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CHINA'S AI ECOSYSTEM

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EXECUTIVE SUMMARY

This report presents an overview of China's AI ecosystem, emphasizing policy and governance, ecosystem actors and development, strengths and challenges, and takeaways for Swedish AI actors. The report has been produced by the Stockholm China Economic Research Institute at the Stockholm School of Economics and the work has been funded by Vinnova, the Swedish Innovation Agency. The purpose of the report is to:

- Map out and increase the understanding of China's advancements in AI and its implications for members of the Swedish AI ecosystem

To do this, the report aims to:

- Examine China's AI policy framework in terms of scope and implementation
- Map out the scope of investments, regional AI hubs, leading corporate actors, national actors, and talent and education
- Identify strengths and challenges for China's AI ecosystem
- Discuss opportunities and challenges for members of Sweden's AI ecosystem

To fulfill the purpose and aims, the report begins with a detailed discussion of how China's national policy framework has evolved, starting with a comprehensive national strategic plan that was announced in 2017. Here, it also gives insight into how that as well as complementary plans are being implemented and touches upon the governance framework that has begun to take shape in China.

Moving over to the AI industry, the report provides an overview of investments in the AI space before it examines AI hub development across the country and the Chinese government's focus on building a national AI team and other leading players in the corporate sector. This is followed by an overview of government activity and some of the main national actors, after which research, talent, and education are examined.

Having a complete picture of the AI industry, the report then examines some of the strong points in China's rapidly evolving AI ecosystem, including the country's unique socio-political context,

a relatively lax regulatory framework, and access to large amounts of data. It then sheds light on some of the challenges China's AI ecosystem is facing in its future development. These challenges include the demand-supply disparity for AI talent, geopolitical tensions, a lack of domestically developed core technological tools, and the challenge for China to take a leading role in the development of an international AI governance framework.

Finally, the report provides an overview of the opportunities for foreign AI actors before it highlights some of the challenges that such actors are facing if they decide to expand their business activities to China.

Key Findings

- China has developed a comprehensive policy framework for AI development that leverages central and local governments, the private sector, academia, and research organizations
- AI is deemed a national priority and as such receives significant attention and support at all levels
- A governance framework is evolving, mostly with a focus on overall ethics, but recently laws for data security and personal information protection are also being implemented
- Private investments in AI are steadily increasing and China is now second only to the US
- Three major AI hubs have developed: the Beijing-Tianjin-Hebei, Yangtze River, and Pearl River regions
- The Chinese government is supporting a select number of leading AI companies, the so-called national AI team, which are developing open platforms in their respective areas
- Other domestic AI companies are also emerging and becoming important players
- The priority placed on AI can be seen in the many government organizations that are actively involved in its development
- China has several important national alliances and collaborative efforts across the corporate sector, higher education, research organizations, and sectoral organizations
- China is strong in AI research and has become a world leader in research publications and patent applications, even though the US is still ahead when it comes to high-impact research

- The government has identified talent shortage as a priority and the country's educational institutions have quickly expanded the number of graduates with an AI focus
- The AI talent demand-supply disparity, in particular when it comes to top AI talent
- Major strong points for the development of China's AI ecosystem include the unique socio-political context, a previously lax regulatory framework, and access to large amounts of data
- Some of the challenges China is facing include the remaining talent shortage, geopolitical tensions, a lack of domestically developed core technological tools, and the difficulties in taking a lead in the development of a global AI governance framework
- Ample opportunities for international AI actors exist in China, not the least due to its sizeable market and its world-leading manufacturing and industry sector
- Challenges include fierce market competition, Chinese companies receiving government support, the increasing geopolitical tensions between China and the US (and its allies), and an ongoing tech sector crackdown and changing regulatory framework

INTRODUCTION

The role of artificial intelligence (AI) techniques and tools in business, the global economy, and society at large has become one of today's defining topics. The progress in this area over the last decade has resulted in substantial breakthroughs and demonstrations of the role AI can take in almost every industry. Continuous growth in computer processing power, access to increasingly comprehensive big datasets, and the blend of AI into existing technologies have resulted in AI being used in a wide range of applications. It is already having important implications for industrial structure¹, and it is commonly believed that AI may herald radical and unprecedented changes in how people around the world live and work. Simulations by McKinsey & Company suggest that AI has the potential to deliver an additional global economic activity of around \$13 trillion globally by 2030, which would amount to an additional 1.2% GDP growth per year.²

Over the last decade, China has emerged as an increasingly important player in the global AI ecosystem. Early on, Chinese tech companies utilized inherent advantages in China such as access to large data and relatively lax data privacy regulations to develop cutting-edge AI applications in areas such as finance, visual and facial recognition, language recognition, intelligent robots, and retail applications. However, while these inherent advantages combined with a brutally competitive internal market drove development in a wide range of commercialized AI applications early on, a major driver during the last five years has been the introduction of a comprehensive national AI plan in 2017. With the introduction and implementation of this plan, “AI has reached the peak of China’s national strategy”³, and the mobilization of the state, private sector, academic institutions, and the military is propelling AI development in a wide array of sectors.

For China’s policymakers, AI is one important piece in the puzzle to transform the country’s traditional economic model based on very high levels of investments into a model that is more balanced and in which innovation drives growth through more productive use of capital. This is not least seen in President Xi Jinping’s aspiration of a dual circulation economy with a better balance between internal consumption while maintaining an openness to the rest of the world. It has repeatedly been stated that innovation will drive the dual circulation economy, and in this process, AI is seen as a key driver. For China’s military, AI constitutes an opportunity to leapfrog and get the upper hand on the US military.

Today, China and the United States are the two leading countries in AI in terms of investments, research and development (R&D) efforts, and national AI industries. It has been argued that the concentrated efforts and the resulting rapid growth of the AI ecosystem signal that China will become the first truly global AI superpower in the near future.⁴ As China's prominence in AI grows, it is attracting the attention of international policymakers, organizations, and not least businesses. At the same time, an increasingly complex geopolitical setting, a lack of knowledge of China's AI strategy, and China's evolving domestic rules and regulations can make it challenging for actors in foreign AI ecosystems to grasp the challenges and opportunities that China presents.

The main purpose of this report is to map China's AI ecosystem by examining

- China's AI policy framework in terms of scope and implementation
- The scope of investments, regional AI hubs, leading corporate actors, national actors, and talent and education
- Strengths and challenges for China's AI ecosystem
- Opportunities and challenges for members of Sweden's AI ecosystem

Based on this, the report is broken down into four parts: policy and governance, the AI industry, strengths and challenges, and implications for foreign AI actors.

This report is the result of a study conducted by the Stockholm China Economic Research Institute at the Stockholm School of Economics and is funded by Vinnova, the Swedish Innovation Agency. Desktop research on the evolving AI ecosystem in China has been complemented by interviews with relevant businesses, organizations, and academic experts. The report is meant to provide insight into China's rapidly evolving and growing AI ecosystem. It also aims to provide concrete information to support actors in the Swedish ecosystem in their understanding of one of the world's most important AI ecosystems today.

POLICY AND GOVERNANCE

While the first national plan for AI was announced as late as 2017, AI has long been a priority for China's government. The government's support for developing AI and different types of frontier technologies goes back to the State Council's "National Medium- and Long-Term Plan (MLP) for the Development of Science and Technology (2006-2020).⁵ The MLP was ambitious and one of its targets was to promote indigenous innovation. It established fifteen national megaprojects dedicated to science and technology and an estimated \$75 billion in long-term funding for science research. In early 2017, the plan "Artificial Intelligence 2.0" was designated as a megaproject as well, signaling that significant funding would be allocated towards AI.

In May 2015, the now famous "Made in China 2025" was released⁶. This ambitious initiative also emphasized homegrown innovation to reduce China's dependence on foreign technology and promote Chinese technological manufacturers globally. This plan to revamp the domestic industry focuses on areas such as information technology, robots, energy-saving vehicles, medical devices, computerized machines, and high-tech equipment for sectors such as aerospace technology, and maritime and rail transport.

In 2015, another initiative called "Internet Plus" was also established. Jointly issued by the National Development and Reform Commission (NDRC), Ministry of Science and Technology (MOST), Ministry of Industry and Information Technology (MIIT), and the Cyberspace Administration of China, the initiative is closely related to AI development. This can be seen in the release of NDRC's "Three-Year Implementation Plan for Internet Plus and AI", which states that China will speed up the development of the domestic AI sector and reach a \$15.3 billion market value within three years.⁷

These major initiatives together with several smaller-scale policies and initiatives that relate to AI during this period show the increasing interest of the Chinese government. What would come soon thereafter would cement the strong focus on AI up to 2030. Former director of Google China and leading voice on technological development in China Kai-Fu Lee argues that a fundamental change in how China views AI came about in 2016. That year, the reinforcement learning program AlphaGo which had been developed by DeepMind managed to beat the world champion in Weiqi

(or Go in Japanese). Lee says that with this event came a realization of how important AI is and that China must position itself at the forefront of the field.⁸ In fact, while the event was relatively unnoticed by the rest of the world, not only the Chinese government and corporate sector but also ordinary citizens were fascinated. Over 280 million people watched the event live (Roberts et al., 2021). It is often said that this became China's "Sputnik Moment" for AI.

In the following year, the State Council, the primary administrative authority of the People's Republic of China, released its strategic plan to turn the country into a global leader in the AI space. A similar report released by the Obama administration a year earlier was mostly ignored, but the Chinese version in 2017 has had a major impact on AI development in China. While some would say it can be seen as vague, it spells out milestone goals and basic principles with which to reach those goals. It also dissects perceived existing weaknesses and what needs to be done to overcome those weaknesses for China to become a global leader in the AI space. In addition to the main plan for AI, several complementary strategic plans have been introduced to further strengthen the efforts within the AI and data space.

The rest of this section introduces the national AI plan, discusses how it is implemented, and then takes a closer look at the emerging governance framework for AI in China.

The New Generation of AI Development Plan

When the New Generation of Artificial Intelligence Development Plan (NGAIDP)⁹ was issued by China's State Council in 2017, it represented a significant step in the advancement of science and technology in the country. It is the first comprehensive strategic plan for China's AI sphere, and it includes a detailed introduction to policymakers' overall thinking and basic principles, clear strategic goals, primary tasks, and support measures¹⁰.

Strategic Goals

The NGAIDP specifies three strategic goals to be achieved in 2020, 2025, and 2030, respectively. Each of these goals encompasses the level of advancement within the AI industry, AI's contribution to China's economy and society, the establishment of rules and norms, and the size of the AI industry. Each of these goals is summarized in the figure below.

1. By 2020 overall AI technology and application in China should reach a globally advanced level. The AI industry should become a new economic growth point. AI technological applications should have become a new approach to improving people's livelihood. Initial ethical norms, policies, and regulations for vital areas in AI should be in place. The AI core industry should be worth more than 150 billion yuan.

2. By 2025 China should have achieved major breakthroughs in many areas of AI and become world-leading in some AI technology and applications. AI should have become the main driving force of industrial upgrading and economic transformation. Initial establishment of AI laws and regulations, ethical norms and policy systems, and AI safety assessment and control capabilities should have been established. The AI core industry should be worth more than 400 billion yuan.

3. By 2030 China should have been established as the world's leading innovation center in AI. China should have an important foundation from which to enter the forefront of the innovative countries and economic powers around the world and the competitiveness of its AI industry should reach an advanced international level. More comprehensive laws and regulations, ethics and a policy system for AI should be in place. The AI core industry should be worth more than 1 trillion yuan.

The plan thus delineates three milestones that will be reached between 2017 and 2030. As can be seen in the figure above, some of the goals for each of these steps such as China's international standing and the economic scope of the domestic AI industry are clearly defined, while others are vaguer. In terms of general development, the milestones signal three distinct strategic phases in the development of China's AI sector: catching up to leading AI powers by 2020, becoming a world-class AI leader by 2025, and reaching AI supremacy by 2030.¹¹

Strategic Focus

The plan emphasizes three areas in which AI can make a significant contribution to China: national competitiveness, economic development, and social construction or governance. Each of these constitutes an area in which the Chinese government generally places a significant focus.

