

# Asia's AI agenda

## The ecosystem



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# Preface

**A** *Asia's AI agenda* is an MIT Technology Review Insights research program sponsored by ADP, Genesys, Splunk, and the Asia School of Business. It is designed to comprehensively examine the development of artificial intelligence (AI) in Asia Pacific from four distinct angles: Asia's AI ecosystem, the leading use cases and business applications across the region, the evolving talent landscape, and the emerging discussions around AI and ethics. To produce this series, MIT Technology Review Insights conducted a survey of almost 900 executives across 13 countries, and a series of interviews with leading authorities from academia and industry. The research is editorially independent and the views expressed are those of MIT Technology Review Insights.

## The survey

- In September and October 2018, MIT Technology Review Insights surveyed 871 senior business leaders, of whom 29% are CIOs, CTOs or heads of AI or analytics. More than half (53%) are C-suite and director-level executives. Almost 60% are from large companies with over \$1 billion in revenue.
- Survey respondents are based in 13 Asia-Pacific economies: Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, the Philippines, Singapore, South Korea, Thailand, Vietnam, with a minimum of 50 responses from each.
- Respondents are drawn from a wide range of industries, including more than 50 from each of the following sectors: consumer goods and retail; financial services; information technology and communications; manufacturing, pharmaceuticals and healthcare; professional services; property, construction, and engineering; and transport and logistics.

## Expert interviews

We would like to thank the following experts for contributing their time and insights towards this research program:

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**Sinuhé Arroyo**, founder and CEO, **Taiger**

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**Jonathan Woetzel**, director, McKinsey Global Institute, and senior partner, **McKinsey & Company, Shanghai**

**Xue Lan**, professor, School of Public Policy and Management, and dean, Schwarzman College, **Tsinghua University**

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# 1. Executive summary

**A**rtificial intelligence (AI) has quite possibly been the most widely discussed technology theme of 2018. The projections for how these new big data, machine learning (ML), and automation capabilities will transform cities, companies, and societies are startling, and causing policymakers and business leaders around the world to plan for a future where AI is a core competency. Experts increasingly view technological readiness, particularly having a sophisticated AI base, as a determinant of future competitiveness for nations and for companies.

Asian governments have ambitious plans for leadership in the AI era, and this white paper explores the success they are having in building fertile ecosystems that will attract much-needed AI talent and capital, as well as allowing companies to apply AI quickly and effectively across their organizations. MIT Technology Review Insights surveyed 871 Asia-based senior executives to gather perspectives, and conducted in-depth interviews with more than a dozen global experts in the field. The key findings of this research are:

- **With much to gain, most countries have a national plan for accelerating AI adoption**  
From China to Japan, Singapore to India, policymakers across Asia are developing national level plans for how AI can be used to enhance domestic and regional competitiveness, which include public and private sector collaboration.
- **Asia has credible potential for becoming a front runner in the AI era**  
Business leaders in Asia are positive about the AI resources available in the region, particularly the availability of data and quality of talent. More can be done to bolster the R&D environment and governments can still provide greater support.
- **China is rapidly applying AI, but basic research lags**  
The abundance of data, firm government push, and highly innovative tech companies gives China a distinct advantage in applying AI to variety of domains such as healthcare and finance, and across mobile platforms. Yet foundational research can be strengthened by further integrating private sector and academic R&D.
- **Building digital economies and digital societies is a key to competitiveness**  
Asia's domestic challenges and industries are providing focal points for the development of AI. In southeast Asia, this is taking shape in economic future-proofing, through a networking effect that stems from investments in startups, matching business problem statements with research talent, and developing a broad base of AI knowledge.
- **The big issues include securing foundational assets and managing AI's evolution**  
To become self-sufficient in the advancement of AI, Asia must strengthen its research environment and underlying capabilities, such as chipmaking industry and supercomputing strength. Additionally, policymakers need to tackle tricky questions such as how to manage the social contract between citizens (the creators of data) and the companies that capture it.

## 2. AI takes off

With the potential to supercharge the global economy, AI has become one of the hottest—and most hyped—technologies of the past 20 years. Asia has a lot to gain, and the region is gearing up to be a global frontrunner in the development and commercialization of AI. By all measures, global activity to drive advancement in AI has soared in recent years. How to develop and adopt AI at speed and scale is now a leading question and priority for governments, academic institutions, and many businesses worldwide.

Consulting firm PwC estimates that AI could contribute up to \$15.7 trillion to the global economy in 2030, representing GDP growth of more than 14% from 2017 levels.<sup>1</sup> China could be one of the biggest beneficiaries, the PwC report claims, potentially growing its GDP by 26% with gains across the retail, financial services, and healthcare industries.

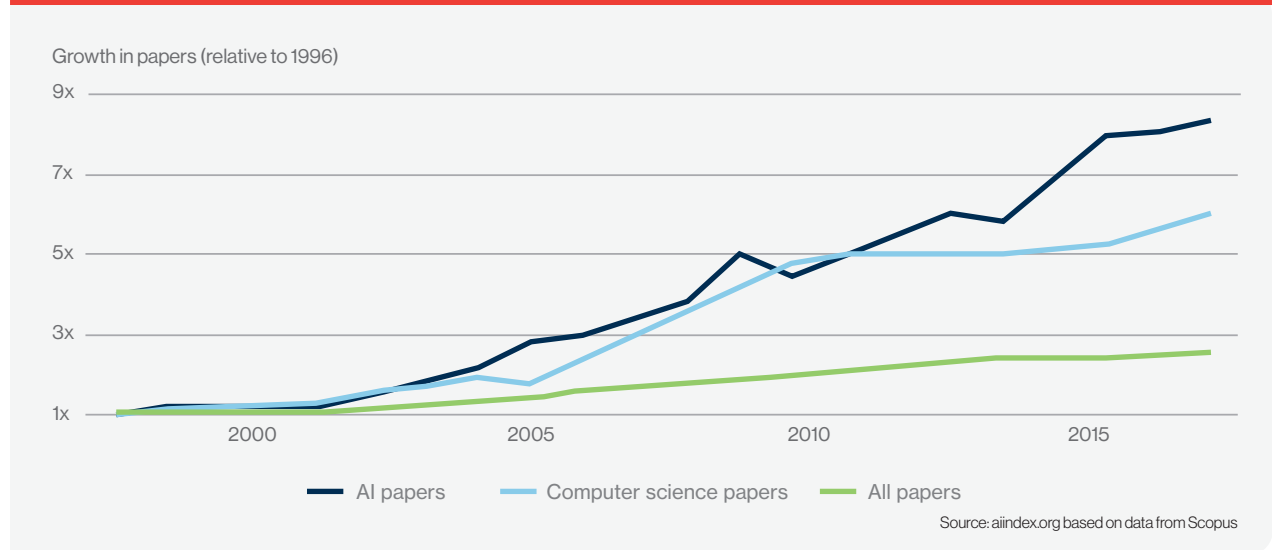
### Research and investment

The global push toward researching, developing, and applying AI can be seen in many fields. In academia, the rate of publishing around AI is

increasing rapidly. The AI Index, an annual effort to quantify and assess research activities in the field by Stanford University's One Hundred Year Study on Artificial Intelligence, reports that AI papers on Scopus (reported to be the world's largest database for books and scientific journals), have increased eight-fold between 1996 and 2017.<sup>2</sup> The number of graduate programs and faculty positions have also been climbing steadily. MIT, one of the birthplaces of AI, announced that it will open a dedicated school for AI, the MIT Stephen A. Schwarzman College of Computing, which will combine AI, ML, and data science with other academic disciplines. The school is due to open in 2022 and will create 50 new faculty positions and numerous fellowships for graduate students.

Private sector investment is gathering pace. Led by the big tech firms, where investment in AI, data centers, and other underlying technology has exploded, IDC estimates that global spending on cognitive and AI systems will reach \$77.6 billion in 2022, more than three times the \$24 billion forecast for 2018—a compound annual growth rate of 37.3%.<sup>3</sup> Big tech and other venture capital firms

**Figure 1: Growth of annually published papers by topic, 1996–2017, global**



<sup>1</sup> [www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf](http://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf)

<sup>2</sup> <http://cdn.aiindex.org/2018/AI%20Index%202018%20Annual%20Report.pdf>

<sup>3</sup> [www.idc.com/getdoc.jsp?containerId=prUS44291818](http://www.idc.com/getdoc.jsp?containerId=prUS44291818)

are also pouring cash into AI and ML companies. Pitchbook, an investment analyst firm, estimates that in 2017, \$6 billion was invested across 643 venture capital deals in AI.<sup>4</sup> In the United States, the number of active startups developing AI systems rose from a few dozen in 2000 to over 600 by 2017, a figure which itself has doubled since 2012.<sup>5</sup>

### The third wave

The rise of AI holds promise for almost every aspect of the global economy. A clear area of advantage will be harnessing the ever-growing pools of data generated by consumers, businesses, and machines to create a sea change in the ability to develop, deliver, and improve products and services, and become faster and more efficient on perhaps every measure of corporate performance. In terms of broader application across society, the future is to use intelligent and increasingly self-aware machines for providing radical new developments in fields such as healthcare, energy management, transportation, and education.

