on their American counterparts in both revenue and market caps. In the age of AI implementation, the impact of these divergent data ecosystems will be far more profound. It will shape what industries AI startups will disrupt in each country and what intractable problems they will solve.

But building an AI-driven economy requires more than just gladiator entrepreneurs and abundant data. It also takes an army of trained AI engineers and a government eager to embrace the power of this transformative technology. These two factors—AI expertise and government support—are the final pieces of the AI puzzle. When put in place, they will complete our analysis of the competitive balance between the world's two superpowers in the defining technology of the twenty-first century.

4

A TALE OF TWO COUNTRIES

Back in 1999, Chinese researchers were still in the dark when it came to studying artificial intelligence—literally. Allow me to explain.

That year, I visited the University of Science and Technology of China to give a lecture about our work on speech and image recognition at Microsoft Research. The university was one of the best engineering schools in the country, but it was located in the southern city of Hefei (pronounced "Huh-faye"), a remote backwater compared with Beijing.

On the night of the lecture, students crammed into the auditorium, and those who couldn't get a ticket pressed up against the windows, hoping to catch some of the lecture through the glass. Interest was so intense that I eventually asked the organizers to allow students to fill up the aisles and even sit on the stage around me. They listened intently as I laid out the fundamentals of speech recognition, speech synthesis, 3-D graphics, and computer vision. They scribbled down notes and peppered me with questions about underlying principles and practical applications. China clearly lagged behind the United States by more than a decade in AI research, but these students were like sponges for any knowledge from the outside world. The excitement in the room was palpable.

The lecture ran long, and it was already dark as I left the auditorium and headed toward the university's main gate. Student dorms lined both sides of the road, but the campus was still and the street was empty. And then, suddenly, it wasn't. As if on cue, long

lines of students began pouring out of the dormitories all around me and walking out into the street. I stood there baffled, watching what looked like a slow-motion fire drill, all of it conducted in total silence.

It wasn't until they sat down on the curb and opened up their textbooks that I realized what was going on: the dormitories turned off all their lights at 11 p.m. sharp, and so most of the student body headed outside to continue their studies by streetlight. I looked on as hundreds of China's brightest young engineering minds huddled in the soft yellow glow. I didn't know it at the time, but the future founder of one of China's most important AI companies was there, squeezing in an extra couple of hours of studying in the dark Hefei night.

Many of the textbooks these students read were outdated or poorly translated. But they were the best the students could get their hands on, and these young scholars were going to wring them for every drop of knowledge they contained. Internet access at the school was a scarce commodity, and studying abroad was possible only if the students earned a full scholarship. The dog-eared pages of these textbooks and the occasional lecture from a visiting scholar were the only window they had into the state of global AI research.

Oh, how things have changed.

THE STUFF OF AN AI SUPERPOWER

As I laid out earlier, creating an AI superpower for the twenty-first century requires four main building blocks: abundant data, tenacious entrepreneurs, well-trained AI scientists, and a supportive policy environment. We've already seen how China's gladiatorial startup ecosystem trained a generation of the world's most street-smart entrepreneurs, and how China's alternate internet universe created the world's richest data ecosystem.

This chapter assesses the balance of power in the two remaining ingredients—AI expertise and government support. I believe that in the age of AI implementation, Silicon Valley's edge in elite expertise isn't all it's cracked up to be. And in the crucial realm of government support, China's techno-utilitarian political culture will pave the way for faster deployment of game-changing technologies.

As artificial intelligence filters into the broader economy, this era will reward the *quantity* of solid AI engineers over the *quality* of elite researchers. Real economic strength in the age of AI implementation won't come just from a handful of elite scientists who push the boundaries of research. It will come from an army of well-trained engineers who team up with entrepreneurs to turn those discoveries into game-changing companies.

China is training just such an army. In the two decades since my lecture in Hefei, China's artificial intelligence community has largely closed the gap with the United States. While America still dominates when it comes to superstar researchers, Chinese companies and research institutions have filled their ranks with the kind of well-trained engineers that can power this era of AI deployment. It has done that by marrying the extraordinary hunger for knowledge that I witnessed in Hefei with an explosion in access to cutting-edge global research. Chinese students of AI are no longer straining in the dark to read outdated textbooks. They're taking advantage of AI's open research culture to absorb knowledge straight from the source and in real time. That means dissecting the latest online academic publications, debating the approaches of top AI scientists in WeChat groups, and streaming their lectures on smartphones.