National competitiveness

The NGAIDP states that “artificial intelligence has become the new focus of international competition.” It also says that China’s increasingly complex situation in terms of national security and international competition means that the country must grasp the strategic initiative in international competition within AI development. As noted by Roberts et al, instead of trying to outspend the US in conventional weaponry, China looks at investments in AI as an opportunity to make leapfrog developments in military technologies and overtake the US that way¹². While there are concerns within China that this effort can result in an arms race and even military escalation, it has been noted that China is the country that has been the most aggressive in pursuing AI for military uses¹³.

Economic Development

The plan notes that AI has become a new driver of economic development. It states that AI will be a core driving force of the next industrial transformation. AI will support the birth of new technologies, products, industries, formats, and models and have a significant impact on the economic structure. While the section on economic development is relatively vague, the emphasis China’s policymakers place on AI as an important tool for economic development and transformation should not be underestimated. It is now commonly accepted that there is a need for a new economic model for China to maintain a high growth rate. This new model needs to shift from very high investment levels to growth that is spurred by a more innovative society. China’s policymakers see science and technology as important ingredients in achieving this transformation. In line with this, a report by PwC in 2017 stated that China is likely the country that has the most to gain from AI¹⁴. The report argues that China can experience a boost of up to 26% of GDP in 2030 with some of the largest gains to be expected in the retail, financial services, and healthcare sectors. Similarly, a report by McKinsey Global Institute estimates that China can add 0.8 to 1.4

percentage points to GDP growth annually through workplace automation alone¹⁵. The potential for AI to act as a driver of economic growth combined with China's need for a structural change to its economy is likely why economic development is seen as an important strategic opportunity in the plan.

Social Construction/Governance

A third strategic focus explicitly spelled out in the plan is that of social construction, or social governance. NGAIDP states that the country is facing societal challenges, including an aging population and environmental issues. The application of AI in a range of fields such as education, medical care, pension, environmental protection, urban operations, and judicial services are seen as ways to improve public services and the quality of life for China's people. For example, AI has already been widely used to reform the judicial system in China. Desks of all judges in China are connected to the smart court system of systems (SoS) which has a role in every courtroom verdict¹⁶. It can also be expected that China's debated Social Credit system will rely on AI for the social governance of China's citizens. The NGAIDP also brings up how AI can be used to "timely grasp the change of group awareness and psychology", suggesting an interest in a wider scope of social governance.

Strategic Principles

The NGAIDP specifies four basic strategic principles that will be employed to achieve the plan's goals. First, it emphasizes **technological leadership**. The focus is on exploring key frontier areas, providing long-term support, and taking the lead in breakthroughs in theory, methods, tools, and systems. Second, the existing **system layout** is to be utilized. Here, the emphasis is on taking advantage of China's social system to concentrate resources that facilitate major AI-related projects. Third, the approach to reaching the stated goals should be market oriented. The focus is on the role of enterprises and the acceleration of the commercialization of AI technologies to create a comparative advantage in the marketplace. In this setting, the government should plan, and provide policy support, security, and market and ethical regulations. Fourth, **open source** will be promoted. The plan encourages the sharing of production, research, and innovation. Sharing

should take place between different stakeholders in the AI field including both civilian and military entities. It also emphasizes active participation in global R&D and the management of AI.

The Three-year Action Plan

In December 2017, MIIT released the “Three-Year Action Plan for Promoting the Development of Next Generation Artificial Intelligence Industry (2018-2020)¹⁷. This plan can be seen as a continuation of a plan released the year before by four ministries titled “Internet + Three-year Action Plan for Artificial Intelligence”. It reaffirmed what the government had committed to in the earlier plan and was also set up to implement the early stage of the NGAIDP.¹⁸ The plan included very specific goals for a select number of AI-related areas, including intelligent networked vehicles, intelligent service robots, intelligent unmanned aerial vehicles, medical imaging diagnosis systems, video image identification systems, intelligent voice interactive systems, intelligent translation systems, and smart home products. Examples of specific goals include an average accuracy rate of Chinese speech recognition at 96% and an accuracy of Chinese-English translation and English-Chinese translation of over 85%.

Implementation

The implementation of the NGAIDP takes place at the national and local levels. However, as is typical for policies, this plan is not driven by the central government. Instead, it can be seen as a signal to local governments that efforts in the AI space should be supported. This section, therefore, begins with a brief overview of how the plan is coordinated and supported at the national level and then provides a more detailed introduction to implementation at the local level.

At the national level, the NGAIDP is coordinated by the Ministry of Science and Technology (MOST) and the *AI Plan Promotion Office* (also under MOST) together with various relevant government bodies. The AI Plan Promotion Office brings together 15 government departments and ministries, including MIST, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Chinese Academy of Sciences, the Academy of Engineering, the Science and Technology Commission of the Military Commission, and the China Association for Science and Technology¹⁹.

In November 2017, MIST also announced that it had formed the *New Generation Artificial Intelligence Strategic Advisory Committee*. The committee is headed by leading Chinese scholar Pan Yunhe. Most of its 27 members are academics and researchers, but five of the members are representatives from the private sector²⁰. The committee provides advice and investigates different types of strategic issues related to AI.

One relatively unique feature in China's economic transition process during the last four decades compared to other reforming countries is the competitive incentives given to subnational government officials. Since the start of the economic reforms and opening up in the late 1970s, regional governments were encouraged to develop more rapidly than other regions. This resulted in competition in economic growth and related variables such as the ability to attract foreign investments. This system resulted in city status upgrading in many cases and, more importantly, it became an important component in the evaluation of government officials.²¹ The reason this is important is that it gives local officials strong incentives to fulfill the aims of policies at the national level. Local governments thus become drivers of national policies and they test ways to follow and deliver on government policies that are defined by the central government. As Roberts et al note, the “plan is not meant to act as a centrally enacted initiative. The AIDP instead functions as a stamp of approval for de-risking and actively incentivizing local projects that make use of AI.”²² What this means in practice is that when a national policy such as the NGAIDP is announced, local governments use it as a starting point for intensified efforts in the specified area of the economy. This is not to say that funding does not originate at the central level as well and this will be discussed in detail below. However, it does mean that a significant portion of overall funding and other types of support is decided and allocated at the local level. Moreover, in many cases, including the NGAIDP, both the government and private sector contribute to the initiative.

Initiatives and Funding

National Level

Stanford University Artificial Intelligence Index Report, which collects data on global trends in AI, notes that China has strong public investments in AI as both the central and local governments

spend heavily on AI-related R&D. As noted previously, the implementation of the NGAIDP is done both at the national and local levels.

At the national level, one important channel used to allocate funds to relevant projects is the National Natural Science Foundation of China (NSFC). It funds projects of varying sizes, and these projects are typically focused on basic research and other pre-commercial projects led by scientists. Another relevant channel is the National Key R&D Programs (NKP), an initiative to support applied research and experimental development.

The allocation of funds through these sources is not fully transparent, making it difficult to gauge the overall size of funding to AI-related projects at the national level. However, a few studies have carried out a more detailed breakdown and estimation of how funding through these channels in 2018, the year after the NGAIDP was announced. For example, a report published by the Center for Security and Emerging Technology looked at NSFC and NKP projects in 2018.²³ They estimate that \$211-452 million were provided to AI-related projects through these mechanisms that year. In a similar study that uses a larger pool of awards through NSFC and NKP and combines these with data on so-called megaproject funding, the authors estimate that the total expenditures on AI at the national level in 2018 were approximately \$138 million.²⁴ This number should be seen as a lower bound, but likely represents the allocation of funds to AI-related projects at the national level relatively well. It has been noted that national-level funding for basic research and pre-commercial projects has increased but also that approval rates are decreasing, suggesting it is getting more difficult to obtain funding.²⁵ Observers have also noted that these numbers are very likely going up significantly year by year.

It is also important to note that these numbers do not capture the full extent of central government funding of AI in China for several reasons. First, they are indirect measures based on estimations using aggregated funding data that is publicly available. Second, the NSFC and NKPs only constitute a part of centrally funded R&D efforts. In 2014, China's State Council announced that it had reorganized centrally funded R&D efforts into five pillars:²⁶

1. the NSFC
2. NKPs
3. Government “guidance funds” (can be seen as state-backed venture capital funds)

4. “Megaprojects” - program to accelerate innovation in selected industries that are seen as strategically important
5. “Bases and Talents” program to establish centrally supported labs and research teams

As the NGAIDP was released, the so-called “‘1+N’ funding strategy for artificial intelligence” was announced. Here, 1 refers to the establishment of the AI-focused megaproject, and “+N” refers to the introduction of different AI-related tasks and topics within the five pillars of funding programs at the national level listed above.²⁷ Data for centrally funded efforts in AI from guidance funds, and the bases and talents program are scarce. However, there is information available on the initial call for the newly established New Generation Artificial Intelligence Megaproject in 2018. The call was for a total of 870 million yuan and was to be used to support up to 39 projects in the areas of fundamental theory, key technologies, and smart chips and systems.²⁸

While it is difficult to map out the regional allocation of national funds with certainty, the awards of programs in NSFC offer hints as to which regions attract the most. Looking at the latest available annual report for NSFC (2019), funding is very concentrated in China’s first-tier regions, in particular Beijing, Shanghai, Jiangsu, and Guangdong.²⁹ It is thus likely that funding for AI follows this pattern, especially as these are the regions in which we find the large AI clusters (see the section on regional competitiveness and local ecosystems for more details).

Local Level Funding and Support

At the local level, efforts vary depending on different factors, including the assertiveness of local government officials as well as existing local entrepreneurial ecosystems. Developments since the NGAIDP was announced in 2017 suggest that AI has been given high priority in many regions across the country. Several of the leading regions when it comes to science and technology have even published their own AI development plans. Much of what is said in these plans echo the national plan in content and sentiment.

The decentralized nature of the implementation of the NGAIDP where local governments are incentivized to promote the local AI industry through various means also brings with it difficulties in obtaining a comprehensive picture of the effort in terms of funding. However, several cases of

projects and programs at the local level have been announced since 2017. Below follows an overview of such efforts in some of the key cities in China's AI ecosystem.

In 2018, Beijing announced that it would build a \$2.1 billion AI research park in the Mentougou district. The Zhongguancun Development Group, selected to develop the project, would explore the possibility of partnering up with foreign universities for the project which would take five years to complete. It also aimed at building a national-level AI lab in the park. The focus of the park would be to attract enterprises that work on issues related to big data, biometric identification, deep learning, and cloud computing.³⁰

Shanghai has been very active in the AI space since the announcement of the NGAIDP. In August 2019, the city launched the Shanghai Artificial Intelligence Industry Investment Fund, an AI investment fund that will support Shanghai's pledge to build a "first-class AI innovative ecosystem".³¹ The fund is led by a consortium of Chinese state-owned enterprises including Guosheng Group and Lingang Group together with private equity firms such as Yunfeng Capital. The fund's size would initially be 10 billion yuan (about \$1.4 billion) and the plans are for it to be expanded up to 100 billion yuan (\$14 billion). Another example of financial support from the local government in Shanghai is the launch of the Shanghai Artificial Intelligence Development Special Program. It was launched by the Shanghai Municipal Commission of Economy and Informatization in 2017 and funds projects that focus on R&D, applications, and commercialization of AI. The funding covers up to 30% of a project's total budget, with a maximum of 3 million yuan for projects with a total budget below 15 million yuan, and a maximum of 20 million yuan for projects with a total budget above 15 million yuan.³²

An early case of a larger-scale local AI initiative became public shortly after the national plan was announced in 2017. In May 2018, Tianjin stated that it would set up a fund worth 100 billion yuan, or about \$16 billion to support the city's AI industry.³³ The city would allocate funds to developing sectors such as robotics, software, and hardware. Almost 30 billion yuan would also be placed in a subfund that would focus on intelligent devices as well as intelligent upgrades for traditional industries. The city also promised to provide 30 million yuan to every AI-related research institution that decides to set up operations in the city. However, while the scale of this initiative is impressive, the announcement also stated that the funds would be raised from financial

organizations inside and outside China, as well as from private companies and other market actors.³⁴ The funding of the large-scale effort thus does not come solely from the local government in Tianjin.

