China's Drive for Technological Leadership in Artificial Intelligence. Key Policies and Government-Industry Integration

Adrian Bazavan and Catalin-Emilian Huidumac-Petrescu

Abstract The world has shifted to the digital economy and data has become one of the most valuable commodities. As internet applications have made data collection seamless, artificial intelligence systems bring significant productivity gains by revolutionising the way data is processed and transformed into added-value. Artificial intelligence has a deep impact over our industrial and production means, supply chains and consumer patterns, as well as over education, mass-media, governance, and national security. Therefore, artificial intelligence development has become a priority of strategic importance to most nations. China, within the last decades, has advanced from a labour-intensive and low-cost manufacturing base to an increasingly sophisticated economy that is able to deliver high added-value goods and services to the world markets. In this transition, China is now openly aiming to become an innovation powerhouse that holds the global edge in crucial technologies. Given the fertile grounds laid by China's market scale, high digital penetration rates and massive pool of consumers, but also the government's interest in deploying social governance systems and increasing military capabilities, artificial intelligence became a top policy priority that is reflected at all levels. Within the evolutionary framework of Learning Models and drawing upon a data collected from public policy documents, specialised commercial databases and qualitative interviews conducted on the ground, this paper will examine the main characteristics of China's AI development policy, highlighting the role played by the central and local governments within the AI ecosystem and the complex interactions with tech companies, universities and talent. At the same time, it aims to address several pertaining misconceptions in existing literature about China's AI landscape and finally, on this basis, propose a set of key recommendations to the European Union regarding AI development.

Keywords China · Artificial intelligence · Innovation policy · Industry-government integration · Talent attraction

A. Bazavan (✉) · C.-E. Huidumac-Petrescu
Bucharest University of Economic Studies, Roman Square 6, 010374 Bucharest, Romania
e-mail: adrian.bazavan@stud.ase.ro

C.-E. Huidumac-Petrescu
e-mail: catalin.huidumac@economie.ase.ro

M. Busu (ed.), *Digital Economy and the Green Revolution*, Springer Proceedings in Business and Economics, https://doi.org/10.1007/978-3-031-19886-1_2

1 Introduction

Humanity has evolved from the agricultural economy to the industrial economy and more recently, to the digital economy. Nowadays, some of the world's biggest companies are not selling to consumers physical goods, services nor software, as the use of their products is free of charge (Android Operating System and Google products, Facebook, messaging applications, Baidu products etc.). Instead, as we are now in a new stage of development when knowledge is the most valuable commodity, their business model is based on collecting, processing and transaction information. Applications of all sorts are harvesting immense quantities of data from users around the world. However, in order to transform raw data into business usable information and thus create added value, data must be processed efficiently and fast.

Traditionally, collecting data about humans was difficult and expensive, sometimes requiring methods such as street and telephone surveys. Nowadays, with the use of social platforms, e-commerce and so many mobile applications, the volume of ready-to-collect data is immense. The challenge however becomes to structure, label and categorise it, tasks that frequently require human specialised assistance. Traditional computer systems are manually programmed for pre-defined tasks, or in other words, receive human-coded rules, based on which they can process data inputs to get output answers. Due to the complexity and ever-evolving nature of data, this frequently proves to be insufficient. In contrast, artificial intelligence systems receive both input data and output answers, alongside a generalised strategy for learning, being able to produce the processing rules. Without further programming, AI systems can automatically adapt self-learned rules to new sets of data and produce original answers (Barton et al. 2017). To some extent, they act like humans that can constantly improve, but in contrast, have the capacity to process much larger strings of data. Artificial intelligence, or the idea that computers can perform functions associated with the human-mind, has indeed gone from far-fetched speculation to contemporary reality. As compared to humans, AI systems have the advantage of being able to instantly access and process any source of information, from anywhere and anytime.

Questions about what AI is, what applications it has in the present and its future ways of development cut across politics, economy, law and ethics. From a technological perspective, AI is a broad term covering machine learning, neural networks, cognitive computing, language processing and others. It constitutes a paradigmatic shift in processing data as it enables a computer to observe its environment or use a large set of representative data, learn and take intelligent action or propose decisions for which it has not been explicitly programmed (Craglia et al. 2018). However, AI is not yet capable of generalised intelligence or common sense and cannot translate experiences from one type of task to another, requiring specialised (human) expertise for every single new domain of use.