This rich connectivity allows China's AI community to play intellectual catch-up at the elite level, training a generation of hungry Chinese researchers who now contribute to the field at a high level. It also empowers Chinese startups to apply cutting-edge, open source algorithms to practical AI products: autonomous drones, pay-with-your-face systems, and intelligent home appliances.

Those startups are now scrapping for a slice of an AI landscape increasingly dominated by a handful of major players: the so-called Seven Giants of the AI age, which include Google, Facebook, Amazon, Microsoft, Baidu, Alibaba, and Tencent. These corporate juggernauts are almost evenly split between the United States and China, and they're making bold plays to dominate the AI economy. They're using billions of dollars in cash and dizzying stockpiles of

data to gobble up available AI talent. They're also working to construct the "power grids" for the AI age: privately controlled computing networks that distribute machine learning across the economy, with the corporate giants acting as "utilities." It's a worrisome phenomenon for those who value an open AI ecosystem and also poses a potential stumbling block to China's rise as an AI superpower.

But bringing AI's power to bear on the broader economy can't be done by private companies alone—it requires an accommodating policy environment and can be accelerated by direct government support. As you recall, soon after Ke Jie's loss to AlphaGo, the Chinese central government released a sweeping blueprint for Chinese leadership in AI. Like the "mass innovation and mass entrepreneurship" campaign, China's AI plan is turbocharging growth through a flood of new funding, including subsidies for AI startups and generous government contracts to accelerate adoption.

The plan has also shifted incentives for policy innovation around AI. Ambitious mayors across China are scrambling to turn their cities into showcases for new AI applications. They're plotting driverless trucking routes, installing facial recognition systems on public transportation, and hooking traffic grids into "city brains" that optimize flows.

Behind these efforts lies a core difference in American and Chinese political culture: while America's combative political system aggressively punishes missteps or waste in funding technological upgrades, China's techno-utilitarian approach rewards proactive investment and adoption. Neither system can claim objective moral superiority, and the United States' long track record of both personal freedom and technological achievement is unparalleled in the modern era. But I believe that in the age of AI implementation the Chinese approach will have the impact of accelerating deployment, generating more data, and planting the seeds of further growth. It's a self-perpetuating cycle, one that runs on a peculiar alchemy of digital data, entrepreneurial grit, hard-earned expertise, and political will. To see where the two AI superpowers stand, we must first understand the source of that expertise.

NOBEL WINNERS AND NO-NAME TINKERERS

When Enrico Fermi stepped onto the deck of the RMS *Franconia II* in 1938, he changed the global balance of power. Fermi had just received the Nobel Prize in physics in Stockholm, but instead of returning home to Benito Mussolini's Italy, Fermi and his family sailed for New York. They made the journey to escape Italy's racial laws, which barred Jews or Africans from holding many jobs or marrying Italians. Fermi's wife, Laura, was Jewish, and he decided to move the family halfway across the world rather than live under the antisemitism that was sweeping Europe.

It was a personal decision with earthshaking consequences. After arriving in the United States, Fermi learned of the discovery of nuclear fission by scientists in Nazi Germany and quickly set to work exploring the phenomenon. He created the world's first self-sustaining nuclear reaction underneath a set of bleachers at the University of Chicago and played an indispensable role in the Manhattan Project. This top-secret project was the largest industrial undertaking the world had ever seen, and it culminated in the development of the world's first nuclear weapons for the U.S. military. Those bombs put an end to World War II in the Pacific and laid the groundwork for the nuclear world order.

Fermi and the Manhattan Project embodied an age of discovery that rewarded quality over quantity in expertise. In nuclear physics, the 1930s and 1940s were an age of fundamental breakthroughs, and when it came to making those breakthroughs, one Enrico Fermi was worth thousands of less brilliant physicists. American leadership in this era was built in large part on attracting geniuses like Fermi: men and women who could singlehandedly tip the scales of scientific power.

But not every technological revolution follows this pattern. Often, once a fundamental breakthrough has been achieved, the center of gravity quickly shifts from a handful of elite researchers to an army of tinkerers—engineers with just enough expertise to apply the technology to different problems. This is particularly true when the

payoff of a breakthrough is diffused throughout society rather than concentrated in a few labs or weapons systems.