As the examples show, support for AI-related projects at the local level comes in many forms, including direct funding from government-backed funds and funding programs, and the establishment of new environments that support companies in the AI sector.

Case Study of Local AI Strategy Development: Shenzhen

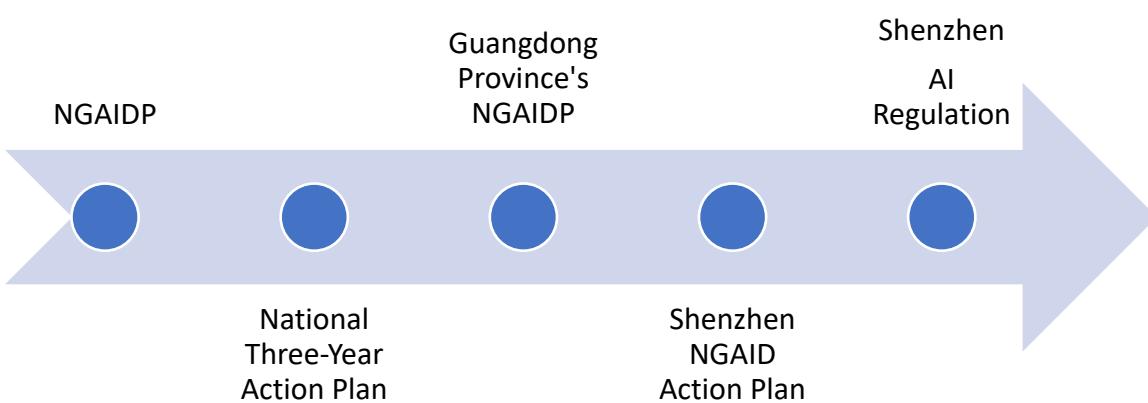
After the national NGAIDP and the three-year action plan were released in 2017, local governments at various levels including provinces, districts, cities, and special economic zones started to announce their own action plans. One of them was Shenzhen, a city located next to Hong Kong on the Chinese mainland. Over the last few decades, Shenzhen has grown into a global center in technology and research. The city is often called China's Silicon Valley and is home to many of the country's leading tech companies like Tencent and Huawei. Like other cities at the forefront of technology, Shenzhen has followed in the footsteps of the NGAIDP and the national three-year action plan and has gone to great lengths to support the national AI plan and compete against other cities across the country.

In 2019, the Shenzhen government published the “Shenzhen New Generation Artificial Intelligence Development Action Plan (2019-2023)”³⁵. The plan aligns with the NGAIDP, the national three-year action plan, and Guangdong province's own “Guangdong Province's New Generation Artificial Intelligence Development Plan”. Shenzhen's action plan echoes what was stated in the national three-year plan that was released the previous year. It has been noted that local plans such as this contain lofty goals and boilerplate language.³⁶ Shenzhen's goals for 2023 are for the core industry of AI to exceed 30 billion yuan, to have built more than 20 innovation carriers, to have cultivated more than 20 leading AI companies, and to have created 10 key industrial clusters. The local action plans typically also have local elements. In the case of the Shenzhen action plan, examples of such local elements are the aim to leverage the National Supercomputing Shenzhen Center, for universities and industrial areas in the city to promote the local AI industry, and to set up the Guangdong-Hong Kong-Macao Greater Bay Area (Shenzhen) Artificial Intelligence Open Innovation Platform.

To further establish itself as a leading AI center in China and globally, Shenzhen became the first Chinese city to explore local regulations for AI. The ability to do so was made possible due to a five-year plan made by China's State Council and the Chinese Communist Party in which Shenzhen has the autonomy to make decisions on various local policies.³⁷ As a result, Shenzhen can explore legislative frameworks for different emerging technologies. This is akin to how Shenzhen and other selected special economic zones have been allowed to experiment with economic reforms throughout the period of economic transition in China. In June 2021, it publicized a draft for “Regulations on the Promotion of Artificial Intelligence Industry of Shenzhen Special Economic Zone” to establish an overarching framework for AI-related activities.

The final version of the regulation was agreed upon in 2022 and it is significantly shorter than the original draft. This local regulation will become effective in November 2022. They encourage government agencies to adopt AI at an early stage and they also establish an AI ethics committee to develop safety guidelines for the industry. The municipal government in Shenzhen will also establish public data-sharing rules and different types of data for companies and institutions working with AI.³⁸

Figure 1. Shenzhen AI Policy and Regulatory Timeline



Military Spending

In addition to the various forms of public spending discussed here, the Chinese military is pursuing AI capabilities for combat and support functions. As noted earlier the Chinese government and military see AI as a significant opportunity for leapfrogging and getting the upper hand on the US military. In a recent study, the Center for Security and Emerging Technology at Georgetown University examines the efforts by China's People's Liberation Army (PLA) in the AI space.³⁹ It finds that the annual AI spending by the PLA is at least \$1.6 billion per year. Most of these funds are allocated to the development of intelligence analysis, predictive maintenance, information warfare, and navigation and target recognition in autonomous vehicles.

It is important to understand that most of the AI-related supply to the Chinese military does not come from state-controlled defense contractors. Instead, privately owned Chinese tech companies constitute the main suppliers of AI equipment to the PLA. Many of these suppliers benefit directly or indirectly from support from the state in the form of capital, equipment, personnel, and information, or capital. As of 2022, there are at least 30 military tech startups in China.⁴⁰ However, it is not only newer companies focused on military AI applications that work with the military. The Chinese Communist Party has instructed the private sector that it should share new technologies with the PLA through the implementation of “military-civil fusion”. As a result, private Chinese tech companies work directly or indirectly with the Chinese military. One example of this is Baidu’s creation of a lab for intelligence command and control technology together with China Electronics Technology Group, a company that develops electronic warfare technology for the People’s Liberation Army.⁴¹ Military AI spending should thus be regarded as acting as another significant driver of China’s AI industry.

Governance

Several bodies within the Chinese bureaucracy are active in shaping the country’s quickly evolving AI governance framework. In July 2021, MOST published a set of guidelines that outlines ethical norms for the use of AI, “Ethical Norms for New Generation Artificial Intelligence”⁴². This is an effort to integrate ethical norms into the complete AI lifecycle and to provide ethical guidelines for individuals, legal persons, and other organizations that are engaging in activities that involve AI. As such, the norms cover different issues, including the use and protection of personal

information, human control over and responsibility for AI, and the issue of monopolies in areas related to AI. The set of ethical norms published by MOST includes ethical concerns related to privacy, prejudice, fairness, and discrimination.⁴³ Six fundamental ethical requirements are put forward: enhancing the well-being of humankind, promoting fairness and justice, protecting privacy and security, ensuring controllability and trustworthiness, strengthening accountability, and improving ethical literacy. MOST has also called for companies, universities, and AI labs to establish their review committees to oversee ethics issues. Observers have noted that the publication of the set of norms by MOST constitutes a relatively hands-off approach, and the main policy document does not clarify how the stated norms are to be enforced or any potential punishments for those who violate them.⁴⁴

Another government body, the Cyberspace Administration of China (CAC), released a draft for a set of 30 rules to regulate internet recommendation algorithms. Seen as part of the overall effort to crack down on big tech in China, these rules were announced in August 2021 and CAC said it welcomed public feedback until September of that year.⁴⁵ In September it also published an ambitious three-year road map for governing all internet algorithms⁴⁶. In January 2022, CAC together with three other state departments finally announced that "Internet Information Service Algorithm Recommendation Management Regulations" would come into effect from March 1⁴⁷. These new rules state that companies must inform users of their platforms if algorithms are being used to push them in some way. They make it clear that users should be able to opt-out of receiving algorithmic recommendations. They also include provisions against fake news generation and the exploitation of gig workers using algorithms.⁴⁸ The fact that China is so early in releasing these types of regulations signals that the government is looking to take a prominent international position when it comes to the governance of AI. CAC is seen as the country's top internet regulation and has grown powerful and centralized.⁴⁹

A third effort to develop AI governance is that of the China Academy of Information and Communications Technology (CAICT). CAICT is a well-known and influential think tank under the MIIT. CAICT is in the early stages of developing tools for measuring and testing AI systems. While at an early stage, this could provide a foundation for China's national AI governance framework where systems are characterized by accuracy, explainability, interpretability, reliability, robustness, security, privacy, and safety. CAICT published a white paper on trustworthy

AI in September 2017 in collaboration with JD Explore Academy, a research lab at tech company JD⁵⁰. Recognizing that the EU and the US have placed improvements in user trust and continued development of trustworthy AI systems at the center of ethics and governance frameworks, the white paper argues that stability, explainability, and fairness of AI are at the center of concern to all parties involved in the development and use of such systems. CAICT is also collaborating with the government-sponsored China's AI Industry Alliance to evaluate and certify AI systems.⁵¹ The two have recently begun to issue certificates for trustworthy AI.

So far, it is not clear how these efforts driven by different administrative bodies will fit together. They are seemingly complementary to each other combining a somewhat looser set of ethical norms, regulations for AI algorithms, and governance of trustworthy AI. However, they originate from different government bodies, and Chinese government bodies can often be competitive rather than cooperative in nature.⁵² However, these developments will influence not only actors in the domestic AI industry but are also very likely going to influence developments in AI regulations and governance in the rest of the world.

Data

China has long had lax data protection regulations. The lack of privacy protection has made it possible for both public and private sector actors to collect very large amounts of personal information that would normally not be allowed in, for example, the US and Europe. A change has taken place in the last five years. In 2017, the Cyber Security Law was announced. In the following year, a privacy standard called the Personal Information Security Specification was released as an effort to develop a clear view of the protection of personal data and the right for individuals to control their information. However, this specification should not be compared to, for example, the EU's General Data Protection Regulation (GDPR) as it is mainly a guideline aligned with the Cyber Security Law. Perhaps more importantly, Roberts and co-authors point out that the general weakness in legislation related to privacy issues in China has been less due to its non-legally binding status and instead more to the many loopholes that can be found in it.⁵³

Chinese companies have long had a competitive advantage over companies in other countries when it comes to data. The sheer size of the Chinese market means that enormous amounts of data can be collected and analyzed using AI. It has been argued that compared to the US, China has an edge in data that is three times based on mobile user ratio, ten times in terms of food delivery, 50 times in terms of mobile payment, and up to 300 times in shared bicycle rides.⁵⁴

In addition, private sector companies in China have often been able to gain access to government data when they provide services to the state. It has been shown that this exchange has stimulated significant commercial innovation in areas such as face recognition.⁵⁵

However, recent developments have resulted in major challenges to how actors in the AI industry will be allowed to use data moving forward. Two new laws not only emphasize the right and protection of private data but include severe penalties as well.

The Data Security Law

The Data Security Law (DSL) was enacted in June 2021 and commenced in September of that year.⁵⁶ The DSL regulates the creation, use, storage, transfer, and exploitation of data within the borders of China. An important feature of the DSL is that it requires data that are collected by domestic as well as foreign entities in China to be localized. It strictly prohibits the export of such data unless a so-called cybersecurity review has been conducted. The review process is still not clear, making it difficult to ascertain how severe these limitations on data transfers are in practice. Companies that wish to do a data transfer have to do an internal security review and then apply for security assessment and approval from the CAC and additional relevant authorities.⁵⁷ Moreover, both domestic and foreign companies are not allowed to hand over data to foreign justice or law enforcement institutions without approval from Chinese authorities. However, there are no clear guidelines on which Chinese agencies the law refers to, something that adds more uncertainty. It is also clear that violations against the DSL can have significant consequences. Some of its articles spell out the penalties for violations of the law, including monetary penalties and potential suspension or revocation of business licenses.

