.
102 METI, 2017b.
103 Cf. Overview of individual projects of the companies in: EU-Japan Center, 2016: 20 ff.
104 Japan Times, 2018a.
105 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index).
106 EU-Japan Center, 2016: 11.
107 EU-Japan Center, 2017: 18.
108 Asgard Human Venture Capital/Roland Berger, 2018 (cf. Methodology of the Cambrian AI Index).
109 CB Insights, 2017b (cf. Methodology of the Cambrian AI Index).
110 Cf. METI, 2015.
111 Jones Day, 2018.
112 European Alliance for Research Excellence, 2018.
113 Japan Times, 2016.
114 Cf. IAPP, 2017. There also a comparison of the EU GDPR with the *Act on the Protection of Personal Information.*
115 Government of Japan, 2018b: 9.
116 Ibidem.
117 Japan Local Government Center, 2016.
118 METI, 2018a.
119 Guardian, 2018.
120 Government of Japan, 2018b: 10.
121 Cf. Asakura, 2017.
122 EU-Japan Center, 2017: 17.
123 Ibidem.
124 Government of Japan, 2018b: 13th
125 Ibidem: 14.
126 World Economic Forum, 2017 (cf. Methodology of the Cambrian AI Index).
127 Strategic Council for AI Technology, 2017: 21.
128 Japan Times, 2018d.
129 Japan Times, 2018c.

Israel

Startup Nation and Knight of the Cognitive Age

- Doubling of research expenditure by foreign corporations
- Military as a talent factory and innovation driver
- Commercialisation of research by *Technical Transfer Companies*
- Support programmes and incentives for startups and multinational corporations
- But: scaling and added value from AI application research is generated abroad (especially in the USA)

I.) Introduction

In Israel, the highest density of researchers and the highest share of research expenditure in the gross domestic product (GDP) in the world meet an innovation ecosystem ("Silicon Wadi") in which science, business and government (military) closely cooperate. With only about eight million inhabitants, there are now more than 360 AI startups, which, after the USA, have at their disposal the second highest density of venture capital worldwide. For all these developments, there has been no need for an AI strategy so far, yet such a strategy is now apparently in progress.[130]

Like the US and China, Israel can be viewed as a "*knight of the* cognitive *era*", since "defense-based innovations that radiate into academic and private fields and enable a range of commercial applications".[131] In the absence of domestic Internet giants, research institutions and start-ups are adopting a network approach with a highly international orientation, but a focus on the USA, above all. Globally operating tech companies, such as IBM, Google, SAP and Samsung, are present with research centers and account for a large proportion of research spending. At the same time they take over local start-ups. This promotes innovation but at the same time it also

means that scaling and added value of applications and developments is generated mostly by multinational companies and hardly by local companies.

II.) Requirements for AI

The country has comparatively few Internet users (around 6.8 million, only Finland and Singapore have fewer).[132] In terms of access to and quality of public data, Israel only ranked 28th in the world in 2016 and is roughly on a par with India in the countries surveyed.[133]

So far, none of the commercially available Top 500 supercomputers are in operation in Israel,[134] which could prove to be a strategic disadvantage in the further development of AI in the country and in comparison with other major AI players, as a senior NVIDIA employee warns.[135] At the computer science institutes in which AI research has been actively performed since 2016, about 560 Master's students graduate annually. This is a comparatively large pool of talent (ranked fourth after the USA, China and Great Britain) and impressive considering Israel's small population.[136]

III.) Institutional framework

Although Prime Minister Netanyahu speaks on AI in public and envisages economic opportunities in the fields of medicine, cyber security and mobility,[137] his office refers to the *Israel Innovation Authority* (IIA) as the competent authority (November 2017).[138] So far there are no signs of a coherent interdepartmental AI policy, which might change with the development of an AI strategy.

As successor to the *Office of the Chief Scientist*, which had existed since 1969, the *Israel Innovation Authority (IIA*), which reports to the Ministry of Economics and Industry, was established in 2016[139] and was granted funds of around 380 million Euro.[140] It is expected create and strengthen the necessary infrastructure and the required framework conditions to support innovation and technology development. Moreover, the authority monitors all state-funded industrial R&D. In addition to the IIA, the Ministry of Science, Technology and Space, the Planning and Budget Committee of the *Council on Higher Education* and the Ministry of Finance are involved in the formulation and/or implementation of guidelines for innovation and technology industries. The Prime Minister's office manages the relevant sector ministries for autonomous driving and digital health programmes[141] and the Ministry of Defense develops and procures AI technology for the military. There is also a digitisation strategy in place, referred to as *Digital National Initiative* that the Ministry of Social Equality presented, but which is not mentioned in AI.

IV.) Research and Development

The country has the highest density of researchers (8,250/one million inhabitants)[142] and the highest research expenditure in relation to its GDP among all the countries surveyed (currently more than four percent).[143] Total expenditure on research and development has more than doubled in the last ten years.[144] In absolute figures, however, they amounted to only around 12 billion Euro in 2016 (eighth place among the twelve countries surveyed), with the share of the public sector in these expenditures declining.[145] More than 65 percent[146] of research spending originated from foreign private donors in the form of research centres, mainly US companies such as Intel, Google or Qualcomm. Roland Berger estimates for 2016 that "almost every major IT company in the world" will operate research centres in the country, including Deutsche Telekom and SAP.[147] The total number of research centres is estimated at about 300.[148] This is a blessing in disguise, as it promotes research in the country and creates jobs in R&D, on the one hand, but at the same time absorbs many AI talents whose developments are primarily scaled and translated into value by US companies.[149]

Research areas and instruments

In the absence of an AI strategy, there is no dedicated AI research funding, either. Due to the dominance of foreign research institutes, the commercial application research predominates.

At public universities, research is carried out into AI fundamentals and applications, which the state only supports with investments in framework conditions. A single governmental (Israeli-French) science program supports research on the application of AI for "digital agriculture" on a small scale.[150]

Although research on AI has been going on since the 1980s and Israeli researchers have already won the prestigious Turing Award,[151] five times (of 62), they produced a total of only 225 citable AI publications, whose worldwide influence also remained rather small (H index 132, ranking them seventh among the twelve countries surveyed).[152] This is due on the one hand to the fact that the number of scientific publications is generally decreasing, and on the other hand to the fact that many computer science publications are only presented at conferences and are therefore not effective for the H-Index.[153] At the same time, the research universities are very focused on the application and commercialisation of their results. CSRankings currently identifies six information technology institutes,[154] in which about 80 faculty members have been actively researching AI since 2016. It is estimated that they supervise 240 doctoral candidates per year. The *Israeli Association for Artificial Intelligence*, on the other hand, lists eleven public AI institutes as well as a number of industrial researchers, AI laboratories and companies in an overview.[155] What they have in common is good international networking with universities and companies doing research in AI.[156]

The *Hebrew University* stands out from this research landscape, researching at various institutes with a total of around 40 doctoral students and thus having the largest number of AI researchers.[157] Interdisciplinary centres conduct research there on algorithm designs and together with Intel and the *Technion University* on *Machine learning* and new computer architectures. The Faculty of Computer Science also conducts research in the following fields of application *Cyber security*[158] and cooperates with the Fraunhofer Institute, among others. The second largest number of AI researchers (about 30 doctoral candidates[159] and at least 15 professors) work on AI at faculties of the *Technion University;*[160] the Faculty of Computer Science is active among other things, in basic research on *Deep Learning* (theory of neural networks).[161] In October 2018, an AI centre was also opened together with Intel, which intends to do research on *Natural Language Processing*, *Deep Learning* and hardware optimisation for learning algorithms.[162] A total of about 22 doctoral students[163] research at the *Tel Aviv University* including on *Machine learning* (in cooperation with Yandex) and *Optical Signal Processing* and image recognition. For the "Smart Cities" application field, cooperation with Stanford University is maintained.

Within the multiannual funding framework of the *Council for Higher Education* (2017 and 2021), around 480 million Euro will be used to support the development of a "national research infrastructure" in which the areas of IT and *big data infrastructure* are just as important as the training of specialist personnel in various fields. These areas include life sciences (personalised medicine), quantum physics, chemistry (materials), social sciences and humanities. Around 170 million Euro will also be used to support research and the number of students and faculty members in precisely those areas that "the market needs", i. e. electronics and software engineering, information technology and IT.[164]

V.) Commercialisation

Since the 1990s, Israel has developed into a high-tech and innovation location and has become the brand of the "Startup Nation". Asgard and Roland Berger have counted an impressive number of 362 AI startups (third place among the twelve countries surveyed), of which CB Insights considers four (OrCam Technologies, Workey, Twiggle and Prospera) to be among the 100 most influential startups worldwide. The *Israel's State of AI* report counts 950 startups that use or develop AI and estimates that by 2018 they will have cumulatively raised around 3.8 billion Euro through *Market Exits*.[165] CB Insights assumes that four percent of all *private equity deals* concluded worldwide in 2016 took place in the field of AI in Israel (third place after the USA and Great Britain).[166]

In addition to the investment activities of venture capital funds and the establishment of R&D centres in Israel by foreign groups on the basis of incentives and tax relief, the current good position in AI commercialisation is primarily attributable to the following further points: 1) Influs of scientific and technical talents from the former Soviet Union, 2) successful technology transfer from science and the military to the private sector. In the global AI race, however, the country is coming under increasing pressure, to which the government is responding with new initiatives.

The lack of well-trained personnel "is the main obstacle to Israel's growth and competitiveness," states the IIA, estimating the shortage of engineers and programmers for the next decade at up to 10,000.[167] In the past, the the innovation and technology sectors mainly benefited from academics and state industry workers moving into the private sector, and the arrival of tens of thousands of Jewish engineers from the former Soviet Union. Both sources of young talent have dried up in the meantime.[168] In addition, the share of science graduates in the total number of graduates fell from 13 percent in 2004 to 8.7 percent in 2014.[169] Enforced by the increasing global competition, all this has led to a shortage of AI talent whose supply in Israel can hardly keep up with demand in the country.[170] On the one hand, the country's scientific institutions are responding to this by expanding the range of courses they offer in AI.[171] On the other hand, the *Center for Absorption in Science* under the Ministry of Return and Immigration *(Alija*) continues its incentive and support programmes for support of Jewish "returning" specialists and scientists from all over the world as well as companies that integrate them. Besides, the *Innovation Authority* intends to promote extracurricular training programmes relevant to the high-tech industry ("*Coding Bootcamps*").[172]

The military as innovation driver In spite of all the above, the most important talent factory for the high-tech industry is probably the military, which every citizen must join and which has been an important driver of innovation and technology since the 1970s. A highly effective system has evolved to identify top talent and involve them in sophisticated high-tech training programmes equipped with the most advanced technology platforms and extensive resources (especially data).[173] The research and development carried out there serves as a de facto training center and incubator for AI talents.[174] When reserve forces are deployed, others return with extensive AI or digital experience and act as mentors: a reinforcement system for knowledge transfer in both directions. Many of the country's leading high-tech startups were therefore founded by partners who had met during their time in the army.[175] However, the number of recruits is currently falling for demographic reasons.

Technology transfer from universities to the private sector: Together with the USA, Israel is the world leader in cooperation between industry and universities.[176] An important reason for this are commercialisation companies (*technology transfer companies – TTC*), which were founded as subsidiaries of universities, colleges or hospitals. The role of these companies is to seek, develop and market the know-how accumulated in their institutions, to transform a patent into a commercial product and to help set up startups.[177] For example, the well-known AI startup Mobileye, which was taken over by Intel for around 13 billion euros, was a spin-off of the TTC of Technion University.