AI can be deployed across many industry sectors, generating productivity gains and additional insights in domains where established analytical techniques are

already depleted. Much like the steam engine or electricity in the past, AI is a general-purpose technology with the potential to profoundly transform, directly or indirectly, many aspects of our societies and economies (European Political Strategy Centre 2018). Here are just a few examples of AI's commercial use: image recognition and classification; asset valuation, market analysis and risk assessment (banking and finance); clustering sets of consumer segments based on individual data; personalised marketing, prices and promotions; optimization of outcomes such as generating routes with the best combinations of time and fuel (logistics and road traffic); generating novel data based on previous training (create new music or art of the same style with an input piece); personalised health-care and diagnosis; detection of anomalies and predictive maintenance (extending the life-span of machines); speech recognition (customer service management) and autonomous driving (McKinsey&Company 2017). AI is also highly effective for automated hacking, personalised disinformation campaigns, targeted propaganda, social manipulation and invasive automated surveillance. Therefore, the deployment of AI is and should be bound by constraints due to concerns and evolving regulatory framework around pertaining issues such as human rights, individual freedoms, privacy and personal data protection (Chui et al. 2018).

Having these in mind, AI has become a key driver for enhancing productivity and competitiveness, but also an area of strategic importance, as it is crucial for preserving, or advancing, a nation's security and values (Acharya and Dunn 2022). The United States of America (USA), traditional leader in ICT and digital technologies, still holds the initiative in AI development, judging by the complexity of its ecosystem, the number and global reach of its AI companies, the venture capital scene and available pool of talent. Several Asian nations are following closely, starting with China, followed by Japan, Singapore (Government of Singapore 2017), South Korea (Zastrow 2016) and of course, India (European Political Strategy Centre 2018). According to Chinese sources, while strategy and policy documents in China, US and Japan strive to accelerate the integration of AI within the real economy, as well as with defence and national security, the European Union's policy making is rather concentrating on mitigating the ethical and moral risks of AI, rather than the development itself (Tsinghua University Research Centre for Chinese Technology Policies 2018). However, currently within the EU as well, the focus is swiftly changing towards technology development, as recently both the European Union and some of its Member States have stepped up investment and deployed supportive policies around the development of AI.

China, after four decades of economic transformations, envisions becoming a world leader of innovation. Economic growth's low-hanging fruits have been depleted and a model based on low-value production is no longer feasible. Currently, the nation is the world's largest exporter and its shares in global markets continue to rise. That is not because the economy would expand its low-cost manufacturing base, as manufacturing is actually moving out to countries in South-East Asia and Africa. On the contrary, China is moving up the value chain through innovation, shifting its exports to high-value added products (Zhang and Zhou 2015) or from products to services whatsoever. China is therefore very supportive of innovation

at all social and political levels, the word "innovation" becoming a leitmotif across policy documents as well as across commercial strategy guidelines. And amongst innovation areas, artificial intelligence and AI-related industries have steadily moved to the centre stage of China's policy making and economic reform (Creemers 2018).

In November 2017, Eric Schmidt, then CEO of Alphabet, brought attention to the relevance of China on the AI scene with the statement "By 2020, they will have caught up. By 2025, they will be better than us. By 2030, they will dominate the industries of AI" (Arenal et al. 2020). Having in mind that the country is soon to become the world's largest spender on R&D (OECD 2019), its burgeoning venture capital ecosystem, the scale of its internet corporate giants and the pool of AI engineering talent, adding to the ambitious policy targets set by the government, China is set to play an increasingly important role on the global AI scene (Allison et al. 2021).

This paper aims to map the main characteristics of China's AI ecosystem development, drawing attention to the complex role played by the government including an overview of the most relevant policy documents, emerging methods of funding in public–private partnership, AI ecosystem market scale and talent retention strategies. Against this background, within the analytical framework of innovation and economic growth, the final section will draw several policy recommendations for the EU regarding AI development.

2 Literature Review

This section will start with the most influential perspectives about the nature of innovation, its connection to economic development and the mechanisms that enable innovation to occur and spread in a developing economy. On that basis, it will review the most relevant studies and data on China's AI ecosystem development and will highlight the gaps in existing literature.