While much of this seems new, AI industry observers point out that there have been several waves of AI advancement for more than half a century. The first wave, representing about four decades of research through the 1990s, is “symbolic AI, driven by human-created rules—expert systems, logic, and search algorithms,” explains [Hod Lipson](#), professor of mechanical engineering and data science at **Columbia University**, an engineer and scientist whose research focuses on self-aware machines. Data analytics defines the second wave, he says, “when data became, if not ‘abundant’, cheap enough to generate systems which can predict the stock market, or the weather. This was another 20 years of machine learning, and we still use it. Companies compete over who can do analytics better, but it’s not the future of AI.”

That future, in Lipson’s opinion, is beyond AI’s current development incarnation, the third wave, where “deep learning helps us understand the data—images, audio, video—that’s not in the spreadsheet.” This is where much of Asia is focusing now, whether it is in self-aware robots in Japan, or facial recognition systems in China. While the advances have been prodigious, there is still

a long way to go, “when you consider that only 10 years ago, no software could reliably tell the difference between a cat and a dog.” Beyond this, Lipson describes a fourth wave where machines gain the creativity to design mechanics, electronic circuits, and other computer-generated blueprints such as houses and buildings far better than humans could, and also produce “thousands of them in seconds.”

The fifth and sixth phases are where machines become effectively sentient with their own intrinsic motivation, and will face what’s known in the industry as ‘the embodiment problem’. “Machines can be very intelligent in a box, but they cannot sort of walk out of the box, into the real world, and do stuff physically. AI is incredible when it’s inside a virtual world, but if you take even the best robots in existence today, they are no match for a human,” says Lipson.

### Asia’s approach

AI research globally is tacking toward a solution for this final frontier of embodiment, and contributions from Asia (particularly Japan, with its extensive robotic industry) are growing. For now, the main thrust of AI is in using enhanced analytics and computing resources to redesign and revitalize businesses and industries, and making them sustainable and competitive for the long term. The use of intelligent algorithms and predictive analytics forms the basis of “Industry 4.0”, an evolving manufacturing conceptual framework which envisions automated factories adjusting production in real time based on enterprise data and market trends, and proactively repairs and restocks assembly lines.

It is this future that is becoming the unifying vision for AI development in Asia. Asia’s economic planners, whether in more or less developed markets, have for decades looked to marshal national investment projects and coordinate R&D between domestic academic and industrial players, for kick-starting and growing tech industries. These efforts have traditionally been aimed at fostering high-value, export-oriented industries, yet Asia increasingly combines this with investments in ‘next generation’ technologies, such as AI, that can also provide solutions for the region’s myriad social, economic, and infrastructure challenges.

<sup>4</sup> [www.files.pitchbook.com/website/files/pdf/PitchBook\\_1Q\\_2018\\_Analyst\\_Note\\_Real\\_Potential\\_for\\_AI.pdf](http://www.files.pitchbook.com/website/files/pdf/PitchBook_1Q_2018_Analyst_Note_Real_Potential_for_AI.pdf)

<sup>5</sup> [www.aiindex.org/2017-report.pdf](http://www.aiindex.org/2017-report.pdf)

### 3. The AI crucible

Artificial intelligence is being placed in the center of the solution set for Asia's economic and social development. The region's unique capabilities and application of AI to specific indigenous challenges will mark it out as a leader on many AI indicators in the decade ahead.

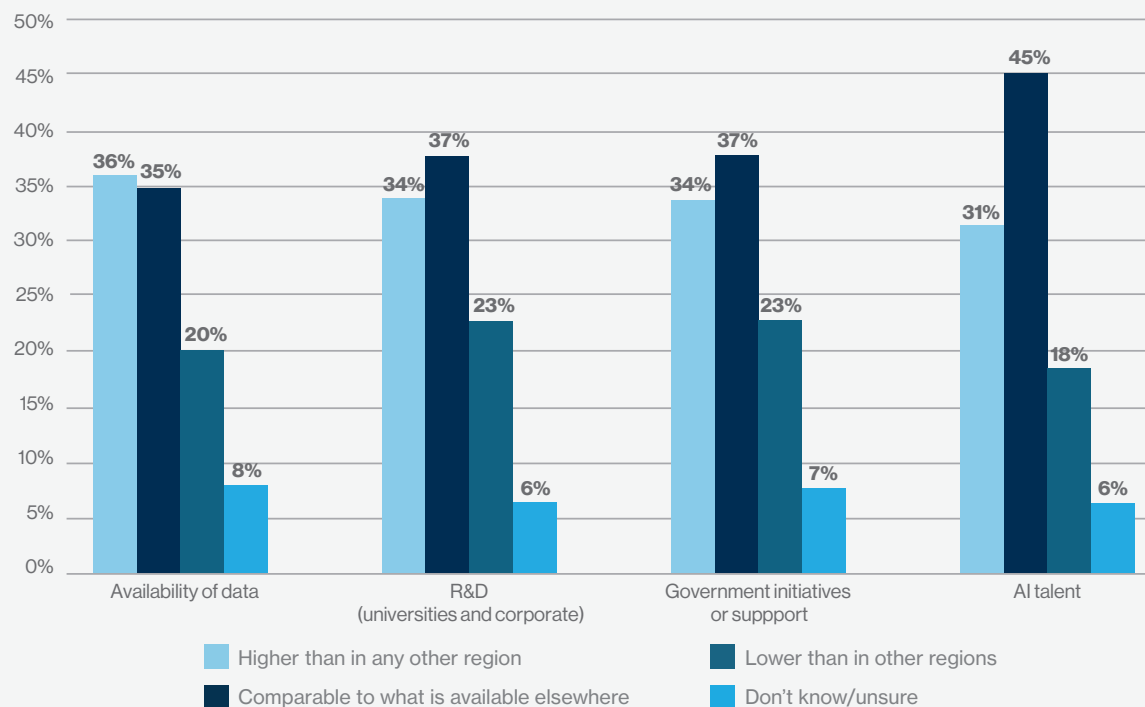
Across Asia, efforts to develop indigenous AI capabilities are quickly gathering steam. Moving from abstract to practical applications, AI is being used to increase efficiencies in agribusiness in Malaysia, traffic management in China, education in Singapore, and smart city initiatives all over the region. Asian governments are throwing considerable resources at AI. The Brookings Institute notes that the Indian government increased funding for its Digital India innovation program (which includes AI and ML) in 2018 to \$477m,

double its 2017 budget. Earlier this year, China's government reportedly put more than \$7 billion into two AI development facilities in Beijing and Tianjin.

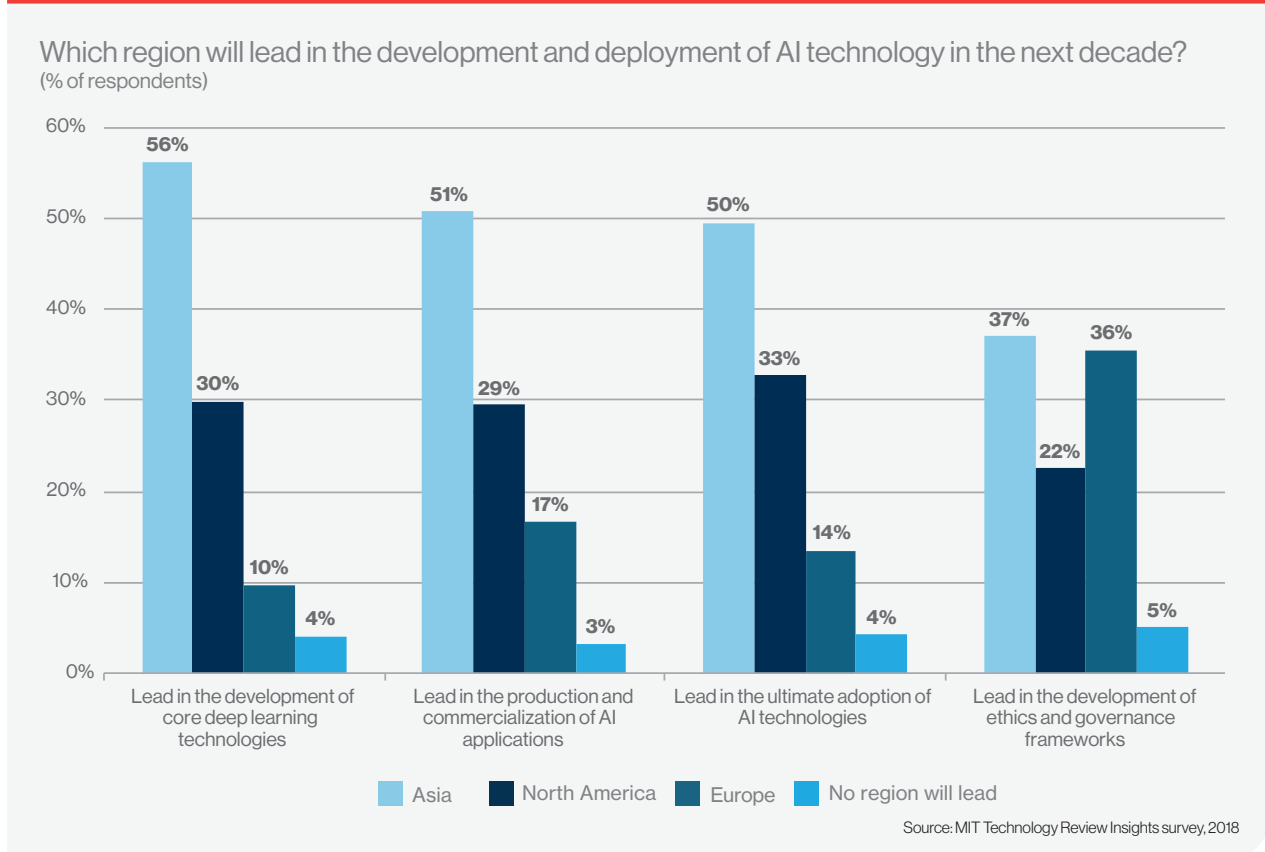
Business leaders who participated in our survey are also sanguine about the opportunities for AI in Asia. A third of the survey panel say that Asia leads the world in the quality of its AI assets, such as the availability of data, quality of R&D, and the support provided by governments. Nearly half consider Asia to be on par with other regions in terms of the available talent and quality of solutions providers and ecosystem. As a result, over 60% of respondents believe that Asia will lead in the development of core deep learning technologies, and nearly half believe that the region will lead in the production of commercialized applications.