Mass electrification exemplified this process. Following Thomas Edison's harnessing of electricity, the field rapidly shifted from invention to implementation. Thousands of engineers began tinkering with electricity, using it to power new devices and reorganize industrial processes. Those tinkerers didn't have to break new ground like Edison. They just had to know enough about how electricity worked to turn its power into useful and profitable machines.

Our present phase of AI implementation fits this latter model. A constant stream of headlines about the latest task tackled by AI gives us the mistaken sense that we are living through an age of discovery, a time when the Enrico Fermis of the world determine the balance of power. In reality, we are witnessing the application of one fundamental breakthrough—deep learning and related techniques—to many different problems. That's a process that requires well-trained AI scientists, the tinkerers of this age. Today, those tinkerers are putting AI's superhuman powers of pattern recognition to use making loans, driving cars, translating text, playing Go, and powering your Amazon Alexa.

Deep-learning pioneers like Geoffrey Hinton, Yann LeCun, and Yoshua Bengio—the Enrico Fermis of AI—continue to push the boundaries of artificial intelligence. And they may yet produce another game-changing breakthrough, one that scrambles the global technological pecking order. But in the meantime, the real action today is with the tinkerers.

INTELLIGENCE SHARING

And for this technological revolution, the tinkerers have an added advantage: real-time access to the work of leading pioneers. During the Industrial Revolution, national borders and language barriers meant that new industrial breakthroughs remained bottled up in their country of origin, England. America's cultural proximity and loose intellectual property laws helped it pilfer some key inventions, but there remained a substantial lag between the innovator and the imitator.

Not so today. When asked how far China lags behind Silicon Valley in artificial intelligence research, some Chinese entrepreneurs jokingly answer "sixteen hours"—the time difference between California and Beijing. America may be home to the top researchers, but much of their work and insight is instantaneously available to anyone with an internet connection and a grounding in AI fundamentals. Facilitating this knowledge transfer are two defining traits of the AI research community: openness and speed.

Artificial intelligence researchers tend to be quite open about publishing their algorithms, data, and results. That openness grew out of the common goal of advancing the field and also from the desire for objective metrics in competitions. In many physical sciences, experiments cannot be fully replicated from one lab to the next—minute variations in technique or environment can greatly affect results. But AI experiments are perfectly replicable, and algorithms are directly comparable. They simply require those algorithms to be trained and tested on identical data sets. International competitions frequently pit different computer vision or speech recognition teams against each other, with the competitors opening their work to scrutiny by other researchers.

The speed of improvements in AI also drives researchers to instantly share their results. Many AI scientists aren't trying to make fundamental breakthroughs on the scale of deep learning, but they are constantly making marginal improvements to the best algorithms. Those improvements regularly set new records for accuracy on tasks like speech recognition or visual identification. Researchers compete on the basis of these records—not on new products or revenue numbers—and when one sets a new record, he or she wants to be recognized and receive credit for the achievement. But given the rapid pace of improvements, many researchers fear that if they wait to publish in a journal, their record will already have been eclipsed and their moment at the cutting edge will go undocumented. So instead of sitting on that research, they opt for instant publication on websites like www.arxiv.org, an online repository of scientific papers. The site lets researchers instantly time-stamp their research, planting a stake in the ground to mark the "when and what" of their algorithmic achievements.

In the post-AlphaGo world, Chinese students, researchers, and engineers are among the most voracious readers of arxiv.org. They trawl the site for new techniques, soaking up everything the world's top researchers have to offer. Alongside these academic publications, Chinese AI students also stream, translate, and subtitle lectures from leading AI scientists like Yann LeCun, Stanford's Sebastian Thrun, and Andrew Ng. After decades spent studying outdated textbooks in the dark, these researchers revel in this instant connectivity to global research trends.

On WeChat, China's AI community coalesces in giant group chats and multimedia platforms to chew over what's new in AI. Thirteen new media companies have sprung up just to cover the sector, offering industry news, expert analysis, and open-ended dialogue. These AI-focused outlets boast over a million registered users, and half of them have taken on venture funding that values them at more than $10 million each. For more academic discussions, I'm part of the five-hundred-member "Weekly Paper Discussion Group," just one of the dozens of WeChat groups that come together to dissect a new AI research publication each week. The chat group buzzes with hundreds of messages per day: earnest questions about this week's paper, screen shots of the members' latest algorithmic achievements, and, of course, plenty of animated emojis.