The Personal Information Protection Law

The Personal Information Protection Law (PIPL)⁵⁸ was enacted in August 2021 and was effective from November of that year. It is the country's first comprehensive legislation on the protection of personal information and has many similarities with the EU's GDPR as it establishes consumers' consent as the legal basis when it comes to processing personal information. It gives individuals the right to access, correct, and even delete the personal data that businesses have gathered on them. The law applies to most if not all data activities, such as collection, storage, usage, transmission, disclosure, and deletion. It also affects activities outside China that analyze individuals in China. Important obligations data handlers face include:⁵⁹

1. Consent requirements – The entity must obtain the subject's voluntary, clear, and informed consent
2. Data localization and data deletion requirements
3. Restrictions on Transfer of Personal Information to Third Parties and Overseas
4. General Compliance Requirements

Like the DSL, the PIPL spells out stringent penalties for violations against it. For example, businesses can be liable to pay fines of up to 50 million yuan or up to 5% of their turnover from the previous financial year. Like the DSL, other potential penalties include the suspension of operations for rectification, or the cancellation of business permits or licenses. Individuals who are directly responsible for data protection can also face significant penalties.

It has been noted that these new laws represent important steps in the Chinese government's efforts to better control big tech in the domestic market.⁶⁰ In essence, it gives Beijing the power to shut down tech firms that are found violating the law. However, it also has a direct impact on foreign enterprises, not only those located in China but also the ones outside China that are engaged in the handling of Chinese data.

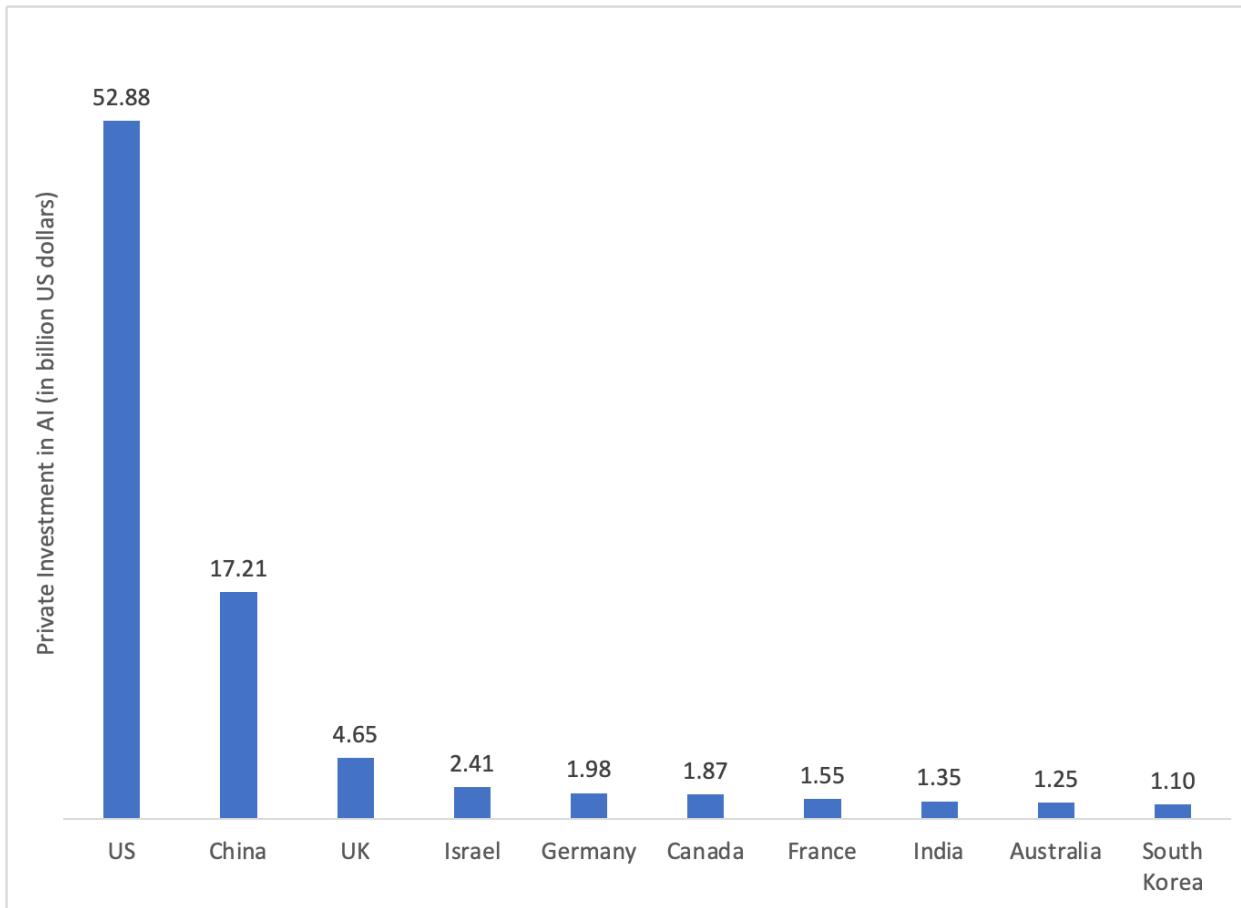
THE NATIONAL AI INDUSTRY

As noted earlier, the NGAIDP launched in 2017 had explicit goals for the size of the country's core AI industry: 150 billion yuan (\$21 million) in 2020, 400 billion yuan (\$56 billion) in 2025, and 1 trillion yuan (\$140 billion) in 2030, respectively. On June 22, Xiao Yaqing, deputy minister of MIIT announced that China's core AI industry had exceeded 400 billion yuan in value and that the number of AI-related companies had exceeded 3000.⁶¹ If this is correct, it would mean that the target set for 2025 has already been met more than two years ahead of schedule. This section first examines private investment in China's AI industry. It then discusses the regional AI hubs, leading companies in the AI industry, and national AI actors in China.

Private Investment

Private investment in the AI industry in mainland China reached \$17.21 billion in 2021. Hong Kong also had an additional \$0.63 billion that year. While sizeable, private investment in China's AI industry still falls short compared to the US, where private investments reached \$52.88 billion in 2021. Over the period 2013-2021, the US had a total of \$149.0 billion in private investments in the AI industry, compared to China's \$61.9 billion. While still not at the level of the US, China is at the top of the list of private investments in AI by country globally. The UK as the third country only had about \$4.65 in the same year. The EU had a total of approximately \$6.42 billion in 2021. These numbers show that the US and China are the two major players in the global AI industry.⁶²

Figure 2. Total Private Investment in AI by Country 2021



Source: Stanford University Artificial Intelligence Index Report 2022.

The Role of China's Tech Giants

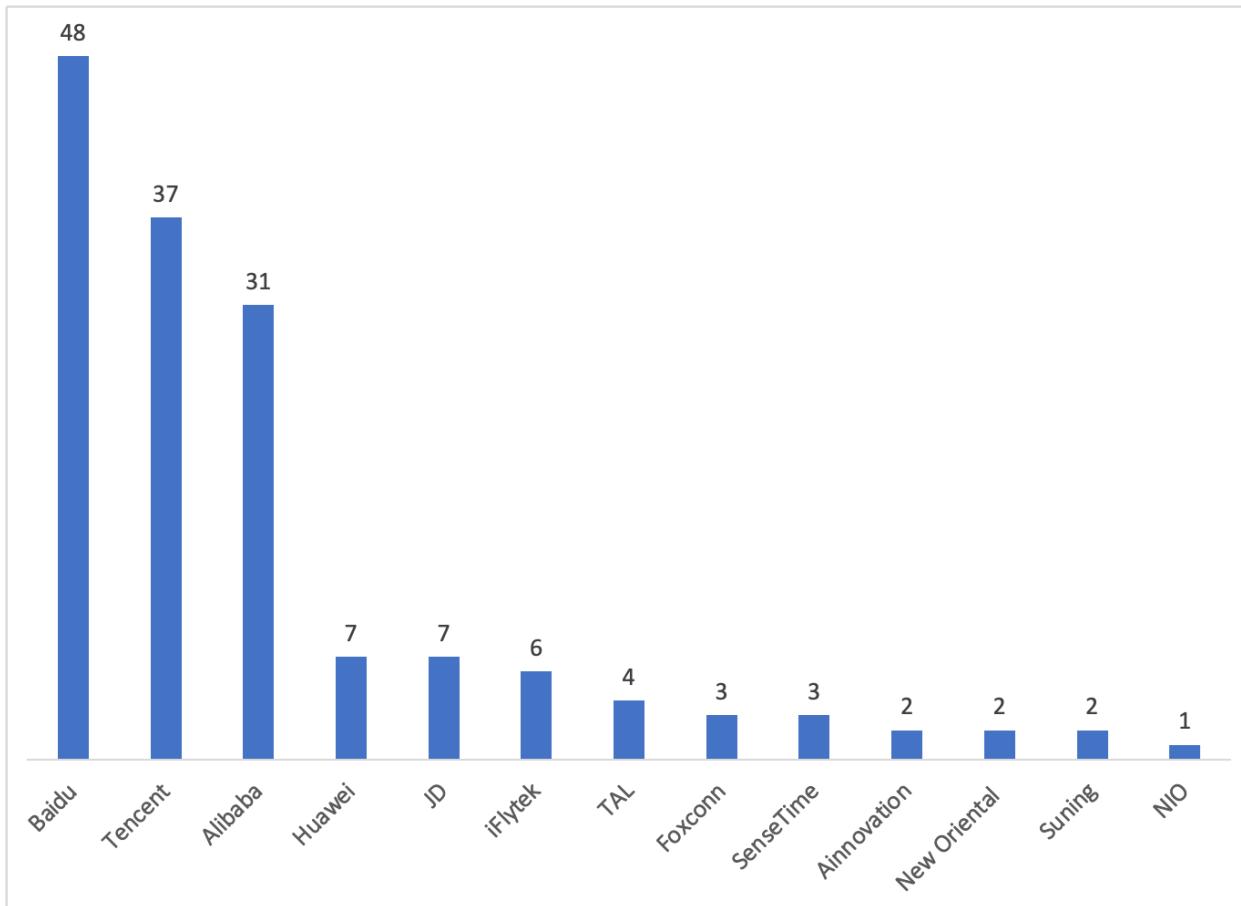
Baidu, Alibaba, and Tencent are the three early tech giants in China. Often compared to Google, Amazon, and Facebook, these three companies have dominated the Chinese tech sector for many years (albeit new players are challenging their positions in different business areas). Baidu has its headquarters in Haidian District, Beijing. It started as a search engine company and has evolved into a company specializing in various internet-related services and AI. Alibaba, which is based in the city of Hangzhou in Zhejiang province, started with an e-commerce platform and has since then introduced several online services, as well as fintech services that were later spun off into a

separate company. Tencent, with headquarters in the city of Shenzhen in Guangdong province, started by offering users a relatively standard messaging app but has since then expanded into social networks, online music, web portals, e-commerce, internet services, online payment systems, smartphones, mobile games, and multiplayer online games. Today, Tencent is one of the highest-grossing multimedia companies in the world. It is also one of the, if not the largest video game companies in the world.⁶³

Baidu, Alibaba, and Tencent all maintain strong incumbent positions in their respective core areas. As noted, AI is likely to continue strengthening the three companies' positions as they have collected enormous amounts of data on their respective platforms.⁶⁴

While all three of these major companies naturally develop and deploy advanced AI solutions in their own business (see the section on China's national AI team for more on this), they are also at the core of the build-up of China's national AI industry. A 2019 article on the three companies' involvement in AI revealed how dominant they are in the domestic AI industry.⁶⁵ It was found that Baidu, Alibaba, and Tencent had invested in no less than 53% of the 190 major AI companies. As shown in Figure 3, the third company on the list, telecommunications giant Huawei was responsible for far fewer investments than the three digital giants.

Figure 3. AI Investments by Company



Source: MIT Technology Review (2019).

Two other takeaways are worth noting when it comes to the three tech giants' involvement in the domestic AI industry. First, all three of them invest in a wide range of sectors, which means they are not focused on their core segments. Second, a clear majority of their funding efforts are geared toward AI applications and much less toward technologies including algorithms and silicon chips, and so on. While this may have been the best short-term strategy given China's AI industry's comparative advantages in terms of its richness in data and a previously lax privacy law environment, it may be a limiting factor in the long-term international competitiveness of China's AI industry.