2.1 Theoretical Framework

The Learning Model, proposed by evolutionary economists such as Dosi (1997) and Metcalfe (1998) to explain innovation, is the most useful to describe China's AI ecosystem. Accordingly, innovation is acquired by firms through a gradual process of developing and accumulating existing capabilities, making use of their available resources and opportunities. The learning sequence starts with low-end manufacture. Climbing reversed product cycles, firms incrementally acquire new designs and skills that enable them to improve their processes, products and marketing, eventually reaching the top of the production chain. Evolution includes "variety creation [..], replication including imitation [..] and selection [that reduce variety in the economic system and discourages the inefficient or ineffective utilisation of resources]" (Malerba and Nelson 2012). The concept of "leapfrogging" will also

prove to be useful during the analysis. This view emphasises the advantage of the latecomer who has the opportunity to skip costly stages of research, to learn and make direct use of the innovation breakthroughs already available (Lu 2000).

2.2 Funding

One of the most cited databases for information regarding China's AI investments in terms of volume, distribution of sources and destination by sectors belongs to Tsinghua University's Research Centre for Chinese Technology Policies. Accordingly, from 2013 to 2018 Q1 China accounted for 60% of world investments in AI, being by far the industry's financial leader, while the US accounted for just 29% (Xue 2018). In 2017, the global scale of AI financing would have reached USD 39.5 billion, out of which China accounted for USD 27.7 billion (70%)—mostly in Beijing and through series A investments. Therefore, in recent years investment in China's AI industry has grown significantly both in nominal value and relative terms as compared to the global total.

2.3 Market Scale

China has the largest market in the world in terms of PPP, ahead of the US and India (IMF 2018). Li, Y. argues that such a scale offers unique possibilities for both domestic and international firms to experiment and find niches for their new products and ideas. As such, the market acts as a complex multi-layered arena of interaction between Chinese companies, foreign firms and government (2017). In June 2018, there were 4,925 companies around the world that have AI at the core of their operations**,** out of which mainland China was hosting 1,011 and accounted for 21% of global share, ranking second after the US which hosted 2,028 companies or 41% of global share (Tsinghua University—Research Centre for Chinese Technology Policies 2018). Third spot is occupied by the United Kingdom (7%), followed by Canada and India. Among these companies, as of Sep. 2018 China had 14 "unicorns", valued at USD 40.5 billion in total (China Money Network, in World Economic Forum 2018) (Fig. 1).

Databases show Beijing as being by far China's leading cluster in terms of market scale, talents and investment (Development Solutions Europe Ltd. 2018). It is also the first city in the world by the total number of AI companies (395, or 40% of national total) (Tsinghua University—Research Centre for Chinese Technology Policies 2018). In China, it hosts more than half of the AI-related State Key Laboratories and major research bases and is also home to tech giant Baidu, as well as to Zhongguancun District, considered to be China's Silicon Valley. Shanghai is the second AI hub in China and 4th in the world by the number of companies (224).

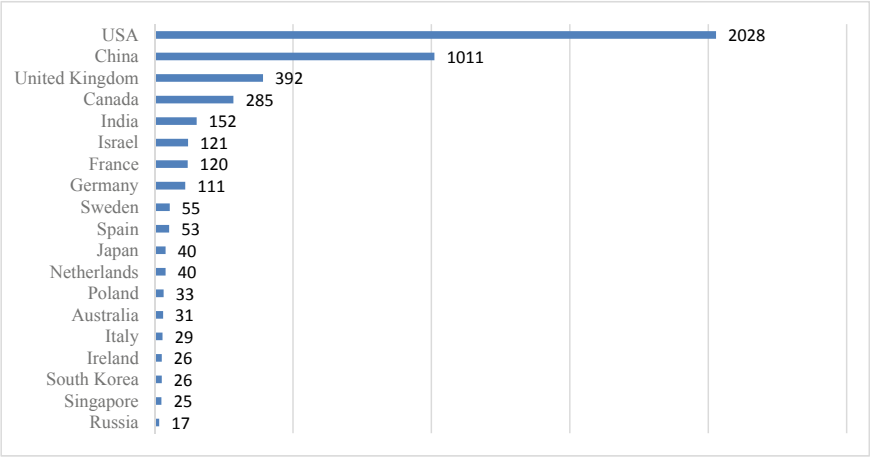

Fig. 1 Number of AI companies by hosting countries. *Source* Tsinghua University—Research Centre for Chinese Technology Policies, 清华大学中国科技政策研究中心 Report on the Development of Artificial Intelligence in China 2018 (中国人工智能发展报告2018)