But Chinese AI practitioners aren't just passive recipients of wisdom spilling forth from the Western world. They're now giving back to that research ecosystem at an accelerating rate.

CONFERENCE CONFLICTS

The Association for the Advancement of Artificial Intelligence had a problem. The storied organization had been putting on one of the world's most important AI conferences for three decades, but in 2017 they were in danger of hosting a dud event.

Why? The conference dates conflicted with Chinese New Year.

A few years earlier, this wouldn't have been a problem. Historically, American, British, and Canadian scholars have dominated the proceedings, with just a handful of Chinese researchers presenting papers. But the 2017 conference had accepted an almost equal number of papers from researchers in China and the United States, and it was in danger of losing half of that equation to their culture's most important holiday.

"Nobody would have put AAAI on Christmas day," the group's president told the *Atlantic*. "Our organization had to almost turn on a dime and change the conference venue to hold it a week later."

Chinese AI contributions have occurred at all levels, ranging from marginal tweaks of existing models to the introduction of world-class new approaches to neural network construction. A look at citations in academic research reveals the growing clout of Chinese researchers. One study by Sinovation Ventures examined citations in the top one hundred AI journals and conferences from 2006 to 2015; it found that the percentage of papers by authors with Chinese names nearly doubled from 23.2 percent to 42.8 percent during that time. That total includes some authors with Chinese names who work abroad—for example, Chinese American researchers who haven't adopted an anglicized name. But a survey of the authors' research institutions found the great majority of them to be working in China.

A recent tally of citations at global research institutions confirmed the trend. That ranking of the one hundred most-cited research institutions on AI from 2012 to 2016 showed China ranking second only to the United States. Among the elite institutions, Tsinghua University even outnumbered places like Stanford University in total AI citations. These studies largely captured the pre-AlphaGo era, before China pushed even more researchers into the field. In the coming years, a whole new wave of young Ph.D. students will bring Chinese AI research to a new level.

And these contributions haven't just been about piling up papers and citations. Researchers in the country have produced some of the most important advances in neural networks and computer vision since the arrival of deep learning. Many of these researchers emerged out of Microsoft Research China, an institution that I founded in 1998. Later renamed Microsoft Research Asia, it went on to train over five thousand AI researchers, including top executives at Baidu, Alibaba, Tencent, Lenovo, and Huawei.

In 2015, a team from Microsoft Research Asia blew the competi-

tion out of the water at the global image-recognition competition, ImageNet. The team's breakthrough algorithm was called ResNet, and it identified and classified objects from 100,000 photographs into 1,000 different categories with an error rate of just 3.5 percent. Two years later, when Google's DeepMind built AlphaGo Zero—the self-taught successor to AlphaGo—they used ResNet as one of its core technological building blocks.

The Chinese researchers behind ResNet didn't stay at Microsoft for long. Of the four authors of the ResNet paper, one joined Yann LeCun's research team at Facebook, but the other three have founded and joined AI startups in China. One of those startups, Face++, has quickly turned into a world leader in face- and image-recognition technology. At the 2017 COCO image-recognition competition, the Face++ team took first place in three of the four most important categories, beating out the top teams from Google, Microsoft, and Facebook.

To some observers in the West, these research achievements fly in the face of deeply held beliefs about the nature of knowledge and research across political systems. Shouldn't Chinese controls on the internet hobble the ability of Chinese researchers to break new ground globally? There are valid critiques of China's system of governance, ones that weigh heavily on public debate and research in the social sciences. But when it comes to research in the hard sciences, these issues are not nearly as limiting as many outsiders presume. Artificial intelligence doesn't touch on sensitive political questions, and China's AI scientists are essentially as free as their American counterparts to construct cutting-edge algorithms or build profitable AI applications.

But don't take it from me. At a 2017 conference on artificial intelligence and global security, former Google CEO Eric Schmidt warned participants against complacency when it came to Chinese AI capabilities. Predicting that China would match American AI capabilities in five years, Schmidt was blunt in his assessment: "Trust me, these Chinese people are good.... If you have any kind of prejudice or concern that somehow their system and their educational system is not going to produce the kind of people that I'm talking about, you're wrong."