China's AI Hubs

During the last decades, several large clusters for technology and innovation have emerged in China. The country has steadily moved up in technology rankings, not the least in rankings that focus on local or regional hubs that foster technological innovation. For example, four of China's major cities have made the top 20 in KPMG's annual technology innovation hub report for several years: Beijing, Shanghai, Hong Kong, and Shenzhen. In the 2021 report, Beijing ended up in fourth place, Shanghai in sixth place, and Hong Kong in ninth place.⁶⁶ This section first discusses the three original digital giants in China and how they have influenced the growth of the AI sector. It then provides a detailed overview of the major regional AI hubs across the country.

Regional Hubs

Chinese companies that operate in the AI industry are relatively concentrated in certain regions. Clusters emerged around the tech giants Baidu, Alibaba, and Tencent in the cities of Beijing, Hangzhou, and Shenzhen, respectively. In addition, strong local ecosystems have developed in other cities across the country. The Chinese Institute of New Generation Artificial Intelligence Development Strategies at Nankai University in Tianjin produces a ranking for competitiveness in the AI industry among regions across China. Their China Regional Competitiveness Evaluation Index for New-Generation AI Tech Industry is based on a series of variables including enterprise ability, academic environment, capital/funding environment, international openness, connectivity, and local government responsiveness. Table 1 provides an overview of the top ten provinces and municipalities in 2022 and historical data for these ten highest-ranked regions during the last five years.

Table 1. Top 10 Regions for the AI Industry in China 2018-2022

Province/ Municipality	Rank				
	2022	2021	2020	2019	2018
Beijing	1	1	1	1	1
Guangdong	2	2	2	2	2
Shanghai	3	3	3	3	4
Zhejiang	4	4	4	4	3
Jiangsu	5	5	6	5	5
Shandong	6	6	5	9	6
Sichuan	7	7	8	6	11
Anhui	8	8	9	12	7
Liaoning	9	10	7	8	13
Hunan	10	9	10	13	16

Source: Chinese Institute of New Generation Artificial Intelligence Development Strategies

Three major regional hubs can be deduced from this and other rankings on the AI industry. These three regional clusters: The Beijing-Tianjin-Hebei region, the Yangtze River Delta region, and the Pearl River Delta region (or the Greater Bay Area if Hong Kong is included as the city is often mentioned as a regional leader in AI as well). These three regions constitute the major economic centers of the country, and they are typically at the top of the regional rankings for technology and innovation in general.

A recent study that complements this index examines AI innovation networks and regional nodes in those networks.⁶⁷ Using data from the Patent Office of the People's Republic of China, the study applies network analysis to shed light on how innovation networks in the Chinese AI industry have evolved and how key nodes have developed. It identifies a very high level of centrality in three distinct regions in the eastern part of China: the Yangtze River Delta, Pearl River Delta, and the Bohai Rim (the economic region surrounding Tianjin including areas in the provinces of Hebei, Liaoning, and Shandong). These findings thus lend support to other studies that have focused more on metrics such as the number of companies in the local AI industry in identifying the three major regional AI hubs in China.

It is also worth noting that each of the three leading tech giants is in one of these regions. Baidu has its headquarters in the Beijing-Tianjin-Hebei region, Alibaba in the Yangtze River Delta region, and Tencent in the Pearl River Delta region.

AI Pilot Zones

To complement the NGAIDP at the national level and local efforts the Chinese government has also begun to establish AI innovation and development pilot zones, or AI pilot zones for short (also called AI innovation zones), in selected cities. The clusters and regional hubs discussed previously can be natural industry cluster developments combined with local government efforts. The AI pilot zones, on the other hand, are established by the central government, thereby lending support to promote the development of local AI industries further.

In August 2019, a notice published by MOST announced that approximately 20 AI pilot zones were to be established by 2023.⁶⁸ The main goal of the pilot zones is to promote the AI industry in selected cities where it already has a strong foundation. In line with this, the announcement of the establishment of each AI pilot zone identifies the advantages in terms of AI in the city in question and then encourages the city to build upon that when it establishes and promotes the new pilot zone. The government expects the activities in the AI pilot zones to focus on AI applications that result in economic, social, environmental, and other benefits to the local area. To make this happen, central and local governments will provide benefits such as financial support and favorable regulations at the local level.

In December 2021, vice minister of science and technology Li Meng stated that 17 pilot zones had been established.⁶⁹ In December 2021, MOST endorsed the establishment of AI pilot zones in three more cities.⁷⁰ This suggests that the goal of 20 pilot zones by 2023 has been reached. Table 2 provides an overview of the 11 first AI pilot zones and their identified strengths.⁷¹

Table 2. Initial AI Pilot Zones

City	Announcement Date	Strengths Relevant to AI
Beijing	February 25, 2019	Multiple leading research institutes, concentration of experts in the field
Shanghai	June 11, 2019	Resources in science education, applications, massive data, openness
Hangzhou	October 18, 2019	Academic research, applications, industrial base
Hefei	October 18, 2019	Intelligent speech, robotics, concentration of experts in the field
Shenzhen	October 18, 2019	R&D capacity, concentration of high-end talent, full production chain
Tianjin	October 18, 2019	Computing capacity, data resources
Deqing County	November 5, 2019	Autonomous driving, smart agriculture, intelligent governance
Chengdu	March 9, 2020	Diversity in applications, science education resources
Chongqing	March 9, 2020	Strong industrial base and infrastructure, applications, smart manufacturing, smart city, AI software, robotics
Jinan	March 9, 2020	Applications, computing infrastructure, strong data resources, applications in agriculture, transport, and manufacturing
Xi'an	March 9, 2020	R&D infrastructure, talent pool in intelligent sensing, processing, and interaction

Source: Ministry of Science and Technology; Center for Security and Emerging Technology.

The Corporate Sector

After the announcement of the NGAIDP, MOST began to handpick leading companies in the AI industry to become members of the “national AI team”. This group of companies was chosen to

pave the way by building new open innovation platforms that would be accessible through application programming interfaces (APIs). The idea was for these large companies to coordinate and set important standards for the development of the national AI ecosystem, for them to become global leaders within their respective niches, and for China as a country to become the world's center for AI innovation. As MOST announced the first batch, it labeled the platforms that each of the selected national AI team members would be responsible "National New Generation Artificial Intelligence Open Innovation Platforms". The initiative thus aims at getting leading companies to promote a comprehensive integration of AI with China's real economy. These companies obtain support and are in return expected to deliver on four specific key tasks: R&D, active participation in the AI ecosystem, sharing data and open-source software, and supporting the development of small and medium-sized enterprises (SMEs).⁷²

Those acquainted with China's previous development strategies may recognize the approach. The Chinese government has long aimed at becoming a key global player in key business sectors. To facilitate this, it has promoted so-called "national champions" that they hope can take leading positions in the global market. These national champions are companies that assist in the furthering of the government's strategic aims. In return, the Chinese government supports its national champions through various forms of preferential treatment, such as providing better access to capital, giving preference in government contract biddings, and at times being allowed to obtain oligopoly or even monopoly status in protected industries. National champions exist in several countries around the world, but many of China's champions have grown particularly strong. Some of them are state-owned, while others are privately owned. In the case of the national AI team, all the selected companies are privately owned (in some instances with partial state ownership). In addition, the handpicked companies already have a strong track record in their respective sectors before being included in the team. Two rounds of team members have been announced so far and each member has been chosen for a specific field within the AI industry.

The First Round of China's National AI Team Members

The first batch of national AI team members was announced in 2017, the year when the national AI plan was released. Not surprisingly, the three giants Baidu, Alibaba, and Tencent were among

the four first team members. Based on their respective in-house expertise, each team member was chosen to take the lead in a specific segment of the national AI industry.

Baidu was chosen to take the lead in the field of *autonomous driving*. While having established its name as China's leading search engine company, Baidu has long been investing time and effort in various fields of AI, not the least autonomous driving, where it is one of the leading players. One example of this is that it recently obtained the first license to operate fully driverless taxis in Shanghai.⁷³ Leading e-commerce company **Alibaba** was selected to lead the development of *smart city* technology. Among its already extensive work in this field, the company has developed City Brain, a software platform that makes extensive use of AI and big data to improve urban management, e.g., traffic management. Tencent was chosen to be a national and global leader in the field of *medical imaging*. As part of its work in this field, the company announced that it was launching AI-powered medical imaging and data management services that would enable medical professionals as well as consumers to share medical data safely and securely in October 2020.⁷⁴ **iFlytek**, while not as large as the three original tech giants, was a natural choice to take the lead in the development of China's *smart audio* sector. The company was founded as early as 1990, is partially state-owned, and is a leading player in speech recognition and related fields. It operates the iFlytek Open Platform, an AI platform for global developers that focuses on intelligent speech interaction. In 2018, the fifth team member **SenseTime** was selected to spearhead development in the field of *smart vision*. SenseTime was founded in Hong Kong in 2014. It develops technologies in a wide range of AI fields but is perhaps most well-known for its work in facial recognition, image recognition, and object detection.

The Second Round of China's National AI Team Members

In August 2019, MOST expanded China's national AI team initiative when it included another ten members. **YITU Technology** was chosen to spearhead the development in the field of *vision computing*. The Shanghai-based company was established in 2012 and is perhaps particularly well known for its facial recognition algorithms. **MiningLamp Technology** became the team member that focuses on *smart marketing*. Established in 2014 in Beijing, the company primarily specializes in intelligent big data mining. Tech giant **Huawei** was selected to take the lead in AI-related *software/hardware (infrastructure)*. The Shenzhen-based telecommunications company was

founded in 1987 and has grown into the leading hardware tech company in China and the world's largest telecommunications equipment supplier. The new team member **Ping An** was selected to spearhead the development of the *inclusive finance* open platform. Perhaps most well-known for its insurance and banking divisions, Ping An is a conglomerate that also has subsidiaries in sectors such as asset management, financial services, healthcare, auto services, and smart city. **Hikvision** was chosen to develop the *video perception* open platform. The surveillance systems giant was established in Hangzhou in 2001.

JD.com will develop an open platform for a *smart supply chain*. The tech giant was founded in Beijing in 2009 and constitutes Alibaba's largest competitor in the e-commerce space. Beijing-based **Megvii** will spearhead development in the field of *image perception*. The company designs image recognition and deep-learning software, and its product Face++ is the world's largest computer vision platform. **Qihoo 360** (full name 360 Security Technology, Inc.) was selected to take the lead in *cybersecurity*. The company was founded in London back in 2005 but now has its headquarters in Beijing. **TAL Education Group** was chosen to be responsible for the *smart education* open platform. Founded in 2003 with its headquarters in China, TAL Education Group offers a variety of services related to education. In July 2019, the company announced its AI open platform that comprises various education-related solutions, including AI-aided classes, homework-correcting, and question-searching. Finally, Beijing-based **Xiaomi** is the team member that leads the work in the field of *smart homes*. Founded in 2010, Xiaomi is perhaps most well-known for its mobile phone division, but the company manufactures a wide range of consumer electronics, home appliances, and household items.

The 15 national AI team members and their respective AI area focus are shown in Figure 4. After the selection of these 15 members, the initiative remains open to new applicants who will be evaluated by a team organized by MOST. During the application phase, the company wishing to become a member of the national AI team must specify the subdomain of AI platform development it plans to open to a range of companies for interaction and development.⁷⁵

Figure 4. China's National AI Team



Source: Stanford-New America DigiChina Project, AI Policy and China (2019).

Other Leading AI Companies

At least 3000 companies are operating in China's AI industry as of 2022. Naturally, not all of them have been chosen or opted to be included in the national AI team with the benefits and requirements that such membership entails. While a complete overview of the industry players is outside the scope of this report, it is worth taking a cursory look at some of the leading actors in the Chinese AI space based on metrics other than being selected by the Chinese government to function as drivers for the country's AI development.

In 2018, China Money Network published a report on the top 50 AI companies in the country. Focusing on privately owned with a core focus on AI technology as well as excluding public companies and technology giants, their list can be seen as constituting a glimpse into the dynamic AI startup community in China. At the time, the 14 unicorns on the list were worth a combined value of \$40.5 billion. The top ten companies are presented in Table 3.