Together with Beijing, Shanghai is also a leader for chips and semiconductors development, which are crucial to support AI applications. Hangzhou is an important hub for AI companies and hosts Alibaba's headquarters. The municipality partners with Alibaba in order to build an integrated intelligent traffic system. Jiangsu Province leads the development of AI hard infrastructure, internet of things (IoF) and cloud computing. It also develops the Jiangsu Brain Plan and the Jiangsu Brain-inspired AI Industry Alliance. In turn, Fujian specialises in IoF, big data, innovation platforms and intellectual property rights, while Guizhou is the new hub for big data.

3 Methodology

Using the framework of Learning Models and "Leapfrogging", this exploratory research aims to provide a contextual macro understanding of the mechanisms and processes that drive China's AI push, by examining the role of the government and public policies, private–public partnership and integration, the advantages brought by the market scale, as well as talent retention programmes as a driver of domestic innovation. The current paper does not aim to measure the scope of performance of AI innovation in China, nor its extent, which would require a different set of input and output quantitative measures. It limits its scope to China at national level, but draws attention to the significant differences amongst provinces and cities. The paper also highlights the frequent misconception in existing literature of viewing China as a monolithic bloc, as private actors and entities are also powerful shapers of the AI landscape (Ding 2018).

Firstly, a review was performed of available relevant academic literature regarding China's innovation policy in general and AI in particular, in English, French and Chinese. Secondly, data regarding market and funding indicators was received from specialised commercial databases with restricted access.

Following, the author conducted qualitative and quantitative research of public policy documents that contain references to the following terms: "artificial intelligence", "machine learning", "deep learning" and "automation". The research was performed at central government level, provincial and local governments, as well as at central party level, local branches and related organisations. Political statements were also reviewed from official press releases.

Finally, qualitative data is also extracted from 12 informal interviews conducted with 4 Chinese officials, 4 top management-level executives in tech companies and 4 leading academic figures in fields related to AI. The interviews were conducted in Chinese and granted anonymity.

Whenever possible, to increase reliability, data has been cross-verified from several sources and using different collecting methods.

4 Results and Discussions

4.1 Policy Making

Innovation has long been considered critical for China's economic development by top leadership. Chairman Deng Xiaoping designated science and technology (S&T) as the 'first productive force' in 1978,[1] whereas the concept of 'revitalising the nation through S&T has become widely used since 1995.[2] Currently, innovation is the first amongst 5 big principles for development which shall lead China to build a moderately prosperous society in all aspects: innovation, coordination, green, open, and shared development (Ministry of Foreign Affairs of PRC 2016). The importance given to S&T is reflected by the massive increase in research and development (R&D) expenditure during the last decades, both in nominal value and as a percentage of GDP. And AI takes an increasingly preeminent role amongst S&T sectors. This section will overview the mixture of policies and roles performed by the Chinese government in relation to AI development. However, it is important to highlight that China's AI policy is not monolithic. Instead, it is formed of a complex network of central and regional, provincial and municipal policies, at different levels of development and support, connected or dissipated.

In May 2015, the State Council released *Made in China 2025*, a framework aimed at transforming China into an advanced manufacturing powerhouse within the following decade, drawing inspiration from the German *Industrie 4.0*. The main

[1] 3rd Plenary Session of the 11th CPC Central Committee of the Communist Party of China, 18 Dec. 1978.

[2] Introducer at the National Science Conference, 1995.

emphasis of the policy falls on smart manufacturing. It also targets the integrated development of information and cyber technologies, production automation and new industrial internet applications, with the general aim to improve precision manufacturing and agile manufacturing capabilities. While AI is not mentioned as such, AI-enabling technologies are a core emphasis of *Made in China 2025.*

In March 2016, following the entry into the Thirteenth Five-year Plan on National Economic and Social Development (2016–2020), The Ministry of Industry and Information Technology with the National Development and Reform Commission and the Ministry of Science and Technologies launched The *13th Five-Year Plan for Developing National Strategic and Emerging Industries* together with the *'Internet+' Artificial Intelligence Three-year Action Plan. China Artificial Intelligence White Paper* followed to provide guidelines for R&D specifically for AI.