The technology transfer process follows some basic principles: (a) Researchers are obliged to report an invention to the TTC of their university. If the TTC gives a positive assessment of the invention's commercial potential, it can apply for a patent and develop a marketing strategy for the invention in order to identify potential trading partners (or licensees) who might be interested in the invention. It negotiates licence agreements with them under which commercial partners can further develop, exploit or market the invention. The revenues from royalties payments and/or royalties from licensees are shared between

the inventors and the research university.[178] Among the renowned university TTCs are the *Yeda Research and Development Company Limited* ofthe *Weizmann Institute of Science* and the *Yissum Research Development Company of* the *Hebrew University of Jerusalem*. This model puts Israel in fourth place (among the twelve countries surveyed) in terms of the number of AI patents registered in the country and internationally enforceable. However, UNESCO estimates that since 2002 almost 80 percent of all applications to the Israeli Patent Office have been filed by foreigners, in particular through the research centres of US companies. Intellectual property therefore primarily migrates abroad.[179]

Promotion of startups and companies: The *Innovation Authority* is the largest public investor in AI startups with its programmes for innovative technology concepts (see text box).[180] The IIA can act largely independently and operates flexible instruments (loan programmes, guarantees, funds and financial instruments).

Support instruments of the IIA „Startup Division“ [181]

Tnufa Incentive: Support for the development of “innovative” technology concepts (up to 85 percent of the costs, maximum around 50,000 Euro over two years)

Incubator Incentive: Up to 85 percent (maximum around 800,000 Euro) of the costs for research and development of “innovative technology concepts” by IIA as an incentive also for private incubators to provide the remaining 15 percent plus premises, legal assistance and partner inventions.

IIA’s *Growth Division* also subsidises the research spending of larger domestic and foreign companies by 20 to 50 percent for cases where new products are developed or existing technologies are upgraded. Long-term R&D projects of local large companies (more than 86 million Euro turnover and more than 200 employees in R&D) can be funded by half.[182] A further ten percent will be taken over if the company invests in the country’s periphery. The number of foreign research centres is also to be further increased, particularly in the fields of biotechnology and medicine.[183] Private investors, who are invest in R&D startups can also deduct investments of up to 1.2 million Euro per startup as current expenses from the tax, thanks to the so-called Angels Law.[184]

With regard to autonomous driving, the Ministry of Transport and the Prime Minister’s Office jointly launched a five-year programme in early 2017 for which some 60 million Euro will be made available. The aim is to further develop Israeli industry in this field. Transport technology companies can receive financial support under the programme of up to 50 per cent of their approved R&D costs. 75 percent of the funds will be allocated to a programme which could have an exceptional impact on the rationalisation and improvement of transport. The supported company pays back the money received from the innovation authority through royalties on the sale, but only if it reaches the commercial phase. So far there is no regulation on autonomous driving in the country, but some test tracks for autonomous driving on military premises and abandoned roads have been authorised.[185]

Some 240 million Euros will be invested in the digitisation of all patient files, in a database open to companies and researchers (with SAP SE) and in support for researchers and startups, with the aim of developing preventive and personalised medicine. The government sees this as an important growth engine.[186]

Regulation of the high-tech sector: So far, it has been more the environment in which commercial AI products can be created that has been regulated. In order to remain attractive for high-tech companies, at the end of 2016, the corporate income tax for these companies was reduced from 25 percent to six to twelve percent, depending on the type of company. This change also introduces additional tax benefits for dividends and investment income. In August 2017, a law was also passed on the completion of high-tech mergers and acquisitions, aimed at facilitating

"necessary structural adjustments".[187] A scheme that reduces capital gains tax for domestic companies by four to six percentage points when "new intellectual property is generated, or acquired from a foreign company"[188] can be understood as an instrument for keeping intellectual property in the country.

The state as user: In addition to its role in the training of talent and knowledge transfer, the military itself is an active developer and user of AI, which the military considers to be a "key to survival in the modern world."[189] Thus, the Israeli Armed Forces (IDF) use AI in autonomous drones[190] and the new version of the standard Merkava IV tank. In the area of *cyber security*, the military carries out its own developments, but also buys from domestic startups, which in turn functions as a *pull factor* for startups.[191] Through the digital medicine program *Big data* and AI based on that can also be used in public hospitals.[192]

Ethics – the discussion is still in its infancy: Although Jewish intellectuals have a critical attitude towards AI (e. g. Prof. Yuval Noah Harari),[193] this has not yet translated into institutions or guidelines on ethical AI. After a scandal over the collection of patient data for an AI application, the Knesset has been dealing with data protection regulation in the health sector since the end of 2017. Uri Maklev, chairman of the Science and Technology Committee of the Knesset, said he would further the efforts: "We see the latest technological developments and are enthusiastic advocates of the further development of AI. The use of the technology is a question of human life, and concerns can be dealt with by appropriate regulations and laws."[194] An IEEE report of 2017, however, sees a number of institutions that could deal with ethical AI, and names the Initiative *AI Ethics Open Source,* which is intended to serve as an umbrella for a discussion on this topic in Israel and to develop guidelines.[195]

130 Globes, 2018b.
131 Groth/Nitzberg, 2018: 126.
132 World Bank, 2018 (cf. Methodology of the Cambrian AI Index).
133 World Wide Web Foundation, 2016 (cf. Methodology Cambrian AI Index).
134 Top500.org (cf. Methodology of the Cambrian AI Index).
135 Jerusalem Post, 2017.
136 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
137 MFA, 2018; Netanyahu, 2016, 2018.
138 Jerusalem Post, 2017.
139 The IIA comprises six divisions: *(a) Startup Division, (b) Growth Division, (c) Technological Infrastructure Division, (d) Advanced Manufacturing Division, (e) International Collaboration Division and (f) Societal Challenges Division. Cf. Israel Innovation Authority, k. D.*
140 IIA, 2017a: 30.
141 MoH, 2016.
142 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index).
143 Ibidem.
144 CBS, 2018b.
145 From 0.8 % of the GDP in 2002 to 0.52 % in 2015. Cf. IMRA, 2016.
146 CBS, 2018b.
147 Roland Berger, 2016: 6 f.
148 Cf. IIA, 2017a: 34.
149 UNESCO, 2015: 424.
150 MST/Republique Française, 2018.
151 Cf. Felner, 2016.
152 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
153 UNESCO, 2015: 417.
154 Technion – Israel Institute of Technology, Hebrew University of Jerusalem, Bar-Ilan University, Tel Aviv University, Ben-Gurion University of the Negev, *Ariel University. Cf. CSRankings 2018.*
155 *Cf. IAAI, k. D.*
156 *See also Felner, 2016.*
157 *Singer, 2018.*
158 *The Rachel and Selim Benin School of Computer Science and Engineering, k. D.*
159 *Singer, 2018.*
160 *Cf. IAAI, k. D.*
161 *Technion, 2017.*
162 *Technion, 2018.*
163 *Singer, 2018.*
164 *CHE, k. D.*
165 *Cf. Singer, 2018.*
166 *CB Insights, 2017a (cf. Methodology of the Cambrian AI Index).*
167 *IMRA, 2016.*
168 *Economist, 2016.*
169 *IMRA, 2016.*
170 *Calcalist, 2017a.*
171 *Ibidem.*
172 *IIA 2017b: 6.*
173 *Cf. Business Insider, 2018.*
174 *Cf. Groth/Nitzberg, 2018: 126.*
175 Cf. Naar, 2018. Quoted in: Groth/Nitzberg, 2018: 126.
176 World Economic Forum, 2018: 82–83 (cf. Methodology of the Cambrian AI Index).
177 CBS, 2018a: 2.
178 Cf. Messer-Yaron, 2014.
179 UNESCO, 2018.
180 Top 10 AI investors: Microsoft Accelerator, Office of the Chief Scientist of Israel (Israel Innovation Authority), JVP, Nielsen Innovate, OurCrowd, Magma Venture Partners, UpWest Labs, Aleph, Glilot Capital Partners and Horizons Ventures. Cf. Singer, 2017.
181 Israel Innovation Authority, k. D.
182 IIA, k. D.
183 IIA, 2017: 34.
184 Ernst & Young, 2018: 125.
185 Globes, 2018a.
186 Bloomberg, 2018; Jerusalem Post, 2018.
187 IIA, 2017a: 14 f.
188 Ernst & Young, 2018: 124.
189 IDF, 2017.
190 Breaking News Israel, 2018.
191 Groth/Nitzberg, 2018: 126.
192 MoH, 2016.
193 ZEIT, 2017.
194 Calcalist, 2017b.
195 Cf. IEEE, 2017: 24 f.

United Arab Emirates

On the way to the user country with central support of the public sector

- AI and technology as pioneers for a diversified economy
- The first approach of an AI strategy in the region, the first AI Ministry of State worldwide
- Focus on AI applications through public sector demand and strategic focus on the healthcare sector
- Cooperation with India to develop the mutual potential of both markets for AI
- Ethical issues do not play a role in the government's public deliberations

I.) Introduction

The United Arab Emirates (UAE), which owe the oil and high finance sector their rapid rise to the international stage, have learned their lessons from the growth and crisis cycles of a globally networked economy.[196] Against this background, the country must diversify its economy and compete with technologically advanced neighbors such as Qatar and Iran. In October 2017, the UAE published the rough structure of an AI strategy as one of the major initiatives of the *UAE Centennial Plan* with the goal to make theUAE "the best country in the world" by 2071.[197] According to Sheikh Maktoum, Vice President and Prime Minister of the UAE, this means enabling future generations to "live happier and better lives, in a better environment, with greater opportunities and greater communication with the world".[198] AI plays a central role in this. It is "the new wave" on which, according to Sheikh Maktoum, all "services, sectors and future infrastructures will rely".[199] The UAE is the first country in the Middle East to publish an AI strategy and the first country in the world to appoint a Minister of State for AI. In addition to using AI to achieve the Vision 2071 scheme and improving govern-

ment performance the strategy is to position UAE as a leader in AI investments in a variety of sectors and to generate a new market for AI. However, the methods to achieve all these objectives have not been specified. Nevertheless, Accenture estimates an annual gross value added potential of 160 billion Euro by 2035 for the UAE.[200] As part of the AI strategy, the government will invest in nine sectors: transport, health, space, renewable energy, water, technology, education, environment and transport. The strategy is embedded in a number of other relevant national plans and strategies designed to pave the way for the UAE to become a knowledge-based economy.[201]

II.) Requirements for AI

The AI ambitions of the government are at odds with the country's hitherto unfavorable conditions in terms of the size of existing data pools, the computing power available within the country, and the size of the talent pool. The low population of the UAE is also reflected by a relatively low number of Internet users (2016: 8.4 million), which is lower only in Israel (6.8 million), Finland (4.8 million) and Singapore (4.5 million) among the countries surveyed.[202] Measured by the Open Data Barometer 2016, the UAE also have catching up to do in terms of access to and quality of public data (only ahead of China among the compared countries).[203] Furthermore, not one of the top 500 supercomputers is currently operated in the UAE.[204] Although the country has a focus on building a knowledge-based economy, there were fewer enrolled students in tertiary education across the country than in the smaller Singapore.[205] According to CSRankings, there is also only one institute in the UAE that has been actively researching AI areas since 2016. The AI talent pool is correspondingly small. That this could change in the near future is shown, among other things, by the launch of the country's first AI bachelor's programme at the British University Dubai in 2018.[206] In addition, the country has hosted its first AI summer camps in cooperation with companies such as IBM and SAP[207] and launched the *One Million Arab Coders* initiative,[208] to increase the pool of qualified professionals.