Table 3. China AI Top 10 (2018)

Company	Industry Focus
Cambricon	AI Chips
Cloudwalk	Computer Vision, Public Security
DJI	Robotics
Horizon Robotics	AI Chips
Megvii Technology	Image Recognition
Mobvoi	Consumer Electronics, Voice Recognition
SenseTime	Computer Vision
Ubtech Robotics	Robotics
Unisound	Voice Recognition, IoT
YITU Technology	Computer Vision, Public Security

Source: China Money Network (2018). China AI Top 50.

In August 2022, AI Startups listed the top 22 AI startups in China.⁷⁶ This list, of which the top 10 companies can be seen in Table 4, is more recent and primarily based on how much funding each company has attracted so far.

Table 4. Top 10 Funded AI Startups (2022)

Company	Industry Focus	Funding (\$)
Bytedance	Content Platforms	9.4B
SenseTime	Computer Vision	2.6B
Megvii Technology	Image Recognition	1.4B
Momenta	Autonomous Driving	1.2B
UBTECH Robotics	Robotics	943M
Mobvoi	Consumer Electronics, Voice Recognition	253M
Cambricon	AI Chips	200M
Pudu Robotics	Robotics	184M
Rokid	Robotics	158M
Sunyi	Healthcare	157M

Source: AI Startups (2022), Top 22 AI Startups in China.

These lists show examples of several companies that are very well funded and at the forefront of the development of their respective industry focus without being a part of the formal government push to develop national AI champions. One important characteristic feature of the AI industry, like so many other industries in China, is that it is extremely competitive. Each industry focus has several top companies actively competing in the pursuit to become the dominant player in their respective field. So, while the national-level policy to develop open platforms in a variety of AI fields through the selection of national AI team members is important, it is likely the case that the Chinese government will try to avoid stifling innovation through competition by suffocating strong actors that are not part of the selected group of companies.

Government

As has been noted, China's government plays a central role in the development of the country's AI sector. When it comes to the implementation of the national AI plan, two ministries are particularly important, MOST and MIIT. The focus of these two ministries differs somewhat and the efforts they put in to advance AI development can thus at least to some extent be seen as complementary. MOST is the ministry that often releases plans and guidelines. Examples of this in terms of AI are the NGAIDP released in 2018 and the set of guidelines that outlines ethical norms for the use of AI released in 2021. MOST also tends to focus more on academic research. MIIT, on the other hand, focuses more on industry development and how different types of technology can be used to improve the country's industry. It does conduct research through a large network of universities and professional associations. It also does oversee seven universities directly, but these are more focused on applied rather than theoretical and basic research.⁷⁷

While the two main ministries are at the core of implementing the NGAIDP and pushing new initiatives forward, NDRC is an overall important actor in the coordination of the country's many industrial plans. Moreover, while MOST and MIIT are the primary state bodies driving the development of the national AI plan, many other state bodies are involved. One important example is the Ministry of Education (MOE), which is central to the development of talent as the gap between supply and demand of AI professionals was identified in the national AI plan and subsequent policy documents. As noted previously, the AI Plan Promotion Office involves no less

than 15 different government departments and ministries, all of which are involved in the support of the NGAIDP. These 15 entities are presented in Table 5.

Table 5. NGAIDP Promotion Office Members

1	Ministry of Science and Technology
2	Ministry of Industry and Information Technology
3	National Development and Reform Commission
4	Ministry of Finance
5	Ministry of Education
6	Ministry of Transport
7	Ministry of Agriculture
8	Chinese Academy of Sciences
9	Natural Science Foundation
10	Academy of Engineering
11	Health and Family Planning Commission
12	China Association for Science and Technology
13	Central Military-Civil Integration Development Committee Office
14	Military Commission Equipment Development Department
15	Military Commission Science and Technology Committee

The importance of this level of involvement of so many of China's ministries and important government organizations should not be underestimated. It signals the importance the government attaches to the development of the country's AI industry and the crucial role the government plays in that development. The push from a wide range of actors at the central government level transfers down to local governments, where officials are incentivized to implement the national plan. As a direct result of this, provincial and municipal governments develop their own AI plan and set up partnerships with research institutions and corporate sector actors. Through this process, new AI innovation ecosystems are established at the local level, which in turn propel R&D throughout the whole AI industry.

National Actors

Alliances and collaborative efforts across the corporate sector, higher education, research organizations, and sectoral organizations constitute an integral part of the national AI plan. Among other things, the NGAIDP emphasizes that the government should “support the relevant industry associations, alliances and service agencies to build AI services for global service platforms.”⁷⁸ A report by the Chinese Institute of New Generation Artificial Development Strategies in 2020 found that there were no less than 190 industry alliances at the end of 2019.⁷⁹ Both central and local governments have established industry alliances and see them as important for emerging industries. Examples of local industry alliances include the Shanghai Artificial Intelligence Association established in 2019 and the Beijing AI Industry Alliance established in 2021.

It is worth noting that it is typically a government entity that establishes an industry alliance. The government sponsor provides funding and then supervises the alliance’s activities. This is in line with how the government and the Chinese Communist Party seek to control the private sector and get it aligned with its objectives. Finally, Chinese industry observers see industry alliances as relationship brokers and use them to gauge the AI competitiveness of regions, further illustrating their importance in China’s AI ecosystem.⁸⁰

This section first examines one of the major industry alliances and then describes additional national actors that are active in China’s ecosystem.

China Artificial Intelligence Industry Alliance

The China Artificial Intelligence Industry Alliance (AIIA) was established in conjunction with the release of the NGAIDP. It was formed by several institutions that in turn were led by NDRC, MOST, MIIT, and CAC. AIIA has members from across the country and senior representatives from many key actors in the AI ecosystem who take up leading roles in the organizations. Examples of such actors are Alibaba, Baidu, Huawei, Qihoo 360, Tencent, Tsinghua University, Zhejiang University, and Zhongxing Telecommunications Equipment (ZTE). In an in-depth data analysis of the organization, the Center for Security and Emerging Technology find that over 70% of the members are in first-tier cities. The corporate members are a combination of diversified

large companies and AI-focused startups and smaller enterprises. A majority of the corporate members also specialize in commercial AI applications.⁸¹

AIIA organizes and supports a variety of events to function as a platform for cooperation between governments, the AI industry, universities, research organizations, and end users of AI applications. It holds many AI conferences every year and organizes various talent training programs. As noted previously, AIIA is also working with CAICT to certify various AI systems.

Chinese Association for Artificial Intelligence

The Chinese Association for Artificial Intelligence (CAAI) was established in 1981. Today, it constitutes the only academic association that focuses on artificial intelligence at the national level. The organization is authorized by the Ministry of Civil Affairs and registered as a state-level organization under the China Association for Science and Technology (an organization for scientists under the Chinese Communist Party). CAAI currently has 51 branches nationwide, with 43 professional committees and 8 working committees. With its size, it is a leading national organization in AI that is engaged in several activities, including the funding and organizing of international conferences, organizing industry awards, and publishing both domestic and international journals in the field of AI. One example of an influential event held by CAAI is the Asian Conference on Artificial Intelligence Technology which is organized in a different Chinese city every year.

China Computer Federation

The mission of the China Computer Federation (CCF) is to advance computing technology and applications as well as to serve professionals in the computing industry. The organization was founded as early as 1962 and has no funding from the government but instead relies on membership fees for its 55,000 paying members. CCF has no less than 48 technical and working committees and 30 chapters across the country. It holds large conferences and competitions, builds platforms to support computing professionals in various fields, and sponsors the international journal Data Science and Engineering.

Several of its activities center on issues that tie in with AI development. Several of its working committees focus on AI-related themes, including committees on AI and pattern recognition, big data, computer vision, and speech, dialogue, and auditory processing. Another example is CCF's Intelligent Robot Special Team, which is focused on channeling investments to push innovation in intelligence robotics forward.⁸²

Hong Kong Society of Artificial Intelligence and Robotics

The Hong Kong Society of Artificial Intelligence and Robotics (HKSAIR) was established in 2018. The main aim of the organization is to promote the application of AI and robotics in Hong Kong, and it wants to bring together scholars and entrepreneurs to help Hong Kong build a leading innovation center and support the synergy of scientific research, government planning, product development, and industrial manufacturing. Its activities include providing input to the Hong Kong government on issues related to AI, arranging large-scale training in AI, organizing exchange activities such as seminars and conferences, and connecting universities and industries.

Artificial Society of Hong Kong

Established in 2016, the mission of the Artificial Society of Hong Kong (ASHK) is to further the development of AI technologies in Hong Kong. The organization wants to create a platform where AI specialists can ideas and knowledge in their respective fields. ASHK also holds monthly events to develop inquiry and curiosity among the wider public. In April 2022, it organized its 200th event in Hong Kong.

Research

Research in AI worldwide has grown rapidly over the last 6-7 years. China is at the very center of this development. Twenty years ago, there was a very wide gap between AI research in China and the US. Since then, the country has become a world leader in AI-related research output. To quantify research output, a notoriously difficult task, two aggregate measures are often used to assess at least the quantitative standing of the research taking place in the country: the number of publications (and to some extent citations) and the number of patents.

Looking at research output in terms of journal publications, the growth rate was relatively modest leading up to 2015. However, the number of annual AI journal publications increased almost 2.5 times from 2015 to 2021, at which more than 172,000 AI journal articles were published. China played an integral part in this development. In fact, China remained the leader with no less than 31.04% of the total number of AI journal publications in 2021.¹ For comparison, the EU and the UK combined stood for 19.05% and the US for 13.57% of all AI journal publications that year. Data on AI journal citations paint a similar picture. China stood for no less than 27.84% of all citations in the world in 2021. In the same year, the EU and the UK together accounted for 21.13%, and the US for 17.45% of worldwide citations in AI journals. If Chinese-language publications are included in the comparison, the gap between China and the US turns out to be extremely large. When Chinese-language publications are added to English-language publications, Chinese institutions publish 4.5 times more than American institutions over the period 2010-2022.⁸³

China not only dominates published articles and citations. It also produces the most AI conference publications in the world. In 2021, it stood for 27.64% of all AI conference papers, compared to 18.95% for the EU and the UK combined and 16.90% for the US. China surpassed the US in the number of AI conference papers in 2014, and the EU and the UK in 2018.⁸⁴

How about research patents? The number of AI patents has exploded during the last decade, with 30 times more AI patents being filed in 2021 compared to 2015. Just as in the case of research publications, China has taken up a leading position in AI-related patent rankings. In 2021, 51.69% of all AI patent filings were made by China compared to 16.92% by the US and 3.89% by the EU and the UK. However, it is worth noting that the picture is somewhat different when it comes to granted patents. China only stood for 5.90% of all granted AI patents in 2021, compared to 36.59% for the US and 7.56% for the EU and the UK.⁸⁵

Again, it is worth noting that the number of journal publications and citations or the number of patents a country produces does not automatically translate into the quality of research in that country. The disparity between patent filings and granted patents indicates that the sheer quantity of R&D taking place in China not always translates into high-quality innovative contributions

¹ Using a somewhat different methodology, the State of AI Report 2022 finds that US-based authors still publish more AI papers than their Chinese peers in 2022. The report does find that China and Chinese research institutions are growing their output rate at a faster rate than their US counterparts.

within AI. However, a recent study by the Center for Security and Emerging Technology finds that China's output of highly cited AI research has reached a similar level to that of the US.⁸⁶ The study also shows that top Chinese AI publications are often cited outside China as well and that China is increasingly contributing with publications at the top AI conferences. Overall, the data signals how important AI is seen in China and how the country is positioning itself as an emerging AI superpower.

AI publications in China are primarily driven by academia. In 2021, 60.24% of total AI publications in China came from the education sector. In the same year, 8.47% came from the nonprofit sector, 3.93% from the corporate sector, 3.62% from the government sector, and 23.74% come from non-designated sectors.⁸⁷ This signals academia's important role in the AI industry. China has many internationally ranked universities and the competition in the domestic academic sector is intense. Table 6 lists the highest-ranked research institutions based on the number of AI publications in 2021. The Chinese Academy of Sciences (CAS) is the country's national academy for natural sciences. Based in Beijing with branch institutes across the country, CAS is the world's largest research organization and has been ranked number one in the Nature Index since its inception in 2014. With over 6517 research publications, it far outranks other research institutions in the field of AI. However, the nine other research institutions also exhibit impressive numbers of AI publications.