**Figure 2: Asia's AI resources**

How does the quality of the AI resources in Asia compare with other regions?  
(% of respondents)



Source: MIT Technology Review Insights survey, 2018

**Figure 3: Regional AI advantages**

China in many ways is the lynchpin of Asia's AI ecosystem, with the massive scale of its smartphone-connected population and its world-leading high-tech manufacturing sector. The government's nationally-coordinated "Next Generation AI Development Program" is a comprehensive effort to fit ML technology into "Made in China 2025", the state's far-reaching blueprint for reinventing its export-oriented manufacturing economy. It calls for no less than global leadership in the field by 2030. That China's AI startups attracted roughly half of all global venture capital last year is evidence for the quality of their innovation and growth potential.<sup>6</sup>

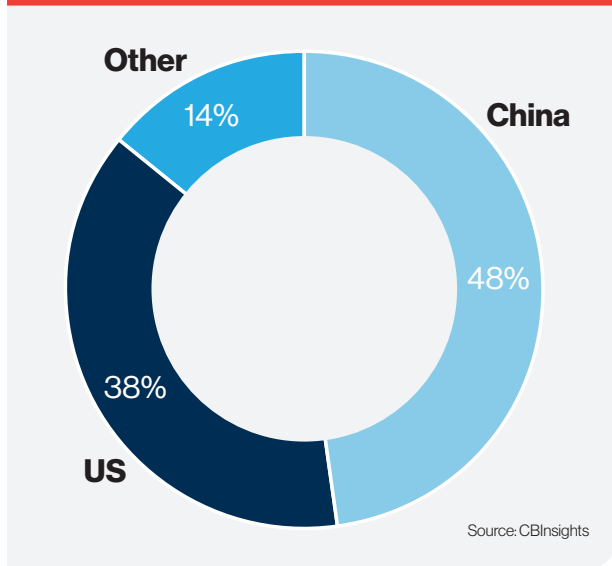
Beyond China, governments of several other Asian countries are launching programs to foster indigenous AI industries, tasked with tackling domestic challenges and spurring growth.

The impetus to create AI self-sufficiency is rooted in a time-honored economic development practice throughout the region: the belief that local mastery of technology combined with a domestic industry ecosystem delivers the most appropriate solutions to infrastructure and efficiency challenges, while also providing a class of goods and services that can be exported profitably.

Two strategies find themselves at work in Asia's efforts to develop ML innovations. The first is to leverage assets by pooling existing skills, industrial experience and, above all, data to create and test algorithms and conduct the deep neural network research needed to build intelligent machines. The second is to leverage networks, and promote lateral collaboration between industry, government, and academia, nationally, regionally, and globally.

<sup>6</sup> [www.cbinsights.com/research/briefing/china-in-ai-trends/](http://www.cbinsights.com/research/briefing/china-in-ai-trends/)



**Figure 4: Share of global AI startup funding, 2017**

Building networks and promoting collaboration is a natural strength for many Asian economies, given their position as global hubs for trade and long experience in exploiting the flow of capital and ideas to service global demand. Indeed, Singapore, one of the region's emerging centers of AI, has only one true AI asset, which is its position as regional and global hub for people, technology, and finance.

This is not necessarily a disadvantage, for it would be almost impossible to develop a leading, or even relevant, AI ecosystem in isolation from the best practices, research, talent, and investment available globally. The following chapters are deep dives into the AI ecosystems emerging across Asia. They highlight how being able to draw on the best of the world's AI assets is rapidly becoming the most important ingredient for success.

## 4. AI superpower

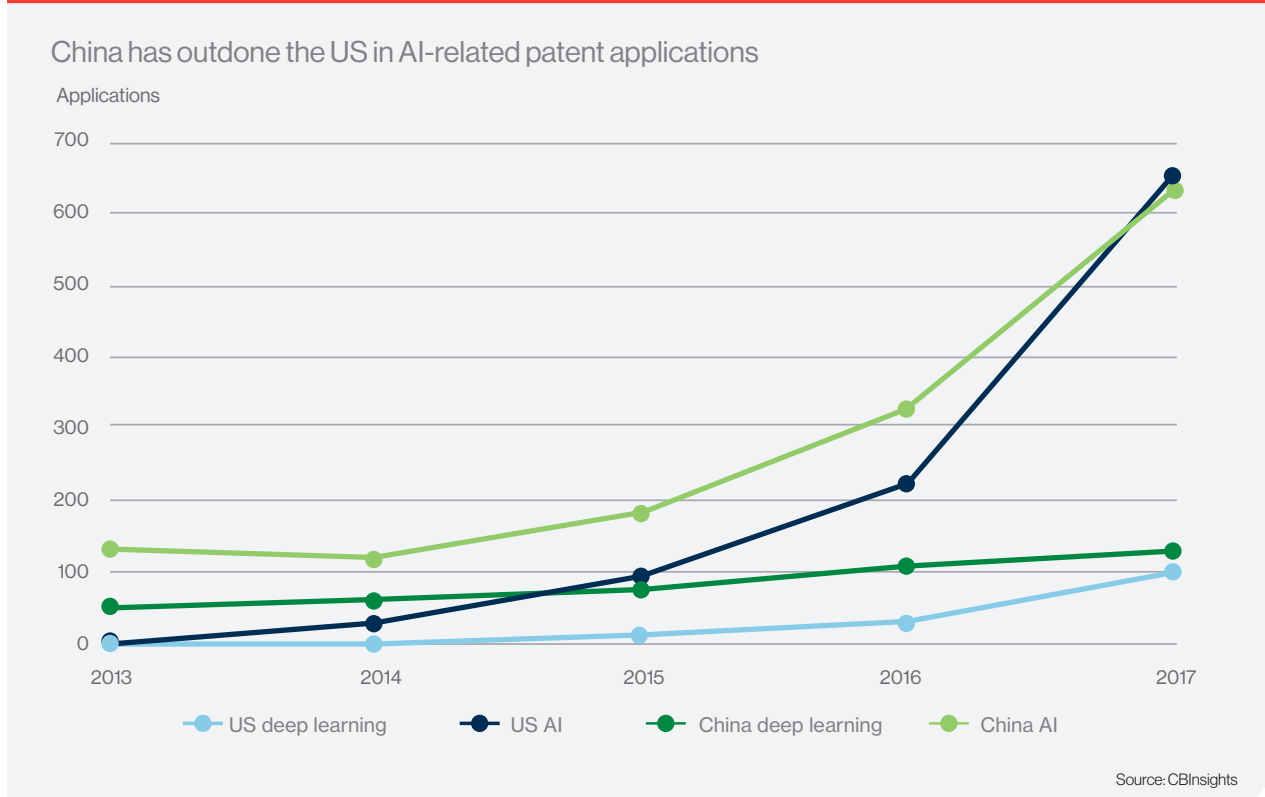
China is a credible global leader in artificial intelligence, accelerated by a powerful technology industry, a ‘mobile first’ society, and a relaxed approach to data protection. Yet more focus is needed on foundational research and building platforms for cross-sector collaboration.

As discussed in the last chapter, China’s leaders have ambitious plans for the country to be the global leader in AI by 2030. They may just achieve them. In June this year, Tsinghua University’s China Science and Technology Policy Research Center released its “China Artificial Intelligence Development Report 2018”, finding that China and Japan have the first- and third-highest number of AI patents registered in the world. With the United States in second place, the three countries together accounted for 74% of the number of all

published AI patents worldwide.