III.) Institutional framework

The federal constitutional hereditary monarchy consists of seven emirates whose executive is the Cabinet. In October 2017, the cabinet was reshaped in the course of the largest "structural change" in the country's history and oriented towards achieving the goals of the *Centennial 2071 Plan*.[209] As part of this reform, new ministries were introduced and structural changes were made to existing ministries. This also implied the establishment of of the world's first ministry of state for AI, which Omar Al Olama has taken over.[210] This restructuring also explains the early stage at which many of the government's relevant strategies still are. As part of the national AI strategy, a ten-member AI council, also headed by Omar Al Olama, was established in March 2018 to monitor the integration of AIs in the government and education sector.[211] The newly established government apparatus reflects the country's ambitions and promises to increase its capacity to act in order to shape technological change in the country.

IV.) Research and Development

In none of the countries surveyed did absolute R&D spending in 2016 turn out to be lower than in the UAE (3.1 billion Euro, or around one percent of GDP). Of the R&D expenditures, 60 percent were financed by the private sector. This value is roughly comparable to France (55 percent).[212] In 2017 only 108 citable documents on AI were published (last place among the twelve countries examined)[213] and their influence remained very limited – while the UAE had a value of 29 in the H index, the USA achieved a value of 437.[214] The reason for this may be the fact that since 2016 only one university institute has actively researched AI.[215] The current weakness of research stands in contrast to the country's ambitions, which Sheikh Maktoum describes as follows: "We believe that science, technology and innovation are the roadmap for building future generations."[216]

Research areas and instruments

R&D is not mentioned in the very concise UAE AI strategy so far. Nevertheless, there are various indications that the country is planning to use science to advance AI in the health sector.

The scientific priority areas of the new research funding strategy 2031[217] aim, among other things, to ensure that all the country's strategic natural resources are made available through national capacity building, promotion of the sustainable energy sector, improvement of water safety and development of an advanced scientific food security system. The health challenges in the UAE are to be mastered by a national science system – however, without describing it in detail. In addition, efforts are being made to develop an advanced industry, to build a system of logistical support based on scientific studies and data, and to create a complex of strategic industries.[218] Although the research strategy does not specify AI in particular, an institution was founded in the form of the *Inception Institutes for Artificial Intelligence* (IIAI), which intends to be active in basic and applied research in AI areas. In the area of fundamental research, the research areas currently planned are the following: *Deep Learning, Reinforcement Learning, Computer Vision* and *Natural Language Processing*. In application-oriented research, the healthcare sector again is given priority, particularly with the fields of *Video Understanding* and *Medical Imaging*.[219]

In order to meet the Institute's claim to global leadership, the IIAI aims to establish state-of-the-art research conditions. This includes: 1) freedom in in academic research, without the pressure of scholarships and teaching, 2) access to data, 3) an advanced computing centre, 4) "extremely competitive" incentives for researchers.[220]

V.) Commercialisation

The economic environment is characterised by a centralised government and a much stronger emphasis on security, protection and stability than on the privacy and freedom of the individual. There are neither AI startups nor significant internationally enforceable AI patents.[221] Robotics and AI are recognised as important trends in the important economic sectors of the country, as the example of the Jebel Ali harbour in Dubai shows.[222] However, the country does not appear in international comparative statistics on the use or manufacture of robots. However, the weak starting position is countered by the ambition to become a leading AI user country. According to a survey by Accenture, half of UAE executives plan to invest in the field of AI next year, putting it second only to the Internet of Things (58 percent).[223] The biggest impacts of AI are expected in the financial services, healthcare, transportation and warehousing industries.[224] In order to tap the potential of technology for politics, the economy and society, the national government as well as the individual emirates have launched various strategy papers in recent months. It will have to show whether the goals set are realistic and whether the government has identified the right instruments for implementation, most of which are still lacking. However, it is emerging that AI is understood as part of a holistic plan of economic development.[225]

Regulations and political objectives: Since the concept was introduced in 1985, more than 30 Special Economic Zones (SEZs) have been established in the UAE.[226] Founded in 1999, Dubai Internet City, one of these SEZs, is now home to technology companies such as Microsoft, Dell and IBM and is the largest information and communications technology hub in the Middle East and North Africa.[227] It can therefore be assumed that SEZs will also play a central role in the economic exploration of AI in the UAE. The instruments with which AI commercialisation is to be achieved in the application areas mentioned remain vague. The multitude of different strategies gives an initial picture of a complex system of objectives with which the government will align future regulations. The strategy to promote the fourth industrial revolution pursues the goal of "strengthening the UAE's position as a global hub for the Fourth Industrial Revolution and increasing its contribution to the economy through the promotion of innovation and future technologies." In addition to initiatives at the national level, the local governments of the seven Emirates have also established

various policies. In particular, the Emirate of Dubai has developed strategic objectives that are not only sector-specific but also technology-specific. These include autonomous traffic systems, 3D printing and data. The *Dubai Autonomous Transportation Strategy* aims to automate 25 percent of transport by 2030 and to achieve an annual economic return of 4.25 billion Euro through increased transport efficiency.[228] The most important goal in the 3D printing strategy is to "ensure that 25 percent of Dubai's buildings are based on 3D printing technology by 2030."[229] The data strategy of Dubai's government pursues the aim of developing and implementing a culture of data exchange and evidence-based decision-making in Dubai.[230] This is particularly targeted at high quality data. In the field of cyber security, a separate strategy pursues five strands of action: 1) increase of public awareness, 2) cyber innovation, 3) cyber security, 4) cyber resilience, 5) national and international cooperation.[231]

Direct support for companies and startups: The only element explicitly promoting an ecosystem is the *Centennial 2071 Plan* referred to as AREA 2071. It is understood as a "room and ecosystem that is geared towards connecting companies, governments, startups, investors, young people and the public with one another in order to shape the future together"[232] The planning and partial implementation of this began already in 2017. Without more comprehensive measures to support a startup ecosystem, the innovative strength and thus productivity of the country's economy will remain limited or dependent on the purchase of innovative technologies from abroad. In this way, the country risks not living up to its ambition of becoming a leading user country.

The state as user: More than in any of the other countries examined, innovation and the use of new technologies are driven by demand from the government apparatus and public procurement. This is also underlined by the results of an opinion poll conducted by the World Economic Forum, according to which the country's government is a global leader in the procurement of advanced technologies and uses this as a targeted stimulus for innovation.[233] This is impressively reflected, among other things, in the plan to have the immigration officials at airports replaced by artificial intelligence by 2020.[234]

The central role of the state as a user of AI is made clear by the cornerstones of the AI strategy as well as in the strategy to promote the "Fourth Industrial Revolution" or the *Blockchain Plan*, which in turn provides for "50 percent of state transactions to be converted into a *blockchain platform* by 2021."[235] The third of the six pillars of the strategy to promote the Fourth Industrial Revolution lists intelligent government services and smart cities. These are used as a basis for the satisfaction and wellbeing of citizens as well as ecological sustainability and improvement of the human lifestyle.[236] VAE's track record in this field is mixed. Masdar City, once a model of an ecological and smart city, is still more a construction site than reality after ten years.[237] At the same time, according to McKinsey, Abu Dhabi and Dhabi are considered leaders in the region in terms of the strength of the Smart City technology base.[238] The *eGateways of* the Emirate of Abu Dhabi (www.abudhabi.ae) already offer over 1,250 government services in 18 different areas, such as transport and real estate. In Dubai, the *Smart Dubai Plan* includes WiFi hotspots as well as networked technology for controlling water consumption and traffic. To develop new technologies for the public sector, the Emirate of Dubai has also launched an initiative called *Dubai 10X* in which 24 government agencies have already participated.[239]

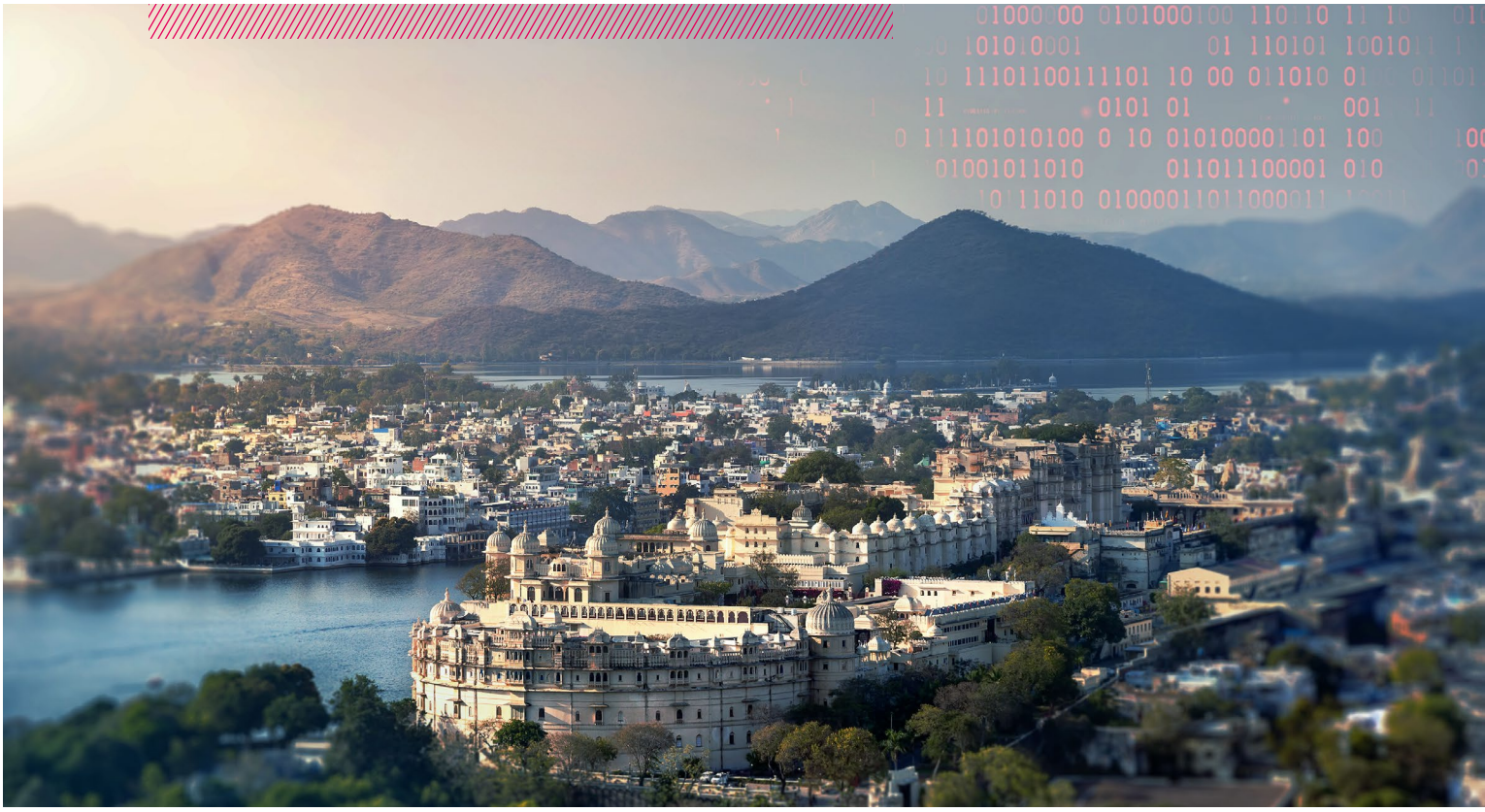
Dubai 10X: [240]
While the number 10 stands for Dubai's claim to be ten years ahead of other world cities, the X stands for "Thinking *Out of the Box*". The *Dubai Future Foundation* initiative provides for the creation of "X units" in each agency, equipped with sufficient resources and staff, with the aim of promoting disruptive innovation and developing so-called *Moonshoot* solutions for the achievement of their goals. The other two components of *Dubai 10X* are for public authorities to scale radical technologies and partner with busi-

nesses and startups. Regulatory obstacles that disruptive companies encounter in such partnerships are to be removed.