THE SEVEN GIANTS AND THE NEXT DEEP LEARNING

But while the global AI research community has blossomed into a fluid and open system, one component of that ecosystem remains more closed off: big corporate research labs. Academic researchers may rush to share their work with the world, but public technology companies have a fiduciary responsibility to maximize profits for their shareholders. That usually means less publishing and more proprietary technology.

Of the hundreds of companies pouring resources into AI research, let's return to the seven that have emerged as the new giants of corporate AI research—Google, Facebook, Amazon, Microsoft, Baidu, Alibaba, and Tencent. These Seven Giants have, in effect, morphed into what nations were fifty years ago—that is, large and relatively closed-off systems that concentrate talent and resources on breakthroughs that will mostly remain "in house."

The seals around corporate research are never airtight: team members leave to found their own AI startups, and some groups like Microsoft Research, Facebook AI Research, and DeepMind still publish articles on their most meaningful contributions. But broadly speaking, if one of these companies makes a unique breakthrough—a trade secret that could generate massive profits for that company alone—it will do its best to keep a lid on it and will try to extract maximum value before the word gets out.

A groundbreaking discovery occurring within one of these closed systems poses the greatest threat to the world's open AI ecosystem. It also threatens to stymie China in its goal of becoming a global leader in AI. The way things stand today, China already has the edge in entrepreneurship, data, and government support, and it's rapidly catching up to the United States in expertise. If the technological status quo holds for the coming years, an array of Chinese AI startups will begin fanning out across different industries. They will leverage deep learning and other machine-learning technologies to disrupt dozens of sectors and reap the rewards of transforming the economy.

But if the next breakthrough on the scale of deep learning occurs

soon, and it happens within a hermetically sealed corporate environment, all bets are off. It could give one company an insurmountable advantage over the other Seven Giants and return us to an age of discovery in which elite expertise tips the balance of power in favor of the United States.

To be clear, I believe the odds are slightly against such a breakthrough coming out of the corporate behemoths in the coming years. Deep learning marked the largest leap forward in the past fifty years, and advances on this scale rarely come more than once every few decades. Even if such a breakthrough does occur, it's more likely to emerge out of the open environment of academia. Right now, the corporate giants are pouring unprecedented resources into squeezing deep learning for all it's worth. That means lots of fine-tuning of deep-learning algorithms and only a small percentage of truly open-ended research in pursuit of the next paradigm-shifting breakthrough.

Meanwhile, academics find themselves unable to compete with industry in practical applications of deep learning because of the requirements for massive amounts of data and computing power. So instead, many academic researchers are following Geoffrey Hinton's exhortation to move on and focus on inventing "the next deep learning," a fundamentally new approach to AI problems that could change the game. That type of open-ended research is the kind most likely to stumble onto the next breakthrough and then publish it for all the world to learn from.

GOOGLE VERSUS THE REST

But if the next deep learning *is* destined to be discovered in the corporate world, Google has the best shot at it. Among the Seven AI Giants, Google—more precisely, its parent company, Alphabet, which owns DeepMind and its self-driving subsidiary Waymo—stands head and shoulders above the rest. It was one of the earliest companies to see the potential in deep learning and has devoted more resources to harnessing it than any other company.

In terms of funding, Google dwarfs even its own government: U.S. federal funding for math and computer science research amounts to less than half of Google's own R&D budget. That spending spree has bought Alphabet an outsized share of the world's brightest AI minds. Of the top one hundred AI researchers and engineers, around half are already working for Google.

The other half are distributed among the remaining Seven Giants, academia, and a handful of smaller startups. Microsoft and Facebook have soaked up substantial portions of this group, with Facebook bringing on superstar researchers like Yann LeCun. Of the Chinese giants, Baidu went into deep-learning research earliest—even trying to acquire Geoffrey Hinton's startup in 2013 before being outbid by Google—and scored a major coup in 2014 when it recruited Andrew Ng to head up its Silicon Valley AI Lab. Within a year, that hire was showing outstanding results. By 2015, Baidu's AI algorithms had exceeded human abilities at Chinese speech recognition. It was a great accomplishment, but one that went largely unnoticed in the United States. In fact, when Microsoft reached the same milestone a year later for English, the company dubbed it a "historic achievement." Ng left Baidu in 2017 to create his own AI investment fund, but the time he spent at the company both testified to Baidu's ambitions and strengthened its reputation for research.