Table 6. Top 10 AI Research Institutions in China 2021

Rank	Research Institution	City and Province	Number of AI Publications
1	Chinese Academy of Sciences	Beijing	6517
2	Tsinghua University	Beijing	3764
3	Shanghai Jiao Tong University	Shanghai	3652
4	Zhejiang University	Hangzhou, Zhejiang	3178
5	Harbin Institute of Technology	Harbin, Heilongjiang	2367
6	Peking University	Beijing	2603
7	Beihang University	Beijing	2145
8	Huazhong University of Science and Technology	Wuhan, Hubei	2359
9	Wuhan University	Wuhan, Hubei	1897
10	Beijing Institute of Technology	Beijing	2012

Source: OECD.AI, AI in China.

Talent and Education

China's national AI plan emphasizes the importance of cutting-edge AI talent, and that the country is far from meeting the demand for such talent. It brings up the talent issue multiple times and has a whole section devoted to how policymakers can accelerate the training of high-end AI talent.

As a response to the existing talent shortage, the Ministry of Education (MOE) released the “Artificial Intelligence Innovation Action Plan for Institutes of Higher Education” in 2018.⁸⁸ The document explains how the government plans to improve AI education at the university level. A key goal is for China’s colleges and universities to become the primary force in the development of global innovation centers. They are also expected to take the lead in building the country’s next-generation AI talent pool to push China to the forefront of innovation-driven countries. As a result, AI has become the fastest-expanding discipline in Chinese universities and hundreds of colleges and universities now offer majors in AI.⁸⁹ Later that year, MOE released two additional documents that further emphasized the importance of AI education. The “Education Informatization 2.0 Action Plan” published in April 2018 included plans to develop the IT curriculum with AI and coding, while the “Primary and Secondary AI Education Program” published in September 2018 was initiated to design high-quality AI courses for K 12 students.⁹⁰ These initiatives signal that the Chinese government is taking action to overcome the AI-talent shortage challenge that country is facing.

In 2020, MIIT also published the “Artificial Intelligence Industry Talent Development Report (2019-2020 Edition)⁹¹, in which it uses surveys and data from job postings to examine the supply and demand of AI talent in China. The report finds that (1) supply is far from meeting demand, (2) there is a clear imbalance between talent being supplied and demanded in that companies need innovative and multidisciplinary talent, and (3) a significant regional imbalance with talent being highly concentrated in the three major AI hubs: the Beijing-Tianjin-Hebei region, Yangtze River Delta region, and the Guangdong-Hong Kong-Macau Greater Bay Area.

What does the situation look like in China compared to other countries when it comes to the supply of AI talent? Paulson Institute’s think tank MacroPolo has developed a unique tracker of global AI talent. They focus on top-tier AI research talent as it is likely that that group of researchers will lead the way with future breakthroughs in research and applications of AI to complex real-world

problems. They show that China constitutes the largest source of top-tier AI researchers as 29% of the talent pool has undergraduate degrees from China. 20% of the top-tier AI researchers come from the US, and 22% come from the EU and the UK combined. More importantly, however, a total of 59% of the top-tier AI researchers work in the US, and 14% work in the EU and the UK. Only 11% of the top-talent pool is working in China. In general, over half of the top-top researchers are immigrants working in another country from where they received their undergraduate degrees. This is not surprising as the top talent in innovative fields such as AI is often attracted to leading ecosystems within their field of expertise.

This pattern is supported by the often-stated argument that very few people working with AI in China carry out basic theoretical research. For example, while many research articles on deep learning originate from China, few of them are genuinely innovative or have a major added value in terms of application. There is also a significant difference in talent development between the US and China at the firm level, with Chinese companies being less willing to invest sufficiently in training very technical AI research teams.⁹²

STRENGTHS AND CHALLENGES

The development of China's AI ecosystem over the last decades has been possible thanks to several factors. At the same time, the continued development relies on the country being able to overcome several challenging factors. Somewhat counterintuitive, some of the strengths that made rapid development and adoption of AI-related technology have recently started to turn into challenges for the Chinese AI industry.

Strengths

1. Socio-Political Context

Many observers have argued that the socio-political context in China has been conducive to the rapid growth of its AI industry. Business innovation is often studied from the triple-helix perspective, i.e., how governments, institutions, and companies interact and form a national ecosystem. This is perhaps even more important when examining a country where the country treats technology as a key priority, such as in the case of China.⁹³ Comparing how the national AI strategy is formulated and implemented to that of other countries shows that a state economy can get different stakeholders in society such as government organizations and officials, the corporate sector, the financial system, universities, and research institutions, etc. aligned and work for a common cause. While this type of system has its disadvantages (see below for some of the challenges it brings), China's development since the beginning of the opening and reforms at the end of the 1970s has shown that it can galvanize key actors to work for a common cause.

One unique way in which China's AI ecosystem differs from those in other countries is how it integrates with industry. As noted earlier, an integral part of the NGAIDP has been to incentivize key actors in the AI industry to develop open platforms and frameworks that can enable partnerships with leading industry players as well as support the growth of SMEs. Candelon et al. argue that this makes China's AI ecosystem unique as it develops a more "equitable set of complementors".⁹⁴ They find that this contrasts with the US, where tech giants and startups compete with industry incumbents that are slow to adapt and adopt AI, and with Europe, where industry incumbents reinvent themselves more through the formation of ecosystems with tech partners, the build-up of AI divisions, and the establishment of AI alliances. In China, the state

pushes the tech giants to build AI ecosystems and work directly and closely with the industry actors. This leads to a great uptake and use of AI by industry incumbents while the key AI industry actors capture a greater share of the value creation that comes from AI. This also means they may capture a greater share of the market, making them more internationally competitive).

The political system has also made it easier for Chinese companies to take leading positions in certain areas that are not as easily navigated in, for example, the US or Europe. One important example is face recognition, where the legal barriers have been much fewer in China compared to the west.

Moreover, public debates have not influenced and shaped the national agenda in China as it has in many other countries. The Chinese government sees the advantage of having a strong AI industry in that it can aid in its pursuit to maintain and improve control over society. While this would be of great concern to the citizens in most western countries, it has not been a sensitive issue for the public in China, at least not yet. The concerns raised by the public related to, for example, privacy issues, have primarily been directed toward the private sector in China. The Chinese government has focused on highlighting the positive achievements that have been made with AI to maintain a positive public view of the technology.⁹⁵ Not surprisingly, a survey by Boston Consulting Group on citizens' perspectives on the use of AI in government in 2019 showed that China is among the most supportive countries when it comes to the use of AI.⁹⁶ In contrast, western countries such as Denmark, Sweden, and Estonia were found to be the least supportive.

2. Lax Regulatory Framework

China has historically lacked clear policies and regulations, perhaps in particular when it comes to privacy, something that has made it possible for companies to develop and commercialize AI applications very fast compared to what they would have been able to in many other countries. One notable example of this is the enormous amount of surveillance cameras that are installed in China. This has created a very large market for AI companies specializing in visual and facial recognition.⁹⁷ Another example is healthcare data, where AI startups such as InferVision have been allowed access to millions of x-rays and lung scans that they use to train and test algorithms.⁹⁸

For obvious reasons the speed and ease with which local AI companies took advantage of these phenomena would not have been possible in most European countries or the US. In the case of surveillance, no country can compare to the sheer amount of data that is readily available. In the case of healthcare data, even though it is collected, gaining access to it requires a lot more time and effort in most other countries. Marked differences in regulatory settings have thus given Chinese AI companies a strong comparative advantage compared to competitors in the US and Europe.

3. Data

The combination of a nationwide effort to develop a world-leading AI industry, the early-stage relatively lax regulatory system and a very large domestic market have resulted in enormous amounts of data being collected, both by the government and the private sector. It is also clear that the Chinese government prioritizes big data. For example, in 2015, the “State Council Action Plan for Promoting the Development of Big Data” was released. Studies have shown how the government is implementing a national big data strategy and that President Xi Jinping personally has been involved in this process.⁹⁹ As a result, 31 provinces had launched action or implementation plans for big data by late 2018.¹⁰⁰

As noted previously, the cooperation between the government and the private sector has also meant that private sector actors have been provided access to data collected by the government for commercialization purposes. The combination of enormous amounts of consumer data and government data being collected and used, often for strictly commercial purposes, has been instrumental in driving the growth of China’s AI industry and partly explains why it is so application driven compared to the AI industry in countries such as the US.

Challenges

1. Talent – Growing a Talent Base only to See It Leaving?

Talent and data are often argued to be some of the most important factors for the success of an innovative industry. When it comes to AI talent, the picture is somewhat complex

However, China falls short when it comes to basic theoretical research. A very limited amount of all the research that comes out of China is truly innovative. It has been pointed out that this problem is twofold. First, the academic system needs to develop further to allow for a more truly innovative talent to emerge. Second, the major focus on application in China's AI industry so far has not been conducive to the development of top talents. As noted earlier, top talent is to a large extent developed within companies. US companies spend significantly more resources on this by employing high-potential talents to work with R&D in advanced AI technology.¹⁰¹

Another challenge China is facing is the inability of its AI sector to attract international AI talent so far. This is perhaps especially clear if one considers that a sizeable portion of the top-talent pool in the US is comprised of Chinese AI talent. Instead of returning to China, many of these AI specialists prefer to stay in the US for a variety of reasons. So, while the effort to train new AI talent in China has been relatively successful so far, the country continues to experience a brain drain with many very talented researchers opting to work in the US. One study estimates that up to three-quarters of top talents left China to work in other countries, and 85% of those who left went to the US.¹⁰² One major reason behind US attraction is the sheer number of top-quality research labs for advanced AI research in both the corporate sector and academia.¹⁰³ The result is striking. As noted, China today leads AI research in terms of quantity. However, in terms of quality, it is still far behind the US.

2. Geopolitical Tensions

Tensions between China and the US have been growing over the last decade, especially after former US president, Donald Trump took office and initiated what has become a de facto trade war. These tensions have also come to affect companies working in the technology sector. The so-called tech war between the two countries has escalated to a point where the US is introducing increasing sanctions on China's tech sector.

In addition to arguments related to market fairness, intellectual property rights, and so on, US research has shown that China's military AI progress is driven by access to American technology as US companies supply China with software, data, and funding.¹⁰⁴ As US policymakers are becoming increasingly aware of this and other issues about tech industry issues, they will likely look for ways to change the rules of the game. They have already started doing so. Throughout

most of 2022, the US has been imposing increasingly comprehensive sanctions on China's semiconductor industry. In October 2022, the Biden administration imposed comprehensive export controls that were meant to cut off China from getting hold of advanced chips for supercomputers and other applications. According to some, this has paralyzed the Chinese semiconductor industry as one effect has been that most foreign senior people working in the industry have been forced to resign from their positions. China is still heavily dependent on chips for work in the AI industry and this will thus influence that industry as well.

While the final impact of these actions and the overall tense relationship between the US and China will be difficult to ascertain at this point, the deteriorating relationship between the world's two largest economies has significant implications for the Chinese tech industry, and not the least the AI industry. To make things more complex, these tensions are not bilateral. US allies are also shifting in their approach to China. These geopolitical changes will continue to constitute a challenge to the further development of China's AI industry.