The *GovTech Award* also underscores the efforts to integrate innovation and technology into government structures worldwide.[241] The annual prize, has been awarded for the fifth time as part of the *World Government Summit* an event in Dubai chaired by the Emir of Dubai. Each year, the summit develops the next generation of governance systems, focusing on innovation and technology for the public sector.[242]

Despite political support, commercialisation of AI is limited by the small size of the internal market. It is against this background that the signing of an agreement between the UAE and India is to be understood in order to combine "the fastest growing market opportunity in the world, with its talent pool of human capital recognised for innovation – and the UAE, a centre for cutting-edge technologies"[243] From this AI partnership both sides expect economic advantages worth 17.5 billion Euro, which are expected to materialise in the next decade.[244] However, similar to the range of strategies mentioned above, concrete contents and specific implementation instruments are not yet known from this document.

196 Groth, Nitzberg, 2018: 162.
197 UAE Cabinet.
198 Gulf Business, 2017.
199 Elsaadani, Hakutangwi, Purdy, 2018: 5.
200 Ibidem.
201 UAE Government, 2018.
202 World Bank, 2016 (cf. Methodology of the Cambrian AI Index).
203 Open Data Barometer, 2016 (cf. Methodology of the Cambrian AI Index).
204 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index).
205 UNESCO, k. D. (cf. Methodology Cambrian AI Index); Ranking, 2018 (cf. Methodology Cambrian AI Index).
206 Achkhanian, 2018.
207 Masudi, 2018.
208 Dubai Future Foundation, 2017b.
209 UAE Government, 2018.
210 UAE Cabinet, 2017.
211 Zacharias, 2018.
212 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index).
213 SJR, 2017 (cf. Methodology of the Cambrian AI Index).
214 Ibidem.
215 CSRanking.
216 Ministry of Cabinet Affairs & The Future, 2017: 4.
217 UAEGovernment, 2018.
218 Ibidem.
219 IIAI, 2018.
220 Ibidem.
221 In 2017, only three internationally enforceable AI patents came from the country. This already represented the peak value in the history of UAE AI patents. M-CAM, 2018 (cf. Methodology Cambrian AI Index).
222 Dartnell, 2018.
223 Elsaadani, Hakutangwi, Purdy, 2018: 5–6.
224 Ibidem: 14.
225 Groth/Nitzberg, 2018: 162.
226 UAE Free Zones, 2018.
227 Ibidem.
228 Dubai Future Foundation, 2016b.
229 Dubai Future Foundation, 2016a.
230 Dubai Data, 2016.
231 Government of Dubai, Dubai Electronic Security Center, 2017: 19.
232 Area 2071, 2018.
233 World Economic Forum, 2017: 289–299 (cf. Methodology Cambrian AI Index).
234 Malek, 2018.
235 UAE Government, 2018.
236 Ministry of Cabinet Affairs & The Future, 2017: 28.
237 Schulz, 2018.
238 Boland, et al. (2018): 10.
239 Dubai Future Foundation, 2017a.
240 Ibidem.
241 GovTech Prize, 2017.
242 World Government Summit, 2017.
243 Gulf News, 2018.
244 Ibidem.



India
AI for everyone

- AI for the improvement of education, health and other social areas
- Focus on establishment of institutions to catalyse synergies between science and industry
- Planned establishment of multi-actor institutions as nodes of a pan-Indian network of research (CORE) and commercialisation (ICTAI)
- So far hardly any directives to implement the AI strategy, no prioritisation of areas of basic research

I.) Introduction

On February 18, 2018, Indian Prime Minister Narendra Modi opened the *Wadhwani Institute for Artificial Intelligence* at Mumbai University and expressed optimism about the role of AI in solving social problems.[245] As the largest democracy in the world, the Indian AI strategy concentrates on the areas of poverty reduction, education, health and universal speech, embedded both in the larger industrial policy *Make in India*[246] and the broader *Digital India* Strategy[247]. Until now, the country has not been able to fully exploit its considerable potential in AI, for example, its large pool of qualified talents. Microsoft and Google are currently managed by Satya Nadella and Sundar Pichai, both of whom studied in India but then moved to a more promising environment. Despite the existing hurdles, significant technology service companies, such as Infosys and Tata, have already been founded in India. In view of this situation, the government aims to create a formalised pan-Indian network to foster cooperation between science and industry and strengthen the AI value chain.

II.) Requirements for AI

India has over 1.3 billion inhabitants, of whom only about 390 million were connected to the Internet in 2016.[248] This clearly illustrates the growth potential for the domestic data pool and

the internal market for AI applications. At the same time, an estimated 480 Master's students graduate from computer science institutes with a focus on AI each year, compared with over 7,000 in the USA and nearly 2.000 in China (Germany approx. 410).[249] There is also a need to catch up in the availability of machine-readable and openly accessible data: According to the *Open Data Barometer*, in 2016 the country only ranked eleventh ahead of China and the UAE.[250] As these areas improve, large data sets with large sample sizes will accelerate the potential for AI in India. But also the low data processing capacity is remarkable: India only operates five of the 500 best supercomputers in the world, which is far from China's 206 and the 124 of the USA.[251] In semiconductor production, the country is a global player and also dependent on foreign computing power.

III.) Institutional framework

So far, the goals of social progress through AI have been embedded in other government policies and schemes. However, these for their part hardly refer to AI.

Institutions that can substantiate synergies between science and industry are the focus of India's *National Strategy for AI*: *#AIforALL* which was published in June 2018 by the *Policy Think Tank* of the government (NITI Aayog).[252] Although the actual budget expenditure for their projects is unknown, #AIforALL is expected to be implemented promptly. It has strong political appeal in New Delhi, since it was supported by high-ranking government officials at the federal level – an important sign in the federal Indian state system.

The comprehensive strategy is strongly influenced by the federal government structure. Every state in India has strong government and the central government often lacks mechanisms to implement certain policies at the local level. Although laws can only be passed by the Indian Parliament, the executive and regulatory authorities have a wide margin of discretion when it comes to implementation. The national AI strategy needs to be implemented in coordination with the Ministry of Industry and Technology and the Indian Regulatory Authority for Telecommunications. However, it must be noted that in 2019 general elections will be held in India in a polarised political climate that could influence the priorities of the government apparatus.

The *Digital India* programme mentioned above has been allocated almost 420 million Euro by the central government in the latest budget.[253] However, it concentrates mainly on the development of the telecommunications infrastructure and does not yet have a programmatic approach for the targeted introduction of AI. The *Make in India* programme, which is primarily aimed at industrial policy and export promotion, does not make any substantial mention of AI, either.[254]

Leading Indian universities and industrial companies have each organised several conferences to discuss the potential of AI for India. However, these events took place independently of each other. For example, an influential business consortium, the *Confederation of Indian Industry*, will host the *Indian Innovation Summit*: *India AI* in July 2018. The over 70 speakers at the summit, however, were almost exclusively business and government representatives. No representative from civil society gave a speech and only two academics from the field of science made it onto the agenda: the director of the Indian *National Centre for the Arts* and a Brazilian professor from the University of São Paulo.[255]

IV.) Research and Development

In 2015, India spent around eleven billion Euro on R&D, equivalent to 0.6 percent of GDP. India is thus investing the lowest percentage of all the countries compared here.[256] This translates into the lowest number of researchers per million inhabitants (156).[257] As a result, Indian AI research performance was weak across all indicators. According to CSRankings, between 2016 and 2018, there were about 70 professors at 15 institutes who did active research on AI and an estimated 200 doctoral students.[258] In terms of citable publications in AI areas the high quantity

is striking, but this is not in line with their quality. India, for example, only lags behind China (6,214) and the USA (4,673) in the broad field of IT applications and in the AI-focused areas of *computer vision* and *pattern recognition* in terms of the number of citable documents (2,223).[259] Measured in terms of the H index, however, in a quality comparison it only ranks tenth among the twelve countries surveyed (ahead of Finland, but behind South Korea).[260] This is due to rigidities in the academic system and the process of awarding research grants in India, which is strongly administrative and slow, creating incentives for less risky but less effective research.

Research areas and instruments

The AI strategy aims at the creation of two types of networks: on the one hand research excellence centres for AI (COREs), on the other hand international centres for transformative AI (ICTAIs). The COREs will be located at technical universities and will focus on the promotion and financing of AI fundamental research. In contrast to that, the ICTAIs will closely cooperate with the industry to use research to create commercial applications. Using a cloud-based pool of robust data, which COREs and ICTAIs will contribute to and draw on, these centres will form a network whose scaling effects will increase over time. These clusters of research and industry would enable scalable knowledge transfer systems and generate the necessary dynamics to create a basis for the start of a domestic AI industry.

According to the Indian national AI strategy of 2018, COREs and ICTAIs are towork together under the umbrella of the *Centre for Studies on Technological Sustainability* (CSTS), which is to ensure that science and industry move in parallel. To bring all major universities together in one "*Hub-and-spoke*" model, India would ideally need about two dozen COREs, each of which would cost about eight million Euro over a period of five years. The costs of ICTAIs are estimated at 40 million Euro over the same period, which may, however, be partly borne by contributions from the private sector, which the strategy considers to be optimistic.

The main channel for the improvement of AI research is the strengthening and equipping of researchers. The strategy recognizes that in the rapidly changing field of AI, university research must work according to a *fast-failure* model. The aim is to enable researchers to leave a failed project early and smoothly, to take risks and cross borders. As mentioned earlier, there is a lack of powerful or high-quality AI researchers based in India and the thematic focus areas of AI research are still unclear. To address the low availability of *rich data*, it is recommended to use a cloud-based pool of robust data that COREs and ICTAIs can use, but also contribute to. In this way, the centres generate mutual benefits and form a network with increasing scale gains that maximise the potential for generating high-quality data.

#AIforALL – Indian proposals for ethical AI: For Prime Minister Modi and his government the provision of a social security network for the poor population of India enjoys high political priority. Many programmes are subject to the *"Sabke saath, sabke vikas"* framework scheme, which translates as "self-determination for all parts of society". Thus, the Indian AI strategy also focuses on directing AI in areas relevant to social progress. These include education and health care, hygiene and the fight against corruption. India, as a voting member of the G77 coalition, has also spoken out on these issues in international fora.