The Tsinghua report estimates that China’s AI market was worth 23.7 billion yuan (\$3.4 billion) in 2017 and consists of over a thousand businesses (albeit only half as many AI companies as in the United States), most active in voice and vision recognition, and natural language processing. The scale of China—economically, demographically, and technologically—has a profound and positive impact on the development of AI, largely because of the volumes of digital data that are generated. As Lee Kai-Fu of Sinovation Ventures notes in the AI Index, “There is no data like more data,” pointing out that China’s smartphone users, of which there will be an estimated 1.4 billion by 2025, shop online in volumes 50 times greater than their U.S. counterparts.<sup>7,8</sup> China’s sophistication in facial

**Figure 5: AI patents, US and China, 2013-2017**



<sup>7</sup> [www.aiindex.org/2017-report.pdf](http://www.aiindex.org/2017-report.pdf)

<sup>8</sup> [www.gsma.com/mobileeconomy/wp-content/uploads/2018/02/The-Mobile-Economy-Global-2018.pdf](http://www.gsma.com/mobileeconomy/wp-content/uploads/2018/02/The-Mobile-Economy-Global-2018.pdf)

recognition technology is largely thought to be peerless—again thanks to the accumulation of a national database of over 1.3 billion digital images in identity records.

Apart from the sheer number of smartphones, the way that people use them gives China a clear AI advantage in the mobile arena. “China’s increasing role in this space comes from their platform services like WeChat, which control every communication, payment, and purchase, amplified by the largest smartphone market on planet, an economy that is almost completely cashless, data collection by government and industry at a scale unheard of in the west, and social policies like sesame credit [Ant Financial’s credit scoring and loyalty program],” says [Toby Walsh](#), scientia professor of artificial intelligence at the **University of New South Wales**. If there is a race to develop AI as an operating model for the future, one where as Walsh describes, “we are not going to have keyboards or screens, where we have long running conversations with our devices,” China could certainly get there first.

### Application over research

Looking more closely at the research environment, while China leads overall in the publication of scientific papers, analysis conducted by Tsinghua University reveals that this volume belies an important lack of diversity and business sector contribution. “Leading Chinese AI companies rank far behind their overseas peers” in terms of publishing, says [Xue Lan](#), a professor at **Tsinghua University’s** School of Public Policy and Management, and dean of Schwarzman College at the university. “Amongst the world’s top 20 enterprises in AI publishing, you see very familiar multinational names—IBM, Microsoft, Samsung, and Google—but you don’t see their Chinese counterparts such as Alibaba, Tencent, or Baidu,” he says. The only Chinese company in the top 20 is the State Grid Corporation of China, the country’s electricity monopoly.

The differing approaches between Chinese tech firms and their U.S. counterparts can be seen in the way that they create AI-related intellectual property. “There are two levels in AI research,” explains [Wang Xiaogang](#), a former MIT AI scientist



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**Xue Lan**  
**Professor, School of Public Policy, and**  
**Dean, Schwarzman College**  
**Tsinghua University**

and co-founder of China’s largest AI start-up, **SenseTime**. “One is the foundation level, the other is the application level. You will see in China a lot of AI companies focused on the application level, scenarios in different industry or process domains,” he says. By contrast, most of the U.S. big tech names in AI focus a greater part of their efforts on deep and/or large-scale ML research, to create the fundamental platforms upon which tools and applications can be built.

Xue sees the disparity as a function of this emphasis on AI application over foundational research, “and it is a phenomenon we also see in the patent filings where again, of the world’s top 20 AI patent holders, the State Grid Corporation is the only Chinese firm among them. In terms of expertise and knowledge, Chinese companies are still in catch-up mode, so it is understandable that they focus on the application side, but at the same time they also need to strengthen their base.”

China’s research capabilities could be strengthened by building lateral collaboration between academia and industry, and between China and the rest of the world. “Less than 3% of all papers published in China are collaborations



“China enables AI to develop faster because of the scale of what it can discover and how it can use its population to get there. For players who do not fully engage with China’s AI ecosystem, it’s going to be very hard to be successful in things that we think are globally scalable solutions.”

**Jonathan Woetzel**  
**Director**  
**McKinsey Global Institute**

between universities and corporations, compared to 8% in France, and 7% in the U.S. and Germany,” says Xue.

### The master plan

Much of China’s growing AI determination has come off the back of strong government economic development policy. Part of this is centrally led, explains [Jonathan Woetzel](#), director at the **McKinsey Global Institute**, based in Shanghai. “The government has put forth a set of hopes and expectations for what AI can do for China. There are some national projects which use government data to achieve government purposes, whether it’s a national identity plan or the automation of the customs system.” But other parts are driven more by the nature of the system itself.

As AI scientist Lee Kai-Fu points out in a recent book comparing Chinese and U.S. AI development practices, “the central government does not simply issue commands that are instantly implemented throughout the nation. But it does have the ability

to pick out certain long-term goals and mobilize epic resources to push in that direction ... Local government leaders responded to the AI surge as though they had just heard the starting pistol for a race, fully competing with each other to lure AI companies and entrepreneurs to their regions with generous promises of subsidies and preferential policies.”<sup>9</sup>

The result is that local governments are forming ambitious collaborations with private sector partners, as is occurring in the healthcare industry. One example is Ping An, the country’s largest insurance company, working with the Chongqing municipality in southwestern China to develop AI models that forecast the spread of different flu strains and other contagious diseases.<sup>10</sup> Another example is how the government has allocated AI projects between the ‘big three’. According to CB Insights, the government announced that China’s first wave of open AI platforms will rely on Baidu for autonomous vehicles, Alibaba Cloud for smart cities, and Tencent for intelligent healthcare.<sup>11, 12</sup>

Yet for all its central planning, China suffers from the same data siloes that hamper governments and businesses around the world. Outside of national projects, such as the ‘Golden Shield’ cybersecurity program or the 909 Project to develop its semiconductor industry, “China doesn’t have a lot of data infrastructure,” Lee argues. “It may have a lot of unorganized data, but it doesn’t have a lot of pools, it doesn’t have a lot of analytics. To the extent it does have [organized data], it’s very clear who owns it—largely China’s e-commerce and telecoms platforms.” Data management will be critical for China in the years ahead.

Xue at Tsinghua University echoes this: “How do you explore the data, when government agency A wants to hold their data for themselves, and does not share with agency B or C? Company A may not want to share data with government agency B? In some cases, this is due to a legitimate concern for citizen privacy, but mostly it is just turf protection,” which can dilute the impact of China’s advantages in scale and AI policy coordination.

<sup>9</sup> [www.aisuperpowers.com](http://www.aisuperpowers.com)

<sup>10</sup> [www.technologyreview.com/s/611551/ai-as-a-force-for-good/](http://www.technologyreview.com/s/611551/ai-as-a-force-for-good/)

<sup>11</sup> [www.cbinsights.com/reports/CB-Insights\\_State-AI-China-Briefing.pdf](http://www.cbinsights.com/reports/CB-Insights_State-AI-China-Briefing.pdf)

<sup>12</sup> [www.pandaily.com/baidu-partners-with-local-government-on-self-driving-services/](http://www.pandaily.com/baidu-partners-with-local-government-on-self-driving-services/)



## Deep dive: China's largest algorithm provider

SenseTime is attempting to address China's relative lack of collaboration by building ecosystem elements into its business model. Established in 2014 and now valued at \$4.5 billion, Beijing-based SenseTime is often referred to as the world's largest AI startup. It's more of an 'AI foundry,' according to co-founder Wang Xiaogang, currently with a team of over 600 AI researchers, including 150 PhDs.

Somewhat unique to AI startups (and particularly application-focused Chinese firms) SenseTime applies AI to multiple domains, including autonomous driving, mobile internet, intelligent mobile phones, smart cities, and medical imaging. With its own deep learning framework, supercomputing centers, and specialism in a range of computer vision disciplines, the company supports two development 'chains'. The first is creating automated industrial applications to service complex, multi-player ecosystems, and the second is operating as a development hub, allowing other AI players to build their own domain-specific applications using SenseTime's framework.

While application-level progress is catalyzing the commercial aspects of China's AI ecosystem, "China's lack of platforms for deeper research is becoming a development challenge," says Wang, referring to the lack of foundational research and supporting infrastructure, such as supercomputer clusters, which he believes will set China at a disadvantage to competition, particularly from the United States. This makes SenseTime's 'two chain' approach uniquely useful since "it helps developers very quickly to get AI solutions. A deep learning framework provides a large volume of AI algorithms and models to quickly design a solution and to solve a particular domain problem—particularly as there is a very limited talent pool in China."

In February 2018 SenseTime announced that it would be the first company to participate in the MIT Intelligence Quest, an initiative to leverage the Institute's strengths in brain and cognitive science and computer science to advance research into human and machine intelligence. It will apply its discoveries to diverse fields—from materials design to finance to early disease diagnosis—while considering deeply the economic, cultural, and ethical implications of AI.