In February 2017, *Artificial Intelligence 2.0* was designated as a mega-project, alongside fifteen other technologies deemed crucial (China Academy of Engineering [中国工程院院刊] 2017). The main outcome of the document was to award AI development substantial additional funding.

In July 2017, the State Council released The *Plan for the Development of New Generation Artificial Intelligence* (2017), as the key document laying the foundations of China's AI industry. The document defines AI clearly as a national-strategic level priority, and emphasises the target areas to be given all-around support by 2030. The goal is responding to the complicated national security and international competition situation, in order to ensure that China maintains the strategic initiative in AI development and thus (1) builds a competitive edge, (2) stimulates the development of new industries, and (3) improves national security (Development Solutions Europe Ltd. 2018) (Tsinghua University—Research Centre for Chinese Technology Policies 2018). The plan envisions three important milestones:

- 2020: Catching up with the most advanced AI powers

By 2020, China's AI industry is about to close the gap on most advanced AI technologies and their applications. Some domestic companies were foreseen to make significant breakthroughs and thus become internationally competitive. AI should have become an important economic growth net contributor, with a gross-output exceeding RMB 150 billion (USD 22.5 billion) for the core AI industry and RMB 1 trillion (USD 150.8 billion) for AI-related industries.

- 2025: Becoming one of the world leaders

By 2025, major breakthroughs would be made in fundamental AI theory, while in a set of priority technologies and their applications China would become the leader. AI technologies should be deployed widely in the market in fields such as intelligent manufacturing, healthcare, smart cities, agriculture and defence. At the same time, the basic legal framework would be defined, including standards, safety, supervision, etc. The gross-output would exceed RMB 400 billion (USD 60.3 billion) for the core AI industry and RMB 5 trillion (USD 750.0 billion) for AI-related industries.

- 2030: Achieving primacy

By 2030, China aims to become the world's leader for AI theory, technologies and applications. China would host world-class innovation clusters and AI would become deeply integrated within production chains, as well as within social governance and defence systems. The gross-output will exceed RMB 1 trillion (USD 150.8 billion) for the core AI industry and RMB 10 trillion (USD 1.5 trillion) for AI-related industries.

4.2 Industry-Government Integration

In November 2017, the Ministry of Science and Technology launched the Association for the New Generation of Artificial Intelligence Development Planning Promotion. Part of this effort included the establishment of four artificial intelligence open innovation platforms, each led by technology giants Baidu, Alibaba Group, Tencent Holdings and iFlyTek respectively:

- Baidu's Autonomous Driving National AI Open Innovation Platform;
- Aliyun's (Alibaba cloud) City Brain (Urban Cognition) National AI Open Innovation Platform;
- Tencent's Medical Imaging National Open Innovation Platform; and
- iFlyTek's Intelligent Voice National AI Open Innovation Platform.

In addition to public funding, the open innovation platforms awarded private companies unprecedented access to public infrastructure and data, marking a cornerstone in industry-government integration.

In terms of funding, the government tunnels public money to private venture funds that are allowed to invest according to market principles through the Government Guided Funds (GGF). GGFs are backed by public money but management and decision-making is delegated to private stakeholders.

As far as academia is concerned, AI tech companies develop joint programs with universities. While companies receive access to the talent pool, alongside public research infrastructure, universities tap into company's resources, get closer connected to market needs and enable their students to find immediate employment.

Finally, it is important to note that the public–private distinction is not clear-cut in China. In those areas of specific interest, the state might own itself, directly or indirectly, important shares of companies, or possess other types of dependency relations (Li 2017). The state might also intervene strongly with protective measures in markets where domestic firms are less competitive and more vulnerable against foreign companies. In turn, this raises significant concerns amongst foreign companies regarding fair competition and the lack of an equal-playing field. Actually, in order to protect domestic companies, China blocks the services of American companies such as Facebook, Alphabet and Twitter. That brings adverse effects within China's domestic market as well, as protecting state-chosen giants harms the chances of emergence and success of new companies that have the potential to stir innovation.