In addition, the strategy aims for incentives to keep Indian AI researchers in the country. A national AI scholarship programme is currently under consideration, to attract the numerous doctoral students who work abroad and maintain connections to India.[261] However, these parts of the proposal are described only briefly and remain unclear as to their actual implementation. Many of the details of India's AI strategy also remain to be determined by India's political process, which can often be opaque. An example of unclear recommendations are the potential research areas for COREs. These are supposed to concentrate on areas with high potential in

AI fundamental research. However, the strategy lists virtually all components of AI research without prioritising them: "Possible AI focus areas for COREs could be: a) *Sensory AI* (*Computer Vision*, IoT, among others), b) physical AI (robotics, industrial automation, among others), c) cognitive AI *(Natural Language Processing*, further education), d) general AI, e) high-precision learning based on small data sets, f) research on new algorithms (such as advances in cryptography, security), data sets, and g) explainable AI. A CORE can decide to work on one or more [sic!] of the focus areas."[262]

India would be able to formulate a stronger AI strategy if it oriented the list of possible areas towards contextual realities. For example, *natural language processing* in local Indian languages would require collaboration with interest groups at subnational level, as Indian citizens speak different mother tongues in over 20 regions of the country. This already gives India a comparative advantage in the creation of cognitive AI adapted to local contexts, which would be difficult for a researcher in the USA or China to replicate.

V.) Commercialisation

At the heart of AI commercialisation are the ICTAIs. These are intended to act as industrial *accelerators* to catalyse the creation of successful companies and apply basic research. The motivation for commercialisation of AI is the solution of social problems, as formulated by Prime Minister Modi. The ICTAIs focus on the following five areas: healthcare, agriculture, education, smart cities and smart mobility/transport.[263] In each of these areas, intensive efforts are being made to improve affordability and quality for economically weaker parts of society. This is unique as almost all other countries focus their AI strategy more on economic growth than on the prosperity and emancipation of broad sections of the population.

Since the economic liberalisation reforms of 1991, India has seen development of an influential and skilful private sector that largely follows market forces rather than government dictates. This, however, is facing a weak AI R&D landscape, leaving the commercialisation of AI lagging behind their potential. According to a study by Roland Berger and Asgard, there are only 82 AI startups in India (2017), while there are almost 1,400 in the US, 106 in Germany and 35 in Singapore.[264] None of the Indian startups ranges among the Top 100 of the most influential AI startups.[265] This small number, especially compared to the overall size of the country, leads to a small proportion of AI patents that are internationally enforceable. Between 2015 and 2017 on average, only 0.4 percent of the international enforceable AI patents came from India, fewer only from Singapore.[266] Also the number of installed industrial robots per 10,000 employees in the manufacturing industry is the lowest indicator of the degree of automation of the economy among the countries compared here (three compared to 631 in South Korea or 309 in Germany).[267]

Support of startups and companies: At the moment, only little progress by Indian companies and start-ups in AI commercialisation[268] is noticeable and even large technology companies like Infosys and Tata Services are no exception. Also the projects announced by these companies[269] currently appear little innovative, but it is still too early to judge their success or failure. Although Indian AI startups are currently overshadowed by most counterparts in the countries compared here, they have shown resilience in parts of the Indian market and still hold untapped growth potential. For example, the Sigtuple Technologies startup in Bangalore, which uses AI to read medical tests accurately and cost-effectively, raised five million Euro in Series A funding in 2017 and a further 16 million Euro in Series B funding in early 2018.[270] In a country where there is a serious shortage of physicians in many regions, a startup that can help close this gap at low cost has a high potential for scalability. These startups are typically financed by smaller venture capital funds, such as Endiya Partners, which alone have invested 25 million Euro in startups operatingin the fields of *Big Data*, *Internet of Things* and sensory AI.[271] Although such funds do exist, most Indian AI startups do not make significant progress in Series A or B financing.

In 2016, the Ministry of Commerce and Industry launched a programme to directly support start-ups *(Startup India)*. Advantages include accelerated patent filing, tax advantages and simplified application procedures for releases and approvals.[272] *Startup India* also has an investment fund of almost one billion Euro, however, with no mention of the share earmarked for AI startups. India has also proactively signed bilateral agreements in connection with the commercialisation of AI, such as with the UAE in July 2018, to generate over 17 billion Euro of economic value added through AI over the next ten years.[273]

Meanwhile, Google, Microsoft, Bosch Engineering and many others in India have made significant investments in AI to gain access to the large potential Indian customer base.[274] There is certainly reason to be optimistic about the future of AI startups in India, but it remains to be seen whether they will be able to manoeuvre out major investments by international competitors in the coming years.

Regulation: The AI strategy itself does not directly address the issue of the regulatory reform. However, the necessity of combining existing data archives in order to make them machine-readable is mentioned, on the one hand. On the other hand, regulations for commercial applications of online user data and data protection are identified as necessary. India's first national telecommunications policy was established in 1994, shortly after economic liberalisation.[275] The latest update of this policy was adopted by the Indian Cabinet in September 2018 under the name *National Digital Communications Policy* (NDCP). The NDCP aims to attract around 90 billion Euro in private sector investment, although it is not clear how much the NDCP focuses on AI-based technologies.[276] India could benefit from the establishment of a tailor-made regulatory framework for the commercialisation of AI. Since the *Special Economic Zones* (SEZ) Act of 2005, the Indian government has used the SEZ model to promote certain industries.[277] In the future, this model could also be used to create special regulatory zones (*sand boxes*) that can be used for AI commercialisation. However, the Indian Special Economic Zones are facing the great challenge of weak relationships with the rest of the economy. At the same time there are accusations of corruption and that they provoke tax disputes.[278]

Large *social media companies* like Facebook are preparing for negative reference in Indian political discourse for the upcoming elections, which could serve as a stress test for AI-generated filtering of online abuse and harassment.[279]

The state as user: The Indian AI strategy also mentions the possibility of the government as a user of AI, but without providing further details or explanations. With the strong focus on improvement of prosperity through AI, the bureaucratic structure of the government must adapt to that in order to integrate AI, but many basic prerequisites are not yet met. As mentioned earlier, many of the Indian government's data stores have not yet been commented and some data points are not yet machine-readable. In order for the government to start using AI, the first step would be to identify areas where it is possible to conduct short-term AI tenders so that the bureaucratic structure can get used to the use of AI to rationalise different processes. Until these issues are resolved, the Indian government is not well equipped to use AI on a large scale.

245 Government of India, 2018a.
246 Government of India, 2018b.
247 Government of India, 2018c.
248 World Bank, 2016 (cf. Methodology of the Cambrian AI Index).
249 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
250 World Wide Web Foundation, 2016 (cf. Methodology Cambrian AI Index).
251 Top500.org (cf. Methodology of the Cambrian AI Index).
252 NITI Aayog, 2018.
253 Mukherjee, 2018.
254 PTI, 2018a.
255 Confederation of Indian Industry, Government of Karnataka, 2018.
256 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index).
257 Ibidem.
258 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
259 SJR, 2017 (cf. Methodology of the Cambrian AI Index).
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261 Goyal, 2018.
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263 IANS, 2018a.
264 Asgard Human Venture Capital/Roland Berger, 2018 (cf. Methodology of the Cambrian AI Index).
265 CB Insights, 2017b (cf. Methodology of the Cambrian AI Index).
266 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index).
267 IFR, 2017 (cf. Methodology of the Cambrian AI Index).
268 Velayanikal, 2018.
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270 J, 2018.
271 Balaji, 2018.
272 Ministry of Commerce and Industry, 2018.
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274 Cumming, 2018.
275 Government of India, 2016.
276 PTI, 2018b.
277 Tantri, 2013.
278 PTI, 2018a.
279 IANS, 2018b.

Singapore
How to think and act like a startup

- Promotion of fundamental research not only from a technical point of view, but also in terms of ethical and social issues
- With *100Experiments*, companies can submit problems for which there is no standardized AI solution and are referred to AI developers
- Understanding of AI within the population through the *AI for Everyone* training programme
- The *Accreditation@SGD* initiative offers customised consulting services in the areas of technical application for companies in early growth phases

I.) Introduction

In recent years, Singapore's government has made it clear how serious it is about promoting AI. In 2017, the *National Research Foundation* (NRF), an agency reporting to the Prime Minister, launched the national *AI Singapore* initiative with the ambition of establishing a firm foothold on the global map of AI sites, and to advance the future of the country's digital economy.[280] With an investment of around 130 million Euro, NRF will join all Singapore research facilities and the AI ecosystem of companies and startups to catalyse, pool and strengthen knowledge, tools and talent in the field of AI.[281] By international standards, it is at least questionable whether Singapore will become an AI leader merely through an AI support programme and 130 million Euro. Compared to that, in China an industrial investment fund of 15 billion Euro represents a single AI promotion instrument.[282] *AI Singapore* pursues an application and commercialisation approach, as the initiative is designed in particular to contribute to "strengthening the bonds between industry and research to ensure that AI research meets the needs of industry"[283]

II.) Requirements for AI

Due to the small population of the country, the number of active Internet users is the lowest among the compared countries.[284] In terms of availability and accessibility of public data, the country is only half as good as the UK according to the Open Data Barometer 2016.[285] This data source for data mining is correspondingly limited.[286] In contrast to that the country has established itself as a strategic location for the data centres of neighbouring countries. Consequently, half of the Southeast Asian data centres are located in Singapore.[287] With an estimated number of around 525 AI Master's students, the country ranks sixth among the countries surveyed here. In relation to the small number of inhabitants this value is remarkable.[288] Furthermore, although only two of the top 500 supercomputers worldwide are located in Singapore, this value is also considerable in relation to the small number of inhabitants.[289] The semi-conductor industry has been a strong driver of the growth of the city-state over the past year. According to the *Economic Development Board*, semiconductor productionincreased by 48 percent in 2017,[290] which does not yet make the country a global location in this sector.[291] The technology-friendly conditions created by the government, especially in relation to the size of the country, are also appreciated by private sector players, who increasingly consider the country a location for innovation.[292] The deep technology company *DataRobot* has announced, for example, that it will invest 13 million Euro in Singapore as part of its expansion plans.[293]

III.) Institutional framework

The government regards technical progress and the promotion of AI as crucial for the development of the country:[294] "Singapore must think and act like a startup to survive as a small open city-state."[295] said the Minister of Communications and Information S. Iswaran. This idea is implemented through numerous initiatives:

Through the *Smart Nation Initiative*, the government aims to steer investment in and use of technological infrastructure to support commercialisation by developing realistic and targeted solutions to urban challenges. In doing so, the initiative refers to the *Digital Government Blueprint*, the *Digital Readiness Blueprint* and the *Digital Economy Framework for Action*.[296] The latter focuses on four frontier technologies: AI, cyber security, immersive media (such as *Virtual reality*) and *Internet of Things*.[297] The *Smart nation* initiative has the highest political priority and is supported by the *Smart Nation and Digital Government Office* coordinated in the Prime Minister's office and supported by other government agencies.[298]

The interdepartmental initiative *AI Singapore* completes Singapore's ambitions in the field of technology promotion. Participants in *AI Singapore* are the *National Research Foundation* (leading entity), the *Smart Nation and Digital Government Office* (SNDGO), the *Economic Development Board*, the *Infocomm Media Development Authority* (IMDA), the state-owned company *SGInnovate*, which funds and promotes Deep-Tech startups, as well as the leading IT analyst in healthcare *Integrated Health Information Systems*.[299] Through *AI Singapore* AI is expected to contribute to overcoming major societal challenges, to adapting human capital to technological change in the sense of AI, and prepare the adoption and use of AI by the industry. Specifically, the Initiative consists of the following programmes: *Foundation Research, Grand Challenge, 100Experiments, AI Apprenticeship, AI For Industry* and *AI For Everyone*.[300]