## Big guns

The ongoing trade war between the United States and China could have a profound impact on China's AI aspirations. On one hand, China's lead in device manufacturing is unparalleled, as is its indelible concentration of other key aspects of global technology supply chains, such as complex assembly and chipset testing. On the other, higher-function microchip development and other related technology is still largely the purview of companies in the United States and East Asia, and the recent tensions have meant that Chinese enterprise access to this is limited.

Should the geopolitical wedge persist, some AI industry observers predict negative outcomes for all players. "China enables (AI) to develop faster because of the scale of what it can discover and how it can use its population to get there,"

says Woetzel at the McKinsey Global Institute. "This might be the area in which it becomes indispensable for product development globally," and that for players who do not fully engage with China's AI ecosystem, "it's going to be very hard to be successful in things that we think are globally scalable solutions."

Will Knight, senior editor for artificial intelligence at **MIT Technology Review**, believes that the trade war will expedite China's independence with regard to chips. "China seems to be making significant progress," he says, "especially in application-specific AI chips (those used to do inference on devices). Evidence for this can be seen in Huawei's latest Kirin chip, and in the devices demonstrated by startups including Cambricon and Horizon Robotics. It's essential for the country to master cutting-edge chipmaking if it wants to become a real tech superpower."

## One country, two systems

SenseTime's origins in Hong Kong, where several of its founders (including Wang) were active in the Special Administrative Region's scientific academic community, also reveal another crucial component China's evolving ecosystem. Hong Kong is a focal point to global venture capital (which is increasingly directed at AI startups), is home to leading regional fintech clusters, has a wealth of cloud computing resources, and a number of highly-ranked scientific universities.

Despite this concentration of assets that should give Hong Kong an advantage, the government's ability to marshal resources and focus industry engagement around AI R&D has been lagging. Ironically, part of this lack of focus

is rooted in civic ambivalence about the role of technology in the future of Hong Kong's economic development. The One Country, Two Systems Research Institute, a local think-tank, published research in June 2018 estimating that AI and automation would endanger up to one million jobs in Hong Kong, including in key industries such as logistics or finance.

This is changing, albeit only recently. In September, the government-linked Hong Kong Science and Technology Parks Corporation, together with Alibaba and SenseTime, launched the Hong Kong AI and Data Laboratory. It aims to provide an accelerator platform for local AI startups, and has inducted an initial crop for incubation, with an emphasis on firms developing analytics, smart mobility, and fintech solutions.

# 5. Fusing digital and physical

Japan is carving a unique niche in 'mechatronics' at the junction of robotics and electrical engineering, which may provide an important role in the development of artificial intelligence in Asia, particularly in the aim to make automation more human.

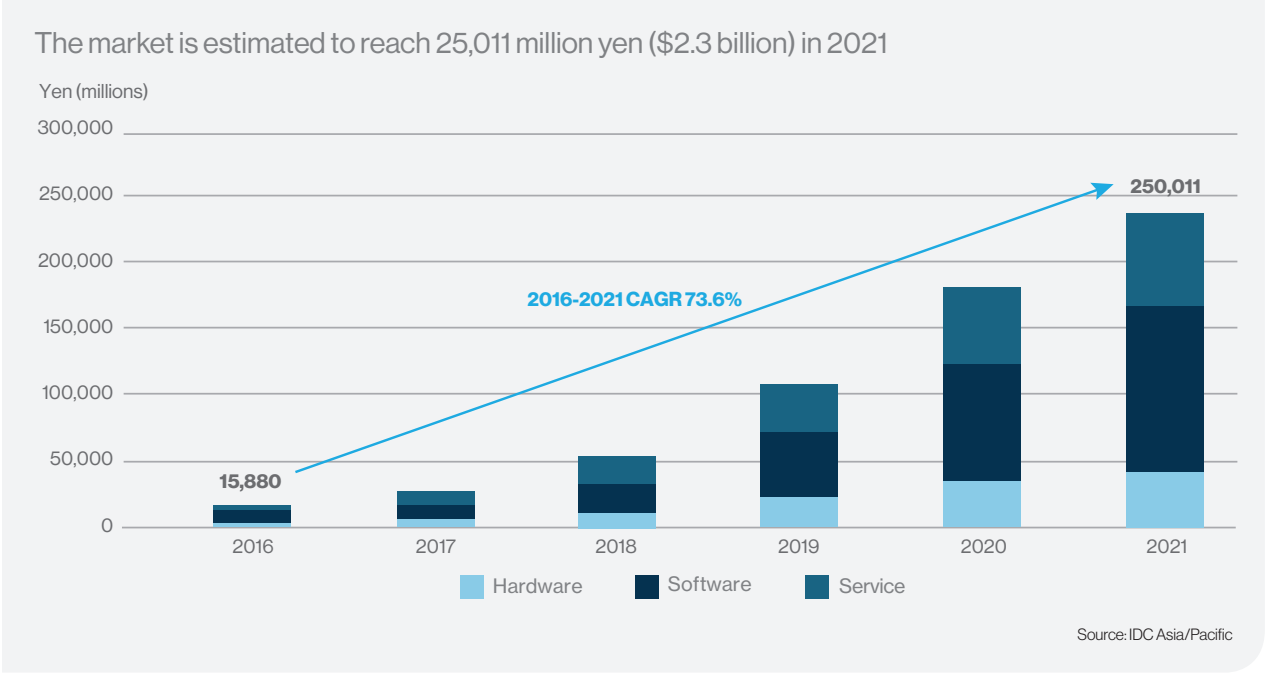
After China, Japan has the largest AI industry in Asia, as well as similarly ambitious plans for its further development. Japan's Strategic Council for AI Technology launched a plan in March 2017 which contains an industrialization roadmap using AI to make progress on three main priority areas: productivity; health, medical care, and welfare; and mobility. A fourth area that cuts across the others is information security. The report's authors state the importance of linking AI to Japan's existing industrial strengths: "In order for Japan to lead the world, it is necessary to come up with a challenging roadmap oriented towards industrialization based on AI technology and other related technology, based on the on-site strengths that Japan possesses with regard to social issues that Japan and the world are directly faced with."

## Mechatronics leader

Ambitions aside, Japan's AI economy seems incongruously small and has yet to reach the mainstream. Technology research firm IDC estimates that its value of AI-specific applications will more than double over the next four years, to 25 billion yen (\$2.3 billion) by 2021—or roughly half of where China's market is today.

However, this measure overlooks the potential which many believe will result from AI's synergies with Japan's 'mechatronics' industry, a term used to describe articulated robotics, automated process-enhanced machinery, and other electronics areas of particular Japanese strength. Japan still produces most of the world's advanced articulated robots—over 115,000 annually, exporting over 75,000 of them to the tune of \$2.7 billion, which the International Federation of Robots estimated is more than half of the world's consumption. Japan is also the world's second largest consumer of robots, behind China, and the volume increased 18% from 2016 to 2017, although

**Figure 6: Forecast of Japanese market for cognitive/AI systems, 2016-2021**



its density of robots to workers has declined in recent years compared to South Korea and Singapore.<sup>13</sup>

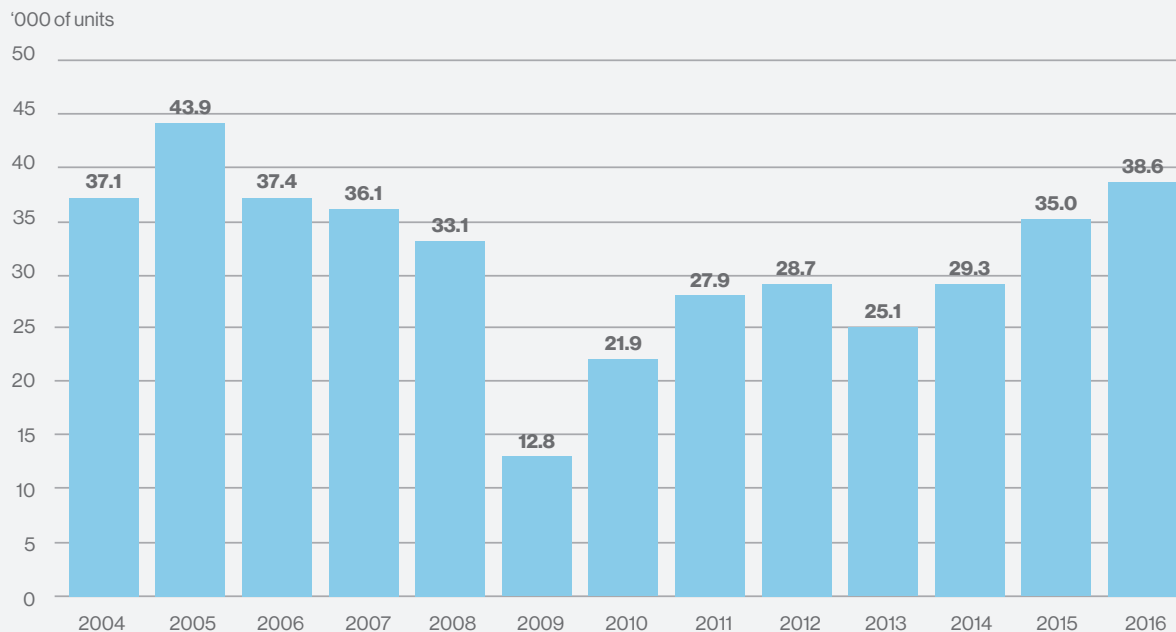
As discussed in chapter 2, robots are still a long way behind humans in their ability to navigate varied and challenging physical environments. The Japanese are making rapid progress, though. Boston Dynamics (acquired by Japanese investment bank SoftBank from Google in 2017) recently unveiled a robot capable of “a few jaw-dropping parkour moves, including an effortless-looking backflip” according to Will Knight, writing for MIT Technology Review.<sup>14</sup> In an example of blending cyber and physical worlds, Japanese conglomerate Yamaha partnered with SRI International to achieve its vision of creating a humanoid robot that can ride a motorcycle autonomously. The result is ‘Motobot 2.0’, a fully autonomous motorcycle-riding robot that can drive around a racetrack at high speed.<sup>15</sup>