4.3 Market Scale

AI have a voracious appetite for data, both in terms of volume and variety. It can be productive only if a threshold of data volume is reached. In primary stages, both AI and other traditional technologies increase their performance concomitantly with the increase in size of data sets. However, after a point, other technologies tend to plateau, whereas AI using deep neural networks continues to increase performance unlimitedly.

AI companies in China have a significant advantage as they can tap into a huge emerging consumer market, tech-savvy and highly-enthusiast on using new technologies. However, the sheer scale of China's internal market, the huge number of Chinese internet users and their potential to generate data cannot be seen as superior to the USA's market. While the USA internal market is smaller, American companies are not limited to it and have global reach. With a presence on most markets around the world (with the notable exception of China), US tech companies not only have access to more data, but also data that is more diversified. The idea that data is easier to be collected in China due to lax privacy regulations, is not valid anymore. In recent years there has been a strong push for regulation regarding data privacy and the Chinese government took strong actions to limit the capabilities of Chinese tech giants, to an extent that could not be foreseen in market economies. Moreover, Chinese consumers have been always more reluctant and attentive to the personal data they voluntarily provide to internet applications, as compared to their peers in Western societies. For instance, there is no email, messaging or social media application where Chinese citizens usually currently use their real name or photo unless it is compulsory.

Currently, Chinese companies are fighting to internationalise but so far results are limited. Bytedance, the owner of TikTok, set an important precedent as the first ever Chinese company that succeeds to act as a global competitor to US tech giants on AI-based services.

4.4 Talent

Given China's economic transformation and ambition to climb supply chains towards higher-value industries, the demand for highly skilled workers and top-notch scientists has continuously increased. In the case of AI more specifically, there is a stringent need for world-class AI engineers. In this area, the USA has a large advantage as a top destination for the brightest minds around the world that China needs to compete with. Employing foreign talents does not only help improve S&T and thus power long-term economic growth, but also contributes to strengthening the commercial relations between Chinese tech companies and the rest of the world (International Labour Organisation 2017). Therefore, in recent decades, attracting researchers trained abroad has consistently formed a key part of China's S&T policy.

The country has established a series of programmes to attract foreign researchers, such as the Thousand Talents Programme. However, despite sustained efforts, the policy's results are mixed.

Foreign researchers are considered those non-Chinese citizens who are PhDs students, post-doctoral fellows or holders of higher academic titles that come to China to work in universities, research institutes or enterprises, being employed specifically for research activities. It is important to note that most talent programs are mixed, targeting both Chinese and non-Chinese citizens, as well as both researchers and other categories of overseas talents.

Governments in China at all levels have been energetically building initiatives for attracting overseas talents, whether returning Chinese or foreign-citizens, particularly those who have studied or worked at the most prestigious universities and companies overseas and who can demonstrate outstanding achievements. These policies included centrally-led schemes like the "Thousand Talent Programme", The Chinese Academy of Science's Hundred Talents Program, regional programs and public–private endeavours. They are usually designed to provide researchers with start-up packages or continuous funding equivalent to what they could expect in Western countries. Beyond the central government, provincial and city-level governments also usually replicate national schemes that can be earned cumulatively by the same individual/team, in addition to national funding.

As a result, the number of foreign Ph.D. holders that venture to Chinese public research institutions or tech companies increased every year, in search of access to generous funding and state-of-the art research facilities, opportunities to get involved in national "big" projects and a vibrant scientific community that is increasingly professional. However, China's talent programmes have a mixed track record as so far the overall number of foreign researchers coming to China is rather low and retention (if China really aims for that) is even lower. A multitude of factors play a role including the fact including difficult cultural and social integration, academic freedom limitations, low internationalisation profile of Chinese universities and companies etc.

5 Conclusion

This paper presents the story of how a developing, manufacturing-based economy can learn, accumulate capabilities and move towards an innovative, competitive and technology-driven growth model in a top-notch industry—artificial intelligence.