IV.) Research and Development

The good education of the population and R&D are important components of the policy to promote competitiveness and economic growth. With about 6,729 per million inhabitants, Singapore has a high density of scientists, especially in comparison to the other countries examined here (USA: 4,255, China: 1.096).[301] The Government provides financial incentives for small and medium-sized local companies to become involved in R&D and thus support the development of innovations.[302] In total, the country spent 5.9 billion Euro on R&D in 2016, which corresponds to about 2.1 per cent of GDP (GDP share comparable to

France, about half the size of Israel).[303] Around 53 percent of investment comes from the private sector, while in China and Japan almost 80 percent of R&D investment comes from the private sector. This conveys the impression that the research impulses in Singapore are set by the state in particular, which basically contradicts the project of developing application-related innovation. The majority of AI research is also financed by government agencies: NRF, Ministry of Education, *A*Star Science* and *Engineering Research Council*.[304] It is estimated that 225 doctoral students graduate annually in AI areas, outperforming competing countries due to Singapore's small population.[305] Scientific publications still have little influence beyond the borders of Singapore. Measured by the H index, which is 125 for the AI sector in Singapore, it is far behind countries such as the US (437) or Germany (186).[306]

Research areas and instruments

In order to address existing deficits in national AI research, various programmes were initiated – both to improve the coverage of the needs of industry and research and to promote young scientists. In the past, the focus of AI research in Singapore was on applications in health care and robotics, while the research directions concentrated on graphic models, neural networks and *Fuzzy systems*. In recent years, the main areas of research have largely been adjusted to the strategies of *Smart Nation* and *AI Singapore*.[307]

Through the recently formed *Singapore Data Science Consortium*, NRF, universities and the *Agency for Science, Technology and Research* are seeking research partnerships between institutions of higher education, research institutes and The industry in order to make technologies usable for practice-oriented challenges.[308]

In the course of receiving a research grant of 2.8 million Euro from the NRF and the IMDA, *Singapore Management University* established a five-year AI research programme, with particular attention being paid to three research areas: AI and society, AI and industry as well as AI and commercialisation. Critical and interdisciplinary perspectives will help to build bridges between academia, industry and government.[309] These research priorities are also considered by research institutions in other countries, but with a funding amount of 2.8 million Euro the *Singapore Management University* cannot keep up financially with the research budgets of institutes of other nations. For example, the *Academy of Finland* made available 13 million Euro for research in the field of the *Machine learning* and AI applications in physics and engineering.[310]

The *AI Singapore Fundamental Research programme* supports basic research and seeks to fill existing research gaps. This includes purely technical research, such as image recognition algorithms, but also research on the social impact of AIs and their socially acceptable use.[311] The research grants will be distributed by means of a tender. Individuals as well as research institutions could apply to obtain subsidies up to 632,000 Euro.[312] Proposals were expected to focus on methodology and algorithms, in particular *deep learning*, rather than sector-specific solutions.[313] At the time of writing, decisions on recipients had not been made.

The *Grand Challenges* programme is designed to work with the public to promote new, innovative ideas in three long-term areas: healthcare, urban solutions and financial technology (in short: FinTech).[314] Criteria for a Grand Challenge are: Inspiration (for researchers, users and the public), measurability (success criteria) and impact (solutions that benefit many people).[315] The funding will be provided in two phases: up to 4.4 million Euro in the first two funding years and up to 17.4 million Euro in the second phase (three more years).[316]

V.) Commercialisation

The cooperation between research and industry is one of the key factors for the adaptation of AI solutions by the private sector. However, it has so far hardly been accepted and used by companies, which the government wants to change by means of initiatives to link research and industry.

There are between 1,600 and 2,400 technology startups in Singapore,[317] however, according to

Asgard and Roland Berger, only a few of them specialise in AI (35). This is a long way from the global peak (just under 1,400 in the USA) and is the lowest in comparison with the countries analysed in this study.[318] Meanwhile, the interest of foreign companies in the AI ecosystem is growing. Thus, in 2017, the investment group Marvelstone, financier of the global Fintech hub "Lattice80" announced to open an AI hub in Singapore. The group wants to bring together scientists, companies and the government to develop AI technologies for the market. To this end, up to 100 AI startups per year can be funded.[319] One of the *25 Hottest AI Companies 2018* according to the *CIO Advisors Ranking* is located in Singapore: AIQ, a company specialising in technologies for visual capture and intelligent recognition.[320] These developments are reinforced by well-trained professionals and close cooperation between universities and industry in research and development (fifth place among the countries surveyed).[321] Between 2015 and 2017, however, only 0.31 percent of all internationally enforceable AI patents were from Singapore – for comparison: in South Korea the figure was around 3.8 per cent.[322]

The manufacturing industry accounts for 20 to 25 percent of the gross domestic product (GDP) in Singapore. The key industries are electronics, chemistry, biomedicine, logistics and transport technology.[323] The country with the second highest robot density in the world (behind South Korea)[324] expects strong consequences of AI for the labour market: Nearly 21 percent of full-time workers could lose their jobs in the next ten years – more than in other ASEAN countries – through the increased use of technologies such as AI and robotics.[325] In order to promote understanding and acceptance of AI among the population, the government offers the *AI For Everyone* programme: In free workshops, up to 100,000 Singaporeans are informed about AI applications in their own companies and in daily life.[326] *AI For Everyone* is financially supported by IMDA and Microsoft.[327]

Regulation: In his speech at *innovfest unbound 2018,* the largest Southeast Asian innovation festival, S. Iswaran promised a progressive regulatory framework for the ICT sector in Singapore. With regard to data protection, this means, in particular, that the *Personal Data Protection Act* of 2012 will be examined for favourable regulations. Up to now, this has legitimised the needs of companies to collect and use personal data on the one hand, and regulates the responsible handling of data on the other.[328] The law has also established the *Personal Data Protection Commission Singapore* (PDPC), which administers the law and its implementation.[329] As early as July 2017, the PDPC issued a guideline for data exchange to explain the *Data protection acts* published. In addition, a framework for the agreement on the exchange of data within a regulatory-*sandbox* will be established that releases companies from certain obligations to test and promotes innovative uses of personal data.[330]

Since *text* and *data mining* are essential for the development of AI, this topic was part of the public consultation on amendments of the *Copy Right Act* in 2016. In it, the Ministry of Justice proposes an exception in the *Copy Right Act* which allows copying of copyrighted documents and data for the purpose of data analysis.[331] Politicians are expected to agree to this proposal.[332]

Business support and startup promotion: The conditions for startups in the country are already very good. According to Genomes 2017 *Startup Ecosystem Ranking* singapore ranks twelfth in the world and promises young startups in the country great opportunities for global success.[333] The value of the Singapore startup ecosystem in 2017 was 9.6 billion Euro, which is comparatively high compared with the global average of 3.6 billion Euro.[334]

In addition to the *SME Go Digital Initiative* announced in 2017,which aims to support small and medium-sized enterprises in strengthening digital capabilities,[335] young companies will be supported by the initiative *Accreditation@SGD* in their early growth phases with tailor-made advice on technical applications.[336] In fact *Accreditation@SGD* was instrumental in the Taiger startup company transferring its intellectual property and key operations to Singapore in 2015.[337] The *Infocomm Media Development Authority* (IMDA) through its coop-

eration with the leading banks DBS, OCBC and UOB offers the following services *Accreditation@SGD* participating companies improved access to innovative Fintech projects.[338] In addition, IMDA has decided to support AI developers in the field of language recognition for the national language corpus in order to prepare their long-term entry into the global speech recognition market.[339]

The *AI for Industry* programme of the *AI Singapore* Initiative is aimed at developing the skills of engineers, managers and executives who already have technical knowledge and wish to develop their programming skills to use data and create AI applications.[340]

In addition, the *100Experiments* programme is intended to connect AI researchers and developers with players from the industry who want to address their specific challenges through AI solutions. Companies can submit problems for which AI could be used as a solution and will be referred to AI experts accordingly. *AI Singapore* finances the project together with the company in equal shares with up to 160,000 Euro.[341] The programme is popular with the industry and initial solutions are already being tested.[342] High initial investment in AI solutions are entry barriers for companies, which the programme helps to overcome.[343]

IMDA has also launched the *AI Business Partnership Programme*. It provides a guided process to bring local companies with potential problems (AI end-user companies) together with providers of existing AI solutions and support these partnerships in the development and deployment of prototypes. In addition, quarterly free AI workshops are offered by IMDA.[344] Problem areas that do not yet have commercially available solutions will be forwarded to *100 experiments* of *AI Singapore*.[345]

Ethical use of AI and data: For the Singaporean government, ethics plays a central role in the use of AI applications and the handling of data. So S. Iswaran in his speech at *innovfest unbound* 2018 announced the establishment of an advisory board on the ethical use of AI and data.[346] In June 2018, the *Personal Data Protection Commission Singapore* published a discussion paper on responsible handling of AI, which stresses the principles of transparency and *"Do no harm"*.[347] After receiving a research grant in 2018, the Singapore Management University opened the *Centre for Artificial Intelligence and Data Governance*, which will examine the societal opportunities and risks arising from these technologies.[348]

The public sector as users of AI: Through the public procurement sector, the government is increasing its demand for cutting-edge technologies and thus encouraging innovation. From 2017–2018, in the *World Competitiveness Index*, the country ranked in fifth place of the 137 countries surveyed in the field of government procurement of cutting-edge technology.[349] The *Smart Nation Initiative* also intends to expand the area of *E-governance* further. This has been specified in the *Digital Government Blueprint* paper, which also states that digitisation and AI are defined as elementary components of the transformation efforts of the public service at the interface between state and citizens and that digital payments and digital signatures are concrete applications. Employees of public institutions are to be provided with digital competences in the workplace in order to meet the challenges between public authorities and citizens more effectively.[350]

Since access to data sets is essential for *machine learning*, S. Iswaran announced that he would expand the provision of public data via the data.gov.sg platform and motivate companies to exchange data responsibly among themselves in order to solve common business problems.

Labour market: As a country with a knowledge-based economy, Singapore also focuses on the training of specialists in the field of AI. This is reflected in the relatively high number of AI talents.[351] As part of the *Industry Transformation Map* that *Infocomm Media Development Authority* (IMDA) aims to further develop the IT and communica-

tions industry through the targeted promotion of skilled workers in the transformation towards a digital economy.[352] It is not clear from the search whether funds have already been spent on this.