3. Lack of Core Technological Tools

While China is at the forefront of many AI-based applications, the country is still behind when it comes to core technological tools. AI researchers and companies in the US have developed most of the leading platforms and libraries used for designing, building, and training AI algorithms. Notable examples include TensorFlow, PyTorch, and Keras. One of the few similar Chinese open-source platforms is Baidu's PaddlePaddle. However, it is mostly used for the quick development of different AI products. It is widely used in China but has not gained much traction in the rest of the world. While foreign open-source platforms can be used in China, this highlights the reliance on US-origin platforms and a significant gap in China's AI ecosystem.¹⁰⁵ This has at least two implications. First, unless China can develop competitive platforms that gain similar widespread popularity, it is hard to see China becoming the true world leader in AI if it has to build it upon foundational software developed in the US. Second, there is an important network effect when researchers want to use the same platform, and frameworks that gain more traction are usually better maintained. This can result in Chinese companies finding it increasingly challenging to compete with well-established frameworks in the global AI industry.¹⁰⁶

China is also behind when it comes to AI hardware. While the Chinese government has spent hundreds of billions of dollars to build a self-sufficient and world-leading semiconductor business, the Chinese tech industry still relies on foreign companies for advanced chips.¹⁰⁷ The socio-political context may have been advantageous to rally the support behind the country's ambitions in AI, but the implementation of industrial policy in China can result in inefficient allocation of capital and support as well. This is the case when it comes to the semiconductor industry, and it has implications for China's ambitions in the AI space. A majority of the world's AI-enabled semiconductor chips are produced by US companies, e.g., Nvidia, Intel, Apple, Google, and Advanced Micro Devices (AMD). The increasing tensions between China and the US highlight the problem this may become for the overall development of China's AI industry moving forward.

4. China's Role in Global Governance

China is looking to drive the development of a global AI governance regime as part of its goal to become an AI superpower by 2030. It wants to move away from being an international norm-taker to a norm-shaper or even norm-maker. By doing so, it sees an opportunity to get national leverage in a highly competitive market and obtain more influence in global institutions.¹⁰⁸ However, as noted by both Chinese and foreign observers, China has very limited abilities to take a global leading position in the development of AI governance norms.

One major limitation to this is today's geopolitical landscape. Most of the existing global initiatives for AI governance of influence exclude or counter China as they focus on democratic values. Considering which countries are leading development in AI, few of China's geostrategic partners play important roles in this development, making it more difficult to mobilize support.

Another limiting factor is the way AI governance is evolving in China. As noted earlier, several actors are involved in shaping ethics and governance in China's AI industry. It is not only ministries and other government organizations that are part of this process. Instead, central and local governments, companies, academia, and the public are all involved. China's process so far has resulted in broader principles without them being put into practice.¹⁰⁹ Observers have noted that it is important to understand that the CCP's top priority is state control and political security rather than individual rights and that this can be seen in how China is using AI for such purposes. The combination of lofty principles and conflicting governance incentives by the state constitutes

a problem as other countries are bound to be skeptical about allowing China into the driver's seat when it comes to developing an international ethics and governance framework for AI.¹¹⁰

TAKEAWAYS FOR SWEDISH AI ACTORS

China's role in the global economy continues to increase and so does its influence in a wide range of industry sectors, not the least so when it comes to the global AI industry. China's quickly developing AI industry, the country's unique socio-political context, its dominant state, and its geopolitical position in the world all play a part in creating a more complex picture for foreign actors that operate in the AI space. China can be seen from the perspective of being a large potential market, providing opportunities for collaborative efforts, and being a source of fierce market competition.

The Market

While China is facing its most challenging economic situation in decades, the country remains one of the largest markets in the world. As noted, Chinese citizens tend to be more positive toward AI compared to people in most western countries, and China is at the forefront when it comes to various AI-driven consumer applications. Similarly, AI-based technologies such as facial recognition are more widely used in Chinese society compared to, for example, the US or Europe. Naturally, the country's enormous manufacturing and industrial sectors also lend themselves well to AI applications. This is strengthened by the fact that the Chinese government is emphasizing the need to increase productivity through innovation as part of the shift from the old economic model built on high investment rates and relatively modest consumption.

Overall, while economic growth will most likely be more modest than the initial 40 years of reforms and opening up, there are ample opportunities for AI companies operating in a wide range of sectors to enter and grow their business in the Chinese market.

Foreign companies that may find the Chinese market difficult to grasp can first reach out to established organizations to explore potential opportunities. For Swedish companies, examples of such organizations are Business Sweden and Nordic Innovation House. As in many other fields, foreign companies may face issues at a regulatory and/or practical level. One example is restrictions and barriers to entry, especially for select sectors the Chinese government sees as strategic. One solution is to partner up with local companies in the specific field, something that may help solve such issues and can, for example, provide better access to data, open offices, and

so on. In addition, many state-affiliated entities in China will often prefer to work with domestic companies, something that can make it difficult for foreign companies to supply products and services directly to them.

There are also opportunities to collaborate with a Chinese counterpart and potentially gain access to government support through programs set up to support entrepreneurial activities in various areas of technology. In some cases, directed calls for collaborative efforts between Chinese and foreign companies, or a Chinese organization and foreign companies, can provide opportunities for funding and, indirectly, support to develop new technology or adjust existing products and services to fit the Chinese market.

Fierce Market Competition

Market competition in the Chinese AI industry is aggressive as the market is very crowded. It is a more closed ecosystem than that of the US and Europe, and in that system, Chinese AI firms compete with large Chinese tech companies and international companies. It has been argued that China is managing this competition by limiting access to big data for foreign companies and limiting the ability to operate for large international tech firms such as Meta and Google, while Chinese companies invest in AI technologies abroad.¹¹¹

Another side of competition is that of talent. The still existing gap between demand and supply of AI talent in China has resulted in increasingly intense competition in the AI talent market. In addition to local tech giants and AI startups competing for top talent, multinational companies have joined the search for AI talent in China.¹¹²

Government Support

Another challenge for foreign companies interested in China is the way Chinese industrial policy work in general. This holds also when it comes to the domestic AI industry as AI is such a prioritized industry and AI development is seen as a top strategic goal. The AI industry differs somewhat from many other key industries in China in that it has evolved without having major state-owned enterprises dominating it. Nevertheless, the state actively supports selected industries in various ways and the domestic AI industry is no exception. Such support often comes in the

way of different forms of funding. For example, it has been reported that voice recognition company iFlytek, one of the national AI team members, has relied on significant funding from the Chinese government. In fact, in 2020, it was reported that the company's subsidy income exceeded its net profit.¹¹³ A major part of those subsidies seem to have come in the form of tax reimbursements and R&D grants.

Over time, a symbiotic relationship between the leading AI firms and the government has formed, in which the government posts AI projects through its various programs (e.g., smart-city and smart-governance programs) and then invites key private companies to apply. Project application managers work in close contact with government officials throughout the application process, thereby forging strong relationships for future opportunities.¹¹⁴ There are several potential problems with how this institutional setting functions. First, it can of course lead to corruption and an inefficient allocation of capital and effort. Second, it can result in the larger selected AI firms crowding out smaller specialized startups that never get a chance to take on these types of products and therefore end up unable to compete with the much larger firms. Over time, this can result in monopolistic or oligopolistic market features in the different AI subsectors. Third, it complicates things for foreign AI companies wanting to grow their business in China. It is unlikely that foreign companies will be able to compete on their own if their Chinese competitors receive direct government support as well as preferential treatment through the allocation of projects that provide funding and access to data that is out of reach for other actors.

Geopolitical Complexities

The growing rivalry between China and the US as well as its allies has implications for foreign companies and organizations in China. A direct effect of measures such as the US export controls on AI and semiconductors is that AI companies operating in China will find it increasingly difficult to operate. The export controls will limit development in China's AI industry by limiting access to high-end AI chips and limiting the design of AI chips domestically in China by limiting access to chip design software. It is too early to see how the extent of the effect this has on firms operating in China but AI-related businesses there will feel these rules. Similarly, the growing tensions between China and other countries on other issues may affect the AI industry. For example, the Chinese government has been accused of committing human rights violations toward the Uighur

minority in Xinjiang and several government officials and companies have been sanctioned. In 2019, the US decided to put Chinese AI company SenseTime on the entity list, a trade restriction list published by the US Department of Commerce's Bureau of Industry and Security because it had filed a patent for a facial recognition feature that enabled its software to distinguish between Uyghur and non-Uyghur individuals.¹¹⁵ In December 2021, just ten days before SenseTime was scheduled for its IPO, the US Treasury Department stated that it would ban all US investments in the firm because it had facial recognition software that could determine an individual's ethnicity and focused in particular on ethnic Uyghurs. While this only delayed the IPO for a short while, it shows that tech companies are increasingly finding themselves in the middle of the high-stakes rivalry between the world's two largest economic powers.

Some would perhaps prefer to dismiss this as something only about US and Chinese companies. However, it would be naïve to assume that AI companies from other countries with a business interest in China will be able to remain unaffected by potential future sanctions, bans, and regulatory changes. As there are no signs of tensions between China and the US (and, increasingly, its allies) abating but rather escalating, the impact geopolitics can have on foreign AI companies and organizations operating in China is uncertain.

Crackdowns and Changing Regulations

The Chinese government's crackdown on the domestic tech industry during the last two years has been comprehensive and relentless. The 'big tech crackdown' is usually seen as having started when the government made a last-minute decision to suspend Ant Group's IPO in November 2020. Since then, many of the leading tech companies in China have been hit, including Tencent, e-commerce company Pinduoduo, food delivery platform Meituan, and ride-hailing company Didi. The whole online private tutoring and education sector has been hit hard as well, with companies such as TAL Education and New Oriental Education being severely affected. The crackdown can be broadly divided into three categories: an antitrust crackdown (e.g., Alibaba, Tencent, Baidu, and most other tech giants), a data security overhaul (e.g., Didi and recruiting platform Kanzhun), and control of capitalist "excess" (Ant Group, New Oriental Education, and TAL Education).¹¹⁶ In the fall of 2021, the number of concurrent different types of crackdowns reached 19. At that point, the movement had come to cover a wide range of issues, including crackdowns on fintech

companies, e-commerce and social media companies, celebrity and fan club culture, tutoring and education companies, gaming companies, companies making heavy use of algorithms, online insurance providers, and bitcoin miners and crypto exchanges.¹¹⁷

A movement of implementing new rules and regulations has accompanied this crackdown. As mentioned earlier, new data security and privacy laws have recently been introduced, resulting in a need for tech companies in China to change how they operate. While the previous lax regulatory setting constituted an advantage for a quickly growing tech sector, the rules of the game are quickly changing. So far, it is not clear how far the government will push its effort to regulate and control tech companies operating in China.

These changes are naturally important for foreign AI companies and organizations looking to explore opportunities in China. The new regulations and laws of course have direct consequences for how international companies operate in the country. For the newly implemented data and privacy laws, there are several implications for foreign firms to consider, including a reassessment of existing storage practices of data originating in China, new limitations when it comes to providing Chinese data to foreign regulators or courts, and new restrictions on marketing activities.¹¹⁸ In addition, the ongoing changes make it challenging for international actors to know what it will look like even a few years down the line.

ACRONYM

AI	Artificial Intelligence
AIIA	(China) Artificial Intelligence Industry Alliance
API	Application Programming Interface
ASHK	Artificial Society of Hong Kong
CAAI	Chinese Association for Artificial Intelligence
CAC	Cyberspace Administration of China
CAICT	China Academy of Information and Communications Technology
CAS	Chinese Academy of Sciences
CCF	China Computer Federation
DSL	Data Security Law
GDPR	General Data Protection Regulation
HKSAIR	Hong Kong Society of Artificial Intelligence and Robotics
MIIT	Ministry of Industry and Information Technology
MLP	Medium- and Long-Term Plan for the Development of Science and Technology
MOE	Ministry of Education
MOST	Ministry of Science and Technology
NDRC	National Development and Reform Commission
NGAIDP	New Generation of Artificial Intelligence Development Plan
NKP	National Key R&D Programs
NSFC	National Natural Science Foundation of China
PIPL	Personal Information Protection Law
PLA	People's Liberation Army
R&D	Research and Development
SME	Small and Medium-Sized Enterprises

ABOUT SCERI

This project has been managed by Anders C. Johansson, Director of the Stockholm China Economic Research Institute (SCERI) at the Stockholm School of Economics, Sweden. As a result of China's growing importance in the world economy, SCERI started as a temporary research project under the President of the Stockholm School of Economics in 2007. In 2013, the program developed into an independent research institute under the umbrella of the school. The Institute conducts cutting-edge research on the Chinese economy and its staff members have published extensively in the fields of political economy, digital media, macroeconomics and finance, and innovation. SCERI also manages a Southeast Asia Research Program that builds upon the long tradition of excellence in research on various Southeast Asian countries at the Stockholm School of Economics.

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