**Kenji Suzuki**, professor at the Center for Cybernetics Research and Faculty of Engineering, Information, and Systems, at the **University of**

**Tsukuba** says that it is the harmony of robotics and other parts of its hardware industry, when coupled with the country’s data ecosystem, that may serve Japan’s overall AI aspirations. “We have a very good medical record system, which the government is looking to leverage to enhance healthcare and health insurance under a broader initiative called Society 5.0,” he says, describing the national efforts to connect physical spaces with social intelligence and cloud intelligence.

Yet as the government forges ahead with plans to create this ‘super smart society’ aimed at overcoming many of the challenges that will be faced by an aging population, Suzuki is concerned that other societal issues could create a dampening effect. “In Japan, we are more afraid of data privacy, and people are very much afraid of using personal data,” observing that credit card penetration is among the highest globally, but usage on e-commerce sites remains low (less than 17% in 2017).<sup>16</sup> “Big data development efforts are suffering a drawback because of Japan’s conservative usage of data,” he says.

**Figure 7: Estimated annual supply of industrial robots, Japan, 2004-2016**



Source: International Federation of Robotics

<sup>13</sup> [www.ifr.org/downloads/press2018/Executive\\_Summary\\_WR\\_2018\\_Industrial\\_Robots.pdf](http://www.ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf)

<sup>14</sup> [www.technologyreview.com/s/609627/the-year-robots-backflipped-their-way-into-our-hearts/](http://www.technologyreview.com/s/609627/the-year-robots-backflipped-their-way-into-our-hearts/)

<sup>15</sup> [www.bbc.com/future/story/20180126-meet-the-motorbike-racing-robot](http://www.bbc.com/future/story/20180126-meet-the-motorbike-racing-robot)

<sup>16</sup> [www.meti.go.jp/press/2016/03/20170308003/20170308003-1.pdf](http://www.meti.go.jp/press/2016/03/20170308003/20170308003-1.pdf)



## Deep dive: Keeping step with its neighbors



To meet its ambitions for becoming a contender in the global AI race, South Korea is looking to both China and Japan for inspiration. The aggressive timelines, development targets, and strong government support all echo China's AI program, such as South Korea's goal to become a top-four AI market globally by 2022. South Korea's government even aims to beat China's 2030 timeline by several years. Yet, in an approach that is more similar to Japan, South Korean AI research is focusing on the country's established and adjacent sectors, particularly process automation and robotics.

In May this year, South Korea's Presidential Fourth Industrial Revolution Committee

announced plans to invest some \$2 billion into AI institutions, including building several new research institutes that will develop AI applications for the robotics and the automotive sectors. The country's Ministry of Science and ICT is working to bolster the nation's AI talent base, to the tune of nearly 5,000 new AI and data scientists by 2022, and strengthen the domestic AI semiconductor industry.

South Korea's private sector is equally committed to advancing the AI industry. Samsung is particularly active, and has announced plans to invest \$20 billion in emerging technologies, largely focused on AI research, autonomous driving, and 5G over the next three years.

# 6. Economic future-proofing

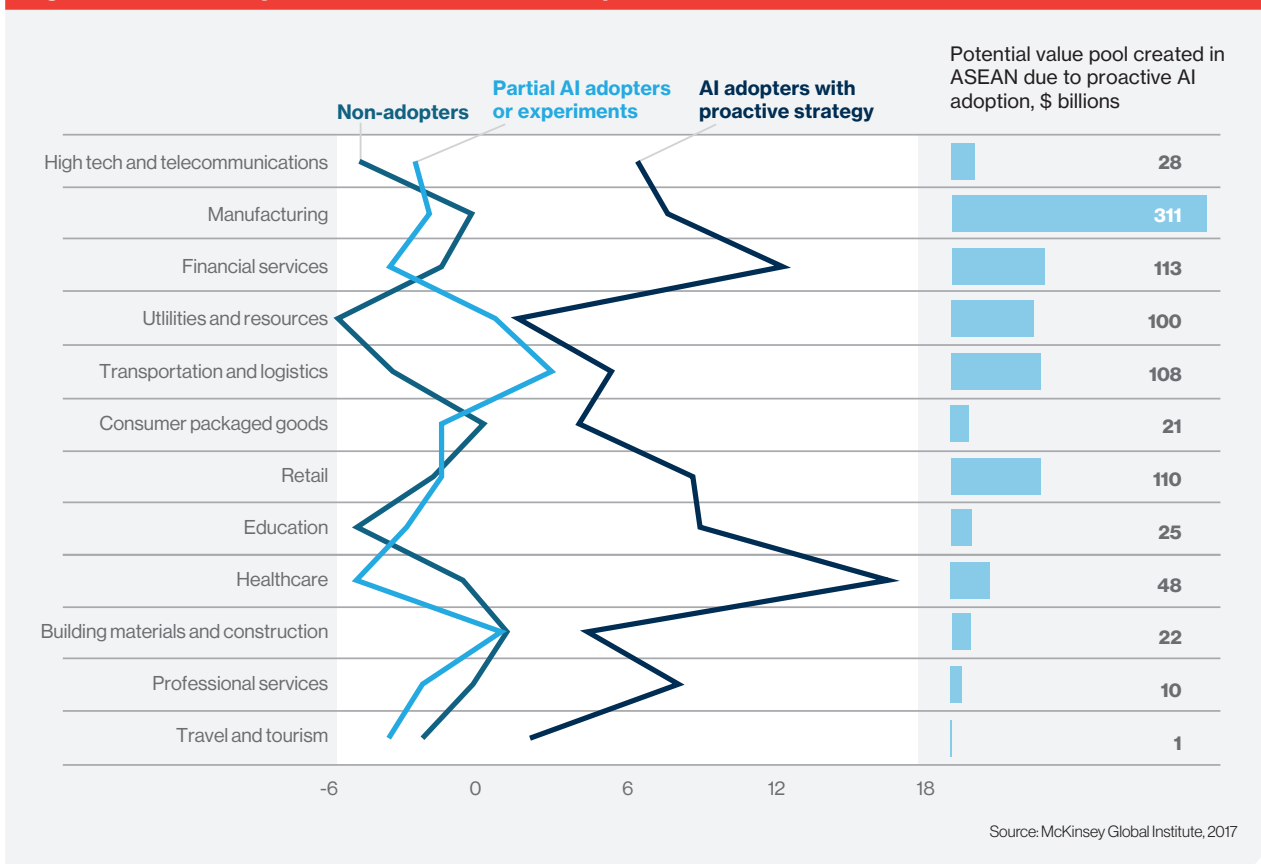
It would be inaccurate to cast all the diverse nations of southeast Asia as having a common approach to accelerating AI development. Yet policymakers and investors across the region are clearly leveraging their deep experience in network economics to compete in AI. Powered by exports and deep participation of global and regional systems of trade, the Association of Southeast Asian Nations (ASEAN) markets have long accrued real economic value in effective coordination between sources of ideas, capital, and the regulatory and policy frameworks that bind them.

Singapore's forward-thinking policymakers have placed AI in a growing, shifting constellation of new technology development that they can exploit for growth, despite the nation's small

size, because of its central role in the region's provision of financial, logistical, and other business services. Other ASEAN markets, Malaysia and Thailand in particular, are following suit by focusing AI collaboration on creating solutions for their more mature export-oriented industries, such as food and energy production or electronics manufacturing.