The nation is one of the largest spenders for A&I development in the world. While some databases put China on top of the list, methodologies and actual means of calculating AI public and private investment vary significantly. But it is a certainty that the Chinese government and China-based companies increasingly have the capacity to allocate large funding to fundamental AI development. While usually R&D financing in China is largely carried by the private sector and the government supports with fiscal incentives, the case of AI is different, as a top policy priority. Therefore, despite

an already mature ecosystem and strong companies in the industry, the government contributed extensively to R&D funding. It does so through a multitude of direct and indirect channels, including direct funding for R&D in public institutes, delegating public resources to private venture capital funds through the Government Guided Funds and establishing overseas talent attraction programs that benefit both universities and domestic corporations.

In recent years, China has made strenuous efforts to attract foreign researchers and top-notch AI engineers. However, due to a mix of cultural, administrative and systemic reasons, China has not yet become a preferred emigration destination for foreign talents and the actual number of highly qualified foreign talents recruited remains disappointingly low, not to mention the retention rate. However, China's talent strategy should not be seen as a public, monolithic, completely top-down approach. The private sector is also very relevant, or sometimes more relevant. The most "natural" and probably the most common way for research talents to come (or return) to China is the commercial path. There are more and more Chinese companies with competitive salaries and state-of-the-art research facilities that employ foreign researchers without applying for governmental assistance. The same is the case for public universities. While there is no authoritative statistics on foreign researchers coming by commercial ways, there are a few iconic examples such as Andrew Ng, former head of Google Brain who transferred to Baidu and Qi Lu, former executive vice president of Microsoft, who has moved to become Baidu's CEO. Therefore, the structure and competitiveness of the private sector contributes greatly to China's capacity to attract and retain talents.

Overall, China's AI industry is developing fast, benefiting from public support. It has also brought its first successful wins on markets overseas. However, China still lacks a critical mass of tech champions that have the capacity, scale and attractiveness to compete with American giants on an equal footing. Nevertheless, China's AI faces vulnerabilities in crucial hardware such as semiconductors (Arenal et al. 2020).

Although we can draw many lessons from China's story, its model cannot be replicated in a different context. China finds itself in different contexts, pertaining to its political establishment, cultural background, market scale and consumer behaviour.

As far as the European Union is concerned, it leads an important and healthy debate about ethics and potential dangers of AI. While the EU should push even harder to properly address worrying privacy issues and ethical concerns, in a potential insufficient focus on technology development, it is deemed to lack the means to actually benefit economically, protect its citizens and set the global standards in the AI revolution. Currently, there is limited funding and policy support for technology development in comparison to global peers, and few steps are made in the direction of bringing domestic EU technology and AI services on the global stage. The fact that the EU lacks its own large internet companies, leaving all its data under the monopoly of non-EU tech companies, does not only inhibit domestic innovations but it also makes it increasingly difficult for the EU to achieve its goal of protecting citizens' security and mitigate AI risks.

In the context of rapid technological breakthroughs in China, USA and the rest of the world, the EU has already set innovation in general and AI in particular as a top

policy priority and deployed a variety of strategies and measures, at different levels, to foster domestic technological progress. While ultimately innovation is driven by the market, the European Commission and Member States should intensify their efforts to become effective facilitators, platform-creators and strategic planners of the AI innovation system. This report proposes 10 policy directions for the EU which include but are not limited to allocating increasing resources for research while targeting certain strategic areas that are omitted by the market, designing AI innovation-friendly policies and improving institutional efficiency, promoting technological European independence, stimulating acquisition of foreign technology, attracting talents and others:

(1) Prioritise AI development in S&T policy-making;
(2) Adhere to an integrated European approach by pooling together Member States' resources;
(3) Increase public funding for AI R&D and AI-oriented venture capital;
(4) Stimulate AI market scale and output, including through public procurement;
(5) Allow and support the emergence of domestic tech champions with global reach;
(6) Design talent retention and attraction programs, with generous funding;
(7) Encourage experimentation and public–private integration;
(8) Encourage university-industry joint ventures;
(9) Designate AI as a key component of common security and defence planning;
(10) Designate a limited number of AI clusters within the EU that receive all-around support.