SkillsFutures is a comprehensive initiative to spread ICT skills and knowledge across the population.[353] Part is also the 2016 announced *TechSkills Accelerator* (TeSA), which takes an integrated approach to the acquisition of ICT skills and the training of ICT practitioners.[354]

Through a partnership between AI Singapore and the *TechSkills Accelerator*, a "pipe line of locally grown, world-renowned AI talents"[355] is to be created: the *AI Apprenticeship Programme*. The training is designed by industry players to meet the demand for trained professionals. Contents include the construction of data pipe lines, *Data warehouses* for AI *Use cases* and adjustment of machine learning algorithms. The nine-month programme is aimed at experts from all fields within the first three years after graduation and includes a combination of in-depth AI courses and hands-on training in industrial projects.[356] The programme has been completed by the first year of students and partnerships have been established between the trainees and industrial actors. The second group will start in November 2018.[357]

280 AI Singapore, k. D.a.
281 National Research Foundation, k. D.a.
282 Ernst, 2016.
283 Iswaran, 2018a.
284 World Bank, 2016 (cf. Methodology of the Cambrian AI Index).
285 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index).
286 World Bank, 2016 (cf. Methodology of the Cambrian AI Index).
287 InfoComm Media Development Agency, 2018a.
288 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
289 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index).
290 Reuters, 2018.
291 Statista, 2018.
292 Linehan, 2017.
293 Goh, 2017.
294 Linehan, 2017.
295 Iswaran, 2018b.
296 Smart Nation Singapore, k. D.
297 InfoComm Media Development Agency, 2018b.
298 Smart Nation Singapore, 2018.
299 AI Singapore, k. D.
300 National Research Foundation, k. D.
301 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index).
302 OECD, 2013: 3.
303 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index).
304 Varakantham et al., 2017: 1.
305 CSRanking 2016–2018 (cf. Methodology of the Cambrian AI Index).
306 SJR, 2017 (cf. Methodology of the Cambrian AI Index).
307 Varakantham et al., 2017: 1; AI Singapore, k. D.
308 InfoComm Media Development Agency, 2018a.
309 Peiling, 2018.
310 Cf. chapter on Finland.
311 Overview of the research areas of the scheme Fundamental Research is made available in the Annex (Annex 2).
312 Open Gov Asia Online, 2018.Cambrian AI Index).
313 Ibidem.
314 AI Singapore, k. D.
315 In September 2018 the Call for Ideas with regard to the challenge: „How can Artificial Intelligence (AI) help primary care teams stop or slow disease progression and complication development in 3H [...] patients by 20 % in 5 years“ (AI Singapore, k. D.). So far, the winning ideas of this first run are not available.
316 National University of Singapore, 2018.
317 Williams, 2017.
318 Asgard und Roland Berger, 2018 (Cf. Methodology Cambrian AI Index).
319 Tegos, 2017.
320 CIO Advisor, 2018.
321 World Economic Forum, 2017: 262–263 (cf. Methodology Cambrian AI Index).
322 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index).
323 SME Portal, 2018.
324 IFR, 2017 (cf. Methodology of the Cambrian AI Index).
325 Tan, 2018.
326 Kwang, 2018.
327 Infocomm Media Development Authority, 2018c: 2.
328 Iswaran, 2018a.
329 Personal Data Protection Commission Singapore, k. D.
330 Infocomm Media Development Agency, 2017b: 4.
331 Ministry of Law, 2016: 34.
332 European Alliance for Research Excellence, 2018: 2.
333 Startup Genome, 2017.
334 RSM International Foundation, 2018: 95.
335 SME Portal, 2018.
336 To this end, see chapter “Commercialization”.
337 Forbes Custom, 2018.
338 Open Gov Asia Online, 2017.
339 Infocomm Media Development Agency, 2017b: 3.
340 AI Singapore, k. D., InfoComm Media Development Authority, 2018c.
341 Ibidem.
342 Iswaran, 2018b.
343 GovTech Singapore, 2017.
344 InfoComm Media Development Agency, 2018d.
345 Infocomm Media Development Agency, 2017b: 5.
346 Iswaran, 2018a.
347 Personal Data Protection Commission Singapore, 2018: 5.
348 Channel NewsAsia, 2018.
349 World Economic Forum, 2017: 262–263 (cf. Methodology of the Cambrian AI Index).
350 Smart Nation, 2018a: 9–11.
351 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index).
352 InfoComm Media Development Agency, 2017a.
353 SkillsFuture, k. D.
354 InfoComm Media Development Authority, k. D.
355 Infocomm Media Development Agency, 2017b: 4.
356 AI Singapore, k. D.
357 Iswaran, 2018a.

Methodology of the Cambrian AI Index ©

The analysis on which this report is based assessed the countries on the basis indicators that incorporate the countries' preconditions, the research and development situation and the degree of commercialisation of AI. In an attempt to integrate these indicators and determine the AI position of a country in an international comparison, the Cambrian AI Index © was developed. The Cambrian AI Index consists of the three segments mentioned above, which in turn consist of different components for which one or more proxy indicators have been identified. The methodology must be specified more, since the index is defined by proxy measurements for which reliable and comparable data from different countries are available. The reason for using the proxies is that the field of AI in its latest phase only provides limited measurable outputs. This is likely to change over the next few years, as the accompanying research on AI is also developing rapidly.

The values of the different proxies are indexed from 0 to 1, with the USA representing the "benchmark" value 1 against which the other countries are measured. Due to the world leadership AI, the United States have been selected the AI benchmark country. The mean value of the indexed proxy values of a component is the component's intermediate value. The mean values of all components of a segment, in turn, result in the total value of the segment. The mean values of the three segments result in the comprehensive Cambrian AI Index. Weighting was not carried out at proxy, component or segment level, since well-founded empirical studies are required for adequate weighting.

Segment	Component	Proxy	Survey Method/Source
General requirements	**Framework conditions**	**Network Readiness Index Value (2016)** Explanation: The index provides insights about the performance of national economies in the use of information and communication technologies to enhance competitiveness, innovation and well-being. Thus it serves as a proxy for the framework conditions of AI.	Survey based on a scale from 1 (worst) to 7 (best). World Economic Forum: https://widgets.weforum.org/gitr2016/
	Data	**OpenData Barometer (2016)** Explanation: In addition to individuals with internet access and businesses, the public sector is the third important source of AI-related data. The OpenData barometer assesses governments worldwide in their willingness to implement OpenData initiatives. It also measures the impact of OpenData on business, politics and civil society.	The data for the OpenData barometer is collected through expert interviews, self-assessments by governments and secondary data sources. World Wide Web Foundation: https://opendatabarometer.org
		Number of Internet users (2016) Explanation: Internet users are persons who have used the internet (from anywhere) via computers, mobile phones, personal digital assistants, gaming machines, digital television, etc. in the last 3 months. This proxy measures internet users in absolute numbers rather than as a percentage of the population, since the quantity of data is what counts for AI.	World Bank: https://data.worldbank.org/indicator/IT.NET.USER.ZS
	Computing power	**Number of 500 most powerful supercomputers per country (2018)** Explanation: Even if computing power can be used across borders, the availability of supercomputers to cope with large amounts of data and increasingly complex algorithms is a strategic factor for a nation.	The website Top500.org counts and lists the top super computers that are publicly known and commercially available worldwide in semi-annual surveys (June and November). It is possible that military high-performance computers exist which are not known. Top500.org: www.top500.org

Segment	Component	Proxy	Survey Method/Source
		Number of 10 most powerful supercomputers per country (2018) Explanation: The Top 10 of the 500 most powerful supercomputers shows that in some countries, e. g. China, the most supercomputers are installed, but they are not the most powerful.	Top500.org: www.top500.org
		Turnover of leading semi-conductor manufacturing companies in billions (2017) Explanation: Turnover from semicon-ductor companies per country gives information about the dominance and thus innovation power in this industry segment. Even though the production of semiconductors is not indicative of the use of semiconduc-tors, production capacities are a stra-tegic factor for a nation.	**China:** HiSilicon Technologies Uni Group Sanechips Huada Goodix **Japan:** Toshiba Renesas Electronics Sony ROHM Semiconductor **Republic of Korea:** Samsung Electronics SK Hynix **USA:** Intel Micron Technology Broadcom Qualcomm Texas Instruments nVidia Skyworks Solutions SanDisk / Western Digital Analog Devices ON Semiconductor Freescale Semiconductor AMD **Statista:** https://www.statista.com/statistics/271553/worldwide-revenue-of-semiconductor-suppliers-since-2009 supplemented by the evaluations of individual annual financial statements.

Segment	Component	Proxy	Survey Method/Source
		Number of leading semiconductor manufacturing companies (2017) Explanation: Complementing the proxies stated above, the number of semi-conductor companies provides information about the strength of a country's semiconductor environment.	Statista, supplemented by further research (see above)
		Revenues from FPGA chips in million USD (2016) Explanation: Intel and Microsoft are confident that FPG chips will be the dominant AI hardware in the future. A paper recently published by Intel engineers titled "Can FPGAs Beat GPUs in Accelerating Deep Neural Networks" provides some of the technical reasons for this speculation. It should be noted that the industry has developed strongly since 2016 (see chapter on China).	EE Times: https://www.eetimes.com/author.asp?doc_id=1331443 Nurvitadhi, E.; Venkatesh, G.; Sim, J.; Marr, D.; Huang, R.; Ong, J. G. H.; Liew, Y. T.; Srivatsan, K.; Moss, D.; Subhaschandra, S.; Boudoukh, G. (2017): Can FPGAs Beat GPUs in Accelerating Next-Generation Deep Neural Networks? http://jaewoong.org/pubs/fpga17-next-generation-dnns.pdf
	Human resources	**Number of students enrolled in all tertiary education programs, both sexes (2016)** Explanation: AI is considered to be basic research technology, which is why the number of students per country is a proxy for the amount of qualified human resources.	UNESCO: http://data.uis.unesco.org
		Estimated number of Master's graduates in AI-relevant fields, at computer science institutes with actively researching teachers Explanation: Master graduates in the above-mentioned areas provide information on the size of the pool of young talents for AI research and commercialization. In contrast, the index assigns the number of doctoral students to the "Research and Development" segment.	The estimate is based on the number of scholars at computer science institutes who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. In order to determine the annual number of Master's graduates, the

Segment	Component	Proxy	Survey Method/Source
			number of scholars was multiplied by a factor of 7. This factor was determined by Mark Nitzberg, Chief Scientist for Cambrian and Head of UC Berkeley CHAI, on the basis of a random sample survey of top AI research laboratories in the USA (potential regional/national differences were not considered). CS Ranking: http://csrankings.org/#/index?none
Research and Development	**General R&D framework conditions**	**Gross domestic expenditure on research and development in 000 USD (2016)** Explanation: The gross domestic expenditure comprises the R&D investments of the private sector, the government, higher education institutions and civil society. This proxy is presented in absolute terms in USD as opposed to the percentage ratio of GDP to reflect the global and mobile value chains of AI.	The data are available in the respective national currency. For comparability, all values have been converted to USD (average exchange rate of 2016). The 2016 expenditures from Singapore and India are not available, which is why they were projected based on historical values. UNESCO http://data.uis.unesco.org
		Number of researchers per 1 million inhabitants (2016) Explanation: The "density" of researchers is a proxy for the serendipity in research in a country. The importance of serendipity in the field of AI is high, since AI is a basic technology with practically unlimited application areas.	UNESCO http://data.uis.unesco.org
	AI-relevant R&D (Input)	**Number of computer science institutes with actively researching teachers in AI-relevant areas** Explanation: The number of computer science institutes provides information about the size of the relevant R&D ecosystem.	Number of scholars at computer science institutes who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. CS Ranking 2016–2018: http://csrankings.org/#/index?none

Segment	Component	Proxy	Survey Method/Source
		Number of scholars actively doing research in areas relevant to AI Explanation: The number of teaching staff is a proxy for research and training of qualified human resources of a country.	Number of scholars at computer science institutes who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. CS Ranking 2016–2018: http://csrankings.org/#/index?none
		Estimated number of doctorate students supervised by scholars actively engaged in research in AI-relevant areas Explanation: The number of doctorate students provides information about the R&D relevant human resources of a country.	The estimate is based on the number of scholars at computer science institutes in universities who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. To determine the annual number of doctorate students, the number of scholars was multiplied by a factor of 4. This factor was determined by Mark Nitzberg, Chief Scientist for Cambrian and Head of UC Berkeley CHAI, on the basis of a random sample survey of top AI research laboratories in the USA (potential regional/national differences were not considered). CSRanking 2016–2018: http://csrankings.org/#/index?none