This highly networked and guided approach to AI development is believed to have the potential to transform southeast Asia's economies. The McKinsey Global Institute, in a 2017 study, found that this 'proactive strategy', could create a value pool (measured in terms of efficiencies created and new sources of revenue) of roughly three-quarters of a trillion dollars across the region.<sup>17</sup>

**Figure 8: Profitability and value creation from AI pools in ASEAN**



<sup>17</sup> [www.mckinsey.com/mgi/overview/2017-in-review/whats-next-in-digital-and-ai/artificial-intelligence-and-southeast-asias-future](http://www.mckinsey.com/mgi/overview/2017-in-review/whats-next-in-digital-and-ai/artificial-intelligence-and-southeast-asias-future)

## Networked and open source

The Infocomm Media Development Authority (IMDA), the developer and regulator for Singapore's digital industries, plays a critical role in Singapore's nation-wide efforts to develop a trusted AI ecosystem. The city-state has well-coordinated ministries and agencies involved in AI efforts (such as the National Research Foundation, Economic Development Board, and sector regulators such as the Monetary Authority of Singapore) and works with academia and a growing collection of homegrown and multinational AI firms.

"All around the world there are countries and big companies investing a lot into AI research. For a country of our size, we have to be very strategic and be very focused in where our research dollar goes to and how to get the best out of this," says Zee Kin Yeong, assistant chief executive, data innovation and protection at **IMDA**. The overarching goal of the program, he says, "is to see how Singapore-based AI research can filter into products and into the hands of companies and consumers. One key feature is matching research talent in our research institutions with specific industry problems."

AI Singapore, the national program for developing artificial intelligence capabilities, has a Grand Challenge initiative with a five-year S\$150m (\$109m) investment fund for developing AI solutions to solve the nation's most pressing problems such as healthcare, finance and urban issues solutions. In addition, there is a business-focused program called 100 Experiments, "which are intended to help companies use AI to solve more day-to-day issues that they are grappling with, be it operational efficiency issues, new product features issues, or getting to know their customer better," says Yeong.

Part of Singapore's approach is to build up an open source library of AI assets that companies can tap into as they develop new products or applications. An example is the National Speech Corpus. Released in November 2018, it contains 2,000 hours of audio and text transcriptions with local accents, place names, and phrases unique to Singapore. The corpus is available to developers, and enables tech companies to provide speech-related



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**Zee Kin Yeong**  
Assistant Chief Executive, Data Innovation  
and Protection  
Infocomm Media Development Authority

applications without needing to develop their own speech library. IMDA has also developed an open source library of algorithms for data analytics.

Building a vibrant core of AI developers and companies is another goal of IMDA's strategy. There are four key initiatives: a nine-month AI Apprenticeship Program for recent graduates; a three-month AI for Industry program for IT professionals and software developers; AI for Students, an online learning program for schools; and AI for Everyone, a short course that will give 10,000 non-technical Singaporean workers basic familiarity with how AI can apply to their jobs and lives.

## AI magnet

It's no secret that Singapore is moving fast in this AI space," says Sinuhé Arroyo, CEO of Singapore-headquartered fintech AI startup **Taiger**, referring to the government's 'SG:D' framework for promoting the digital economy. It was primarily this focus that convinced Arroyo to relocate from Spain, where he originally founded the company, which provides knowledge work automation solutions for financial institutions. "I understood the depth and the commitment of the government here to really create a solid base for companies

like us to prosper, to grow and to thrive. Previously, I was in the U.S. for two years and before that in Europe, where we initially started the business. We didn't see the appetite in those markets. Singapore is very special in the sense that all the key contributing industries, except agriculture, are well represented here, and have enough depth for any company to really understand those industries and then commercialize (AI applications) based on their needs worldwide—from Singapore to the world.”

Singapore's position as a global banking hub was another key attraction, meaning that the best practices and common challenges of global players are all collected in one efficient market, says Arroyo. “That was what we were after: the fact of the matter is no one wants to lay off people, but they are all under similar pressure because their revenue is not growing fast, and their operational costs resist containment.” In Singapore, Taiger has a convenient backyard learning laboratory to develop AI solutions that tackle workflow issues common to banks globally.

## Domestic and regional priorities

In Malaysia, the national applied R&D center, MIMOS, serves as “a cost center for Malaysia's innovation economy,” says Thillai Raj T. Ramanathan, its CTO, who is “tasked with creating, developing, and commercializing intellectual property.”<sup>18</sup> Established initially as a semiconductor research facility in 1985, MIMOS currently carries out its remit through two applied research laboratories, one of which is focused on AI, software engineering, and data analytics. More than 500 patents developed by MIMOS have been commercialized by Malaysian technology companies, which have collectively generated more than RM 1.5 billion (\$368m) in revenue over the last five years. Many of these applications are focused on agribusiness-centric businesses, a key export sector for Malaysia.

Hazlina Selamat, director of the Centre for Artificial Intelligence & Robotics (CAIRO) at the **Universiti Teknologi Malaysia**, has overseen several AI application pilots.



### Deep dive: Australia taps in

Australia, while physically distant from much of Asia's AI ecosystem, has trade and communications connectivity to the region. Like Singapore and Hong Kong, it has fashioned a robust data center and cloud computing industry to service growing domestic and regional demand, as well as a tertiary education system that attracts many of the best and brightest students from across Asia. Worth over A\$32 billion (\$23 billion) in 2017, education services are Australia's third largest export.<sup>19</sup>

Several of these world-class universities are now creating anchors for AI research, in collaboration with government initiatives. The University of Adelaide started the Australian Institute for Machine Learning, earlier this year, and last year, the Australia National University

launched a research center for ‘autonomy, agency and assurance’—the 3A Innovation Institute—to create a full education program of applied science around combined cybernetic and physical systems by 2022.

In a similar approach to that being adopted by other countries across the Asia-Pacific region, Australia is mostly fostering AI applications that link to the country's core industries. For example, with many of Australia's top exports such as agricultural products, and its tourism sector, depending upon the country's unique biodiversity, AI is finding application in efforts to secure the ecosystem, thanks to a trial at Murdoch University to use algorithms (similar to facial recognition) to detect potentially dangerous plants and animals entering Australia.

<sup>18</sup> <https://mit-technology-review.com/iot-blooms-in-malaysian-agro-sector/>


<sup>19</sup> [www.universitiesaustralia.edu.au/Media-and-Events/media-releases/Internationalstudents-inject-32-billion-a-year-into-Australia-s-economy---boosting-Aussie-jobsand-wages#.XBH1MC97FR0](http://www.universitiesaustralia.edu.au/Media-and-Events/media-releases/Internationalstudents-inject-32-billion-a-year-into-Australia-s-economy---boosting-Aussie-jobsand-wages#.XBH1MC97FR0)

“CAIRO has been working with various government ministries – the Ministry of Energy, Science, Environment, and Climate Change, and the Ministry of Agriculture, to develop and automate systems and processes according to the country’s priorities.” In her view, “AI and robotics firms in Malaysia need to focus on technologies for specific local applications (such as palm oil or fisheries) and affordable technologies for local and regional industries,” which Hazlina believes is particularly important in an economy where over 97% of the business landscape is comprised of small and medium-sized enterprises.

CAIRO’s international collaborations include the Tokyo Institute of Technology and Nippon Telegraph and Telephone (NTT) in Japan, and the universities of Burgundy and Nantes in France. These joint efforts have produced AI applications that have resonance in Malaysia, such as Artificial Intelligence in Medical Epidemiology (AIME), a dengue fever outbreak predictive system developed in Brazil for the 2016 Olympics, in which researchers from Universiti Malaysia Sabah participated.

As a market, Malaysia has also attracted much interest from China’s AI leaders, looking for a platform to expand regionally. E-commerce giant Alibaba has set up a second hub of its City

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Southeast Asia provides an example of how a focused strategy and deep understanding of the region’s economic strengths can be used to build an AI ecosystem far more powerful than the sum of its parts.

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Brain (a cloud-based AI program for smart city management, which begun with the municipality of Hangzhou) in Kuala Lumpur.

Malaysia’s focus on AI for pragmatic challenges that address global industrial, agricultural and societal development challenges (many of them commonly shared across fast-emerging economies) complements Singapore’s systemic approach to building an AI ecosystem. Southeast Asia provides an example of how a focused strategy and deep understanding of the region’s economic strengths can be used to build an AI ecosystem far more powerful than the sum of its parts.

## 7. Finding its way


India in some ways has natural AI assets, including deep technology research and a large population, to rival those of China. But multiple structural issues, including a lack of coordination between development agencies, threaten to slow its progress.

“India’s AI is still in a nascent stage,” says B. Ravindran, professor and head of the Robert Bosch Centre for Data Science and AI at the **Indian Institute of Technology**, Madras, although he is quick to point out that the country’s indigenous technology expertise does provide some useful building blocks. “We have the world’s biggest IT services sector, which has provided Indian firms with a lot of experience in the development and use of automated customer service management systems. Similarly, this has helped firms develop machine learning processes and Indian language processing—both by Indian firms and multinationals like Microsoft and Google. If you move away from industry, you see a lot more language modelling and machine learning theory development in academic circles—not at the scale as in China, but steadily growing over the last decade.”