Alibaba and Tencent were relative latecomers to the AI talent race, but they have the cash and data on hand to attract top talent. With WeChat serving as the all-in-one super-app of the world's largest internet market, Tencent possesses perhaps the single richest data ecosystem of all the giants. That is now helping Tencent to attract and empower top-flight AI researchers. In 2017, Tencent opened an AI research institute in Seattle and immediately began poaching Microsoft researchers to staff it.

Alibaba has followed suit with plans to open a global network of research labs, including in Silicon Valley and Seattle. Thus far, Tencent and Alibaba have yet to publicly demonstrate the results of this research, opting instead for more product-driven applications. Alibaba has taken the lead on "City Brains": massive AI-driven networks that optimize city services by drawing on data from video cameras,

social media, public transit, and location-based apps. Working with the city government in its hometown of Hangzhou, Alibaba is using advanced object-recognition and predictive transit algorithms to constantly tweak the patterns for red lights and alert emergency services to traffic accidents. The trial has increased traffic speeds by 10 percent in some areas, and Alibaba is now preparing to bring the service to other cities.

While Google may have jumped off to a massive head start in the arms race for elite AI talent, that by no means guarantees victory. As discussed, fundamental breakthroughs are few and far between, and paradigm-shifting discoveries often emerge from unexpected places. Deep learning came out of a small network of idiosyncratic researchers obsessed with an approach to machine learning that had been dismissed by mainstream researchers. If the next deep learning is out there somewhere, it could be hiding on any number of university campuses or in corporate labs, and there's no guessing when or where it will show its face. While the world waits for the lottery of scientific discovery to produce a new breakthrough, we remain entrenched in our current era of AI implementation.

POWER GRIDS VERSUS AI BATTERIES

But the giants aren't just competing against one another in a race for the next deep learning. They're also in a more immediate race against the small AI startups that want to use machine learning to revolutionize specific industries. It's a contest between two approaches to distributing the "electricity" of AI across the economy: the "grid" approach of the Seven Giants versus the "battery" approach of the startups. How that race plays out will determine the nature of the AI business landscape—monopoly, oligopoly, or free-wheeling competition among hundreds of companies.

The "grid" approach is trying to commoditize AI. It aims to turn the power of machine learning into a standardized service that can be purchased by any company—or even be given away for free for academic or personal use—and accessed via cloud computing platforms. In this model, cloud computing platforms act as the grid, performing complex machine-learning optimizations on whatever data problems users require. The companies behind these platforms—Google, Alibaba, and Amazon—act as the utility companies, managing the grid and collecting the fees.

Hooking into that grid would allow traditional companies with large data sets to easily tap into AI's optimization powers without having to remake their entire business around it. Google's TensorFlow, an open-source software ecosystem for building deep learning-models, offers an early version of this but still requires some AI expertise to operate. The goal of the grid approach is to both lower that expertise threshold and increase the functionality of these cloud-based AI platforms. Making use of machine learning is nowhere near as simple as plugging an electric appliance into the wall—and it may never be—but the AI giants hope to push things in that direction and then reap the rewards of generating the "power" and operating the "grid."

AI startups are taking the opposite approach. Instead of waiting for this grid to take shape, startups are building highly specific "battery-powered" AI products for each use-case. These startups are banking on depth rather than breadth. Instead of supplying general-purpose machine-learning capabilities, they build new products and train algorithms for specific tasks, including medical diagnosis, mortgage lending, and autonomous drones.

They are betting that traditional businesses won't be able to simply plug the nitty-gritty details of their daily operations into an all-purpose grid. Instead of helping those companies access AI, these startups want to disrupt them using AI. They aim to build AI-first companies from the ground up, creating a new roster of industry champions for the AI age.

It's far too early to pick a winner between the grid and battery approaches. While giants like Google steadily spread their tentacles outward, startups in China and the United States are racing to claim virgin territory and fortify themselves against incursions by the Seven Giants. How that scramble for territory shakes out will determine the shape of our new economic landscape. It could concentrate astronomical profits in the hands of the Seven Giants—the super-utilities of the AI age—or diffuse those profits out across thousands of vibrant new companies.