Segment	Component	Proxy	Survey Method/Source
	AI-relevant R&D (Input)	**Number of citable publications in the subject area of AI (2017)** Explanation: The number of citable publications in the field of AI provides information about the scientific productivity of a country in the field of AI.	Scimago Journal & Country Rank: https://www.scimagojr.com Cf. the methodology used there
		Influence of publications in the subject area of AI (2017) Explanation: The influence of publications is a proxy for the quality and innovative power of research in the field of AI. It is unknown whether the index takes into account co-authors and their nationality.	The influence of publications is measured on the basis of the H index. The figure is based on bibliometric analyses, i. e. on citations of the scientist's publications. Scimago Journal & Country Rank: https://www.scimagojr.com
Commercialization	**Knowledge and technology transfer**	**Cooperation between universities and industry on research and development (2017–18)** Explanation: This proxy delivers information on the knowledge and technology transfer between universities and the private sector.	Opinion polls among executives: In your country, to what extent do business and universities cooperate in research and development (R&D)? (1 = not at all; 7 = intensively). Weighted average. World Economic Forum: https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018
		Public procurement of cutting-edge technology (2017–18) Explanation: This proxy provides information about the incentives that the public sector creates by demand for certain technologies and thus innovations.	Opinion polls among executives: To what extent do government purchasing decisions promote innovation in your country? (1 = not at all; 7 = to a large extent). Weighted average. World Economic Forum: https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018

Segment	Component	Proxy	Survey Method/Source
	Patents	**AI patents (with international enforcement expectations) by assignee country in % (average of the years 2015, 2016 and 2017).** Explanation: This proxy provides information on the patent activities of a country's companies. Nevertheless, this proxy is subject to reservation, since the patents are not indicative of the quality of an innovation and are often merely incremental in nature.	Although various sources suggest that China has overtaken the US in terms of AI-related patent applications, most Chinese patents have no international equivalents and are therefore unenforceable outside China. The patents cover AI as well as Machine Learning and Deep Learning. Notice: The process of patent application for patent publication is associated with a considerable time delay, which is why the figures may also vary retroactively. Research by M-Cam: https://www.m-cam.com
	AI startup landscape	**Number of AI startups (2017)** Explanation: The number of AI startups provides information about the diversity of the potentials of AI and the innovative strength of the national economies.	The data collection focused exclusively on startups active in the AI technology industry and ignored companies dealing with other digital topics and technologies. These are startups that produce AI solutions and expressly excludes startups that use existing AI solutions on the market to develop new services or products. Asgard und Roland Berger/Lemaire, A.; Lucazeau, H.; Carly, E.; Romain; Rappers, T.; Westerheide, F. (2018): https://asgard.vc/global-ai
		The 100 most influential AI startups (2017) Explanation: While the above proxy reflects the quantity of AI startups, the number of AI startups in the list of the 100 most influential AI startups per country is a proxy for the quality and future potential of the companies.	The companies were selected from a pool of more than 2,000 startups based on several criteria, including investor profile, technological innovation, team strength, patent activity, financing history, valuation and business model. CB Insights: https://www.cbinsights.com/research/artificial-intelligence-top-startups

Segment	Component	Proxy	Survey Method/Source
		Share of AI private equity deals in all AI private equity deals worldwide (2016) Explanation: This proxy provides information about the countries with the startup landscapes with the highest future potentials in AI as seen by investors.	CB Insights: https://www.cbinsights.com/research/artificial-intelligence-startup-funding
		Number of most active venture capital investors (2012–2016) Explanation: This proxy indicates in which countries the most AI-savvy investors are based and thus have the largest influence in terms of AI startups.	CB Insights: https://www.cbinsights.com/research/artificial-intelligence-startup-funding
	Robotics	**Number of industrial robots installed per 10,000 employees in the manufacturing industry (2016)** Explanation: This proxy provides information about the automation of the manufacturing industry and the consumption and implementation of robot technology, and thus is indicative of the level of experience of the labor market in interaction with machines.	International Federation of Robotics: www.ifr.org
		Number of manufacturers producing service robotics (2016) Explanation: Complementing the proxy, specified above, the number of manufacturers of service robots provides information about the size of the ecosystem in this future technology.	The data only represent the individual figures for the eleven countries with the largest number of such companies. The other thirteen countries in which companies produce service robots have been consolidated in the category “Rest of the world”, with an average of four companies per country. Statista: https://www.statista.com/statistics/658048/service-robotics-manufacturers-by-country

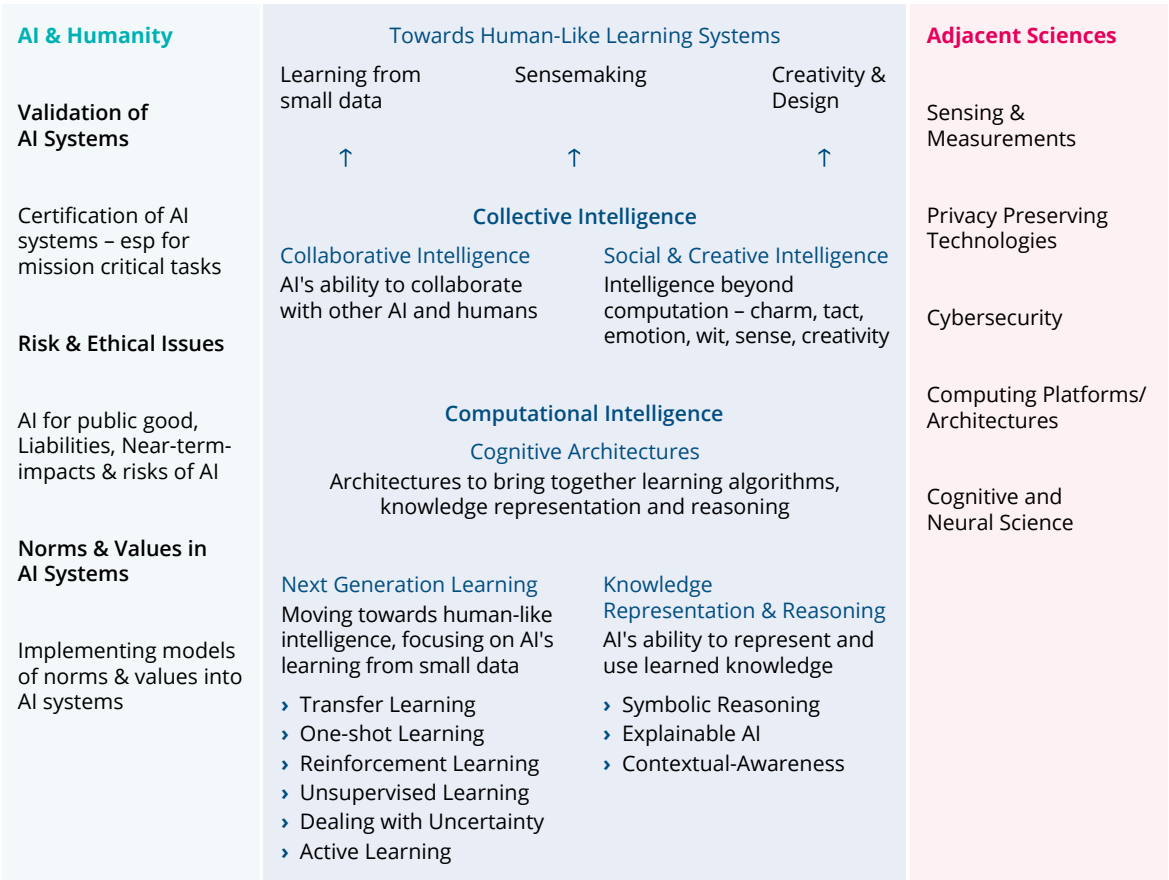
Annexes

Annex 1: Overview of resources and research areas of AIST, RIKEN and NICT (Japan) [358]

Superordinate Research Institute	Superordinate Ministry	AI centre	Budget (2016)	Fields of research
National Institute for Advanced Industry and Technology (AIST)	Economy and Industry (METI)	Artificial Intelligence Research Center (AIRC)	123 million Euro	**Productivity:** preventive fault diagnosis for wind turbines with the help of deep learning, self-learning imitation robots based on neural networks, compatibility of IoT and AI as well as AI that understands human needs **Health:** cancer diagnosis through image recognition and machine learning, development of drugs by "robotic bio-research." **Security:** "Video-to-Text Translation" and recognition of patterns in large groups of people for damage limitation in the event of catastrophes
RIKEN-Institute for Physics and Chemistry	Education and Technology (MEXT)	Center for AI Development (AIP)	56 million Euro	**Fundamental research (20 teams):** Development of AI-supporting general purpose infrastructure technology through research in the fields: Imperfect Information Learning, Structured Learning, Geometric Learning, Tensor Learning, Functional Analytic Learning, High-Dimensional Statistical Modeling, Online Decision Making, Succinct Information Processing, Deep Learning Theory, Computational Learning Theory, Nonconvex Learning Theory, Causal Inference, Approximate Bayesian Inference Search and Parallel Computing, Multi-agent, Discrete, Continuous Optimization, Mathematical Science, Statistics, Analysis, Topological Data Analysis

Superordinate Research Institute	Superordinate Ministry	AI centre	Budget (2016)	Fields of research
RIKEN-Institute for Physics and Chemistry	Education and Technology (MEXT)	*Center for AI Development (AIP)*	56 million Euro	**Application research (24 teams):** **Productivity:** by 2020, information technology for the "revolutionisation of industrial production", a "platform for environmental information that adapts in real time to changing intentions and preferences" (tourism service), as well as a "framework for cooperative data analysis." **Medicine:** by 2020 systems for medical diagnostics from image data and in the field of cancer research **Security:** data-based technology for damage limitation and reconstruction in the event of natural disasters **AI with reference to social sciences (eight teams)** *social impact,* legislation, social systems, ethics and privacy
National Institute of Information and Communication Technology (NICT)	Internal Affairs and Communication (MIC)	*Center for Information and Neural Networks (CiNet)*	17 million Euro	**Basics:** *human-machine interaction* **Medicine:** *Brain information communication technology, neuro feedback technology*
		Universal Communication Research Institute (UCRI)		**For all fields of application:** *universal communication technology* auf Basis von *multilingual speech translation,* **Mobility:** *semantic maps*

Annex 2: Overview of the research areas of the Fundamental Research Programme of the AI Singapore Initiative [359]



358 See Strategic Council for AI Technology, 2017; AIST, 2017: 4; abci.ai, k. D.; RIKEN, k. D.; UCRI Direct, k. D.; NICT CiNET, k. D.; Budgets, vgl. Harayama, 2017: 17.

359 AI Singapore, k. D. (see chapter on Singapore).

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The race for world leadership in Artificial Intelligence (AI) technologies has begun. Since the publication of the AI strategy of the Obama government in 2016, other countries have also started to explore ways to support research and development (R&D) as well as the commercialisation of AI and to catch up with the U. S. as the leading AI nation. With this two-part publication, the Konrad Adenauer Foundation intends to give a comparative overview of the AI strategies of major national economies (Part 1 & 2) and to analyse the German AI strategy in an international comparison (Part 3) in order to enrich the German and international debate. We believe: "Tech is politics" – and politics and civil society should give this more attention and discuss this more vigorously.

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