India’s higher education system provides a solid base for AI, but could be further strengthened, notes Ravindran. “The top-tier research institutes in India are focused on math and theory. So, you have lots of engineers who are really good at math, but not necessarily the hardcore computational aspects of it. And this is what gives (AI research) its additional impetus. Without computers and data—two important resources which India lacks—doing research in theoretical machine learning is less productive.”

### Data, data, everywhere

The lack of structure and coordination around data gathering and sharing present a significant obstacle for the development of an Indian AI ecosystem. Even though India has a huge population and we can read large volumes of data, the data is not recorded in formats amenable for sharing and use, he says. “Privacy and security issues in India mean that it is hard to get our hands on large volumes of external data, which limits the



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**B. Ravindran**  
**Professor and Head of the Robert Bosch**  
**Centre for Data Science and AI**  
**Indian Institute of Technology, Madras**

AI work that India can do. That’s changing, with more international partners coming to India willing to share data, and work with teams here,” and potentially share cloud computing resources.

Ravindran notes that in many ways India’s startups, particularly those aligned with global cloud computing giants like Amazon or Microsoft, have an advantage over academics. He advocates something akin to what Canada has developed: “build a nationwide computing infrastructure for AI. And so different research groups in the country can apply for time, and the amount of time they get is proportional to their contribution.”

There are signs that government readiness for driving AI solutions is increasing. “Not only is the government interested, but it is making a lot of noise, and I think mostly the right noises. Departments that were not willing to share data a couple of years back are now falling over themselves trying to help. The only concern that I have is that India has too many of these AI task forces; every single government department is putting out one. There has to be some kind of convergence to make them effective.”



## Deep dive: AI as a force for good

P. Anandan, is an AI scientist and the CEO of **Wadhvani Institute for Artificial Intelligence**, a Mumbai-based nonprofit research institute tasked with developing AI for social good. He sees Wadhvani's mandate—and all AI actors in India—as being to identify the roots of the country's human development challenges and focus AI on specific solutions.

“The greatest tangible impact AI can have on [India's] economy and industrial landscape is not about process automation, it is about core productivity. The Indian economy is still very driven by human labor, and with 1.2 billion people, that's not likely to change soon. Making those people optimally productive is our biggest challenge.” A key area of economic productivity is India's huge agricultural economy, which still employs half of all workers in India. Anandan's team has been working on AI tools for cotton farmers in Maharashtra, which are helping them tackle such productivity challenges as pest management.

Healthcare is fertile ground for Wadhvani. Anandan describes how 900 million people are served through a national network of 25,000 primary health care facilities, with a further 100,000 sub-centers in rural areas that do not have permanent staff. Nurses or doctors visit once cases have been referred upward. Wadhvani worked with a sister foundation, the Wadhvani Initiative for Sustainable Health (WISH), that had experience in rebuilding, redesigning processes, and running 100 sub-centers in Rajasthan for two years before handing them back over to the government. In

redesigning the processes, the team identified a dozen use cases where AI would help. One was a triaging app for healthcare caseworkers around the identification of risks associated with pregnancies and prenatal care, for prioritizing the locations and sequencing of their field visits. The apps will soon be available for field trials by health and wellness centers on a larger scale.

Anandan sees infrastructure as India's second root challenge. “Public utilities and transportation infrastructure—roads, railways, waterways—can be more efficiently managed and better planned.” The third one “which has always been very important in India, is actually e-commerce itself. We already see middle class and even lower-middle class households in India relying on online mechanisms for doing a number of their everyday purchases.” Making digital commerce more efficient could unlock considerable value in the economy.

While there are many daunting challenges, including India's lack of deep pools of structured data, he is positive on the outlook. “None of them are insurmountable. The kind of decisions, about data collection, will take some time for us to figure out—actually, just gauging the infrastructure on that scale in order to collect and share all the data, and deal with privacy and security issues does create many, many obstacles. But if we start with specific problems and design solutions on a small scale, on a scale of our healthcare initiatives, we can use them as pilots with which we can succeed at a district level, and eventually follow through that scaling process to a national level.”

## 8. Emerging AI imperatives

Asia's future success depends upon its stakeholders balancing domestic artificial intelligence priorities with contributing toward and working within a strong regional and global ecosystem.

As this paper has discussed, Asia has copious AI 'assets', such as well-funded centers of research, populous and data-generating consumer markets, and government expertise in coordinating value networks. But the governments, entrepreneurs, technology firms, and research institutes operating in Asia should not strive for self-sufficiency or closed worlds, even though those might be the ones that emerge. Indeed, they must work together to build a collaborative ecosystem that addresses common development challenges.

One of those potential challenges is balancing the need for large volumes of data to be collected and accessible, while also safeguarding privacy and making sure that it is responsibly and ethically used. This is an emerging topic all around the region, and one that is yet to come to concrete conclusions. Yet governments will pay close attention to data in the years ahead, potentially even as a state asset or national resource. Without adequate focus, says Walsh at the University of New South Wales in Sydney, "it is clear that small players are going to be at a disadvantage to companies like Google, that try to snatch up deals to get access to data. It will put them [big tech companies] in a very favorable situation and people are just waking up to that."


### Foundational assets

Asia also needs to build up stronger assets for producing research. "What we need, simply, is more breakthroughs," says [Tomaso Poggio](#), professor in the Department of Brain and Cognitive Sciences at MIT, who cautions that as we enter the newer, cognitive aspects of automated software and machine design, it becomes more difficult to even perceive from where, and when, the next breakthrough will come.

"My guess is that because the ones we had in the last 10 years came from neuroscience, some of the next ones have a very good chance of also coming from neuroscience. I think understanding our own brain and intelligence will be important for really building intelligent machines. There is a good bet that the natural science of intelligence, meaning neuroscience and ecology science" will produce the next new-new things.

Looking at Asia's AI ecosystem, most of the applications-oriented research is focused on developing engineering solutions. "I haven't really seen much out of China with regards to fundamental breakthroughs that set a new frontier," says [Jeffrey Ding](#), researcher at the **University of Oxford's** Future of Humanity Institute. Asia's ecosystems need, fundamentally, to become open and flexible systems, responsive to changing conditions and future developments. This is not to suggest that they are closed today—indeed, the level of international collaboration suggests the opposite.

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**Tomaso Poggio**  
**Professor, Department of Brain and**  
**Cognitive Sciences**  
**MIT**

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Ding's research examines citation metrics in scientific papers to understand co-authorship networks in AI academia, which "reveal pretty close connections between China and Australia and Singapore in particular," he says. Strengthening all forms of collaboration, internationally and between public and private sector, will allow Asia's AI ecosystem to take larger steps forward.

### Meeting broader goals

The policy of Asian governments to use AI as an accelerator for broader development goals, such as Singapore's Smart Nation, or China's Made in China 2025, is a key success factor. Poggio notes that there is more of a government role in Asian countries compared to the United States, where big tech has a stronger hand.

In Asia, he says, "it's not only companies like Tencent or Baidu that play a role, they work in concert with national-level agendas, much more so than in the U.S. Sometimes people make comparison with the space race, and of course the U.S. government has a big role in supporting researchers in AI," but Asia's attention to the details of bringing all the pieces of the ecosystem together is even more powerful.

As of now, no one region has all of the right pieces, says Ding. "China's drive for indigenous and self-reliant innovation is probably not likely to come completely into fruition," particularly while it remains reliant on U.S. chips. The speed at which China can build up its foundational assets will be central to Asia's AI story in the years ahead.

## 9. Conclusion

This report, the first part of MIT Technology Review Insights' research program, *Asia's AI agenda*, has examined the ecosystem for AI across the region. Based on a survey of almost 900 executives and a series of in-depth interviews with regional and global experts on AI, the main conclusions of the report are as follows:

- 1. Asia is a credible frontrunner in AI globally.** More than two-thirds of survey respondents consider Asia to have an AI asset base of data, talent, service providers, and government support that is superior or comparable with what is available in other regions.
- 2. Asia could take the leadership position in the next decade.** The majority of respondents believe that Asia will be the leading region in the development, application, and commercialization of AI technologies in the coming decade.
- 3. Government intervention has been a driving force for success.** Linking highly-focused government AI programs to broader national objectives has and will continue to allow Asian countries to become AI centers of excellence globally.
- 4. Solving domestic challenges spurs innovation.** Asia's domestic challenges—whether infrastructure deficiencies in India, agricultural productivity in Malaysia, or equitable healthcare provision everywhere—provide research focal points and near-endless opportunities for AI innovators to create the next generation of AI exports.
- 5. Collaboration and indigenous assets must continue to be developed.** Many of Asia's cooperation frameworks do not sufficiently leverage research between industry and academia, or between industry participants. Industry stakeholders must ensure that AI development does not occur in siloes.
- 6. The bigger issues such as data protection must be addressed.** Asia's AI architects will need to create more citizen-centric regulatory frameworks around the use of data, and how the value from that data is generated. This will become increasingly important as the use of AI for social control (such as China's so-called 'social credit' program) demonstrates to citizens and consumers the negative or exclusionary impact it can have. Failure to do this will damage the social contract between creators of data and the companies that use it.

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