References

Acharya, A., Dunn, B.: Comparing U.S. and Chinese contributions to high-impact AI research. CSET Data Brief (2022)

Allison, G., Klyman, K., Barbesino, K., Yen, H.: The great tech rivarly: China vs the U.S. Cambridge, MA (2021)

Arenal, A., Armuña, C., Feijoo, C., Ramos, S., Xu, Z., Moreno, A.: Innovation ecosystems theory revisited: the case of artificial intelligence in China. Telecommun. Policy **44**(6) (2020). https://doi.org/10.1016/j.telpol.2020.101960

Barton, D., Woetzel, J., Seong, J., Tian, Q.: Artificial intelligence: implications for China (2017)

China Academy of Engineering [中国工程院院刊]: New Intellectual Report [新智元报道]: Unveiling of Artificial Intelligence 2.0 Era [人工智能2.0时代序幕开启] (2017)

Chui, M., Manyika, J., Miremadi, M., Henke, N., Chung, R., Nel, P., Malhotra, S.: Notes from the AI Frontier. Insights from hundreds of use cases. McKinsey Global Institute (2018)

Craglia, M., Annoni, A., Benczur, P., Bertoldi, P., Delipetrev, P., De Prato, G., … Vesnic, A.L.: Artificial intelligence: A European perspective. European Union (2018). https://doi.org/10.2760/11251

Creemers, R.: The international and foreign policy impact of China's AI and big data strategies. In: Wright, N.D. (ed.) AI, China, Russia, and the Global Order: Technological, Political, Global, and Creative Perspectives, December 2, p. 122. Strategic Multilayer Assessment (SMA) (2018)

Development Solutions Europe Ltd.: China's '1+N' funding strategy for Artificial Intelligence (2018). http://chinainnovationfunding.eu/china-funding-artificial-intelligence/
Ding, J.: Deciphering China's AI dream: the context, components, capabilities, and consequences of China's strategy to lead the world in AI. Future of Humanity Institute, University of Oxford, March, pp. 1–44 (2018)
Dosi, G.: Opportunities, incentives and collective patterns of technological change. Econ. J. (1997). https://doi.org/10.1111/1468-0297.00239
European Political Strategy Centre: The age of artificial intelligence (EPSC Strategic Notes) (2018)
Government of Singapore: P. M. O. Singapore AI Strategy (AI. SG), 'Artificial Intelligence R&D Programme' (2017)
International Labour Organisation (ILO): Attracting skilled international migrants to China: a review and comparison of policies and practices (2017). https://publications.iom.int/system/files/pdf/attracting_skilled_en_0.pdf
Li, Y.: Innovation pathways in the Chinese economy (2017). Georgia Institute of Technology. http://hdl.handle.net/1853/59127
Lu, Q.: China's leap into the information age: innovation and organization in the computer industry. Oxford University Press (2000)
Malerba, F., Nelson, R.: Economic Development as a Learning Process. Edward Elgar Publishing (2012). https://doi.org/10.4337/9780857937896
McKinsey&Company: Digital China: powering the economy to global competitiveness, December (2017). https://www.mckinsey.com/~/media/McKinsey/GlobalThemes/China/DigitalChinaPoweringtheeconomytoglobalcompetitiveness/MGI-Digital-China-Report-December-20-2017.ashx
Metcalfe, J.S.: Evolutionary Economics and Creative Destruction (First). Routledge, London (1998). https://doi.org/10.4324/9780203275146
Ministry of Foreign Affairs of PRC: (2016). https://www.fmprc.gov.cn/mfaeng/topics665678/xjpdmgjxgsfwbcxlhgcl70znxlfh/t1357701.shtml
OECD: Gross domestic spending on R&D (indicator) (2019). https://doi.org/10.1787/d8b068b4-en
State Council: Notice on Issuing the Plan for the Development of New Generation Artificial Intelligence (Guo Fa [2017] No. 35) 国务院关于印发《新一代人工智能发展规划》的通知 (国发〔2017〕35号). State Council of the People's Republic of China (2017). http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm
Tsinghua University—Research Centre for Chinese Technology Policies (清华大学中国科技政策研究中心): China AI development report 2018 (中国人工智能发展报告), July (2018)
World Economic Forum: Meet China's 5 biggest AI companies (2018). https://www.weforum.org/agenda/2018/09/the-top-5-chinese-ai-companies/
Xue, L.: China AI development report 2018. July (2018)
Zastrow, M.: South Korea's nobel dream. Nature **534**(7605), 19–22 (2016)
Zhang, Y., Zhou, Y.: The Source of Innovation in China: Highly Innovative Systems. Palgrave Macmillan, Basingstoke (2015)