THE CHIP ON CHINA'S SHOULDER

One underdiscussed area of AI competition—among the AI giants, startups, and the two countries—is in computer chips, also known as semiconductors. High-performance chips are the unsexy, and often unsung, heroes of each computing revolution. They are at the literal core of our desktops, laptops, smartphones, and tablets, but for that reason they remain largely hidden to the end user. But from an economic and security perspective, building those chips is a very big deal: the markets tend toward lucrative monopolies, and security vulnerabilities are best spotted by those who work directly with the hardware.

Each era of computing requires different kinds of chips. When desktops reigned supreme, chipmakers sought to maximize processing speed and graphics on a high-resolution screen, with far less concern about power consumption. (Desktops were, after all, always plugged in.) Intel mastered the design of these chips and made billions in the process. But with the advent of smartphones, demand shifted toward more efficient uses of power, and Qualcomm, whose chips were based on designs by the British firm ARM, took the throne as the undisputed chip king.

Now, as traditional computing programs are displaced by the operation of AI algorithms, requirements are once again shifting. Machine learning demands the rapid-fire execution of complex mathematical formulas, something for which neither Intel's nor Qualcomm's chips are built. Into the void stepped Nvidia, a chipmaker that had previously excelled at graphics processing for video games. The math behind graphics processing aligned well with the requirements for AI, and Nvidia became the go-to player in the chip market. Between 2016 and early 2018, the company's stock price multiplied by a factor of ten.

These chips are central to everything from facial recognition to self-driving cars, and that has set off a race to build the next-generation AI chip. Google and Microsoft—companies that had long avoided building their own chips—have jumped into the fray, alongside Intel, Qualcomm, and a batch of well-funded Silicon Valley chip startups. Facebook has partnered with Intel to test-drive its first foray into AI-specific chips.

But for the first time, much of the action in this space is taking place in China. The Chinese government has for many years—decades, even—tried to build up indigenous chip capabilities. But constructing a high-performance chip is an extremely complex and expertise-intensive process, one that has so far remained impervious to several government-sponsored projects. For the last three decades, it's been private Silicon Valley firms that have cashed in on chip development.

Chinese leaders and a raft of chip startups are hoping that this time is different. The Chinese Ministry of Science and Technology is doling out large sums of money, naming as a specific goal the construction of a chip with performance and energy efficiency twenty times better than one of Nvidia's current offerings. Chinese chip startups like Horizon Robotics, Bitmain, and Cambricon Technologies are flush with investment capital and working on products tailor-made for self-driving cars or other AI use-cases. The country's edge in data will also feed into chip development, offering hardware makers a feast of examples on which to test their products.

On balance, Silicon Valley remains the clear leader in AI chip development. But it's a lead that the Chinese government and the country's venture-capital community are trying their best to erase. That's because when economic disruption occurs on the scale promised by artificial intelligence, it isn't just a business question—it's also a major political question.

A TALE OF TWO AI PLANS

On October 12, 2016, President Barack Obama's White House released a long-brewing plan for how the United States can harness the power of artificial intelligence. The document detailed the transformation AI is set to bring to the economy and laid out steps to seize that opportunity: increasing funding for research, stepping up civilian-military cooperation, and making investments to mitigate social disruptions. It offered a decent summary of changes on the horizon and some commonsense prescriptions for adaptation.

But the report—issued by the most powerful political office in the United States—had about the same impact as a wonkish policy paper from an academic think tank. Released the same week as Donald Trump's infamous *Access Hollywood* videotape, the White House report barely registered in the American news cycle. It did not spark a national surge in interest about AI. It did not lead to a flood of new VC investments and government funding for AI startups. And it didn't galvanize mayors or governors to adopt AI-friendly policies. In fact, when President Trump took office just three months after the report's debut, he proposed *cutting* funding for AI research at the National Science Foundation.

The limp response to the Obama report made for a stark contrast to the shockwaves generated by the Chinese government's own AI plan. Like past Chinese government documents on technology, it was plain in its language but momentous in its impact. Published in July 2017, the Chinese State Council's "Development Plan for a New Generation of Artificial Intelligence" shared many of the same predictions and recommendations as the White House plan. It also spelled out hundreds of industry-specific applications of AI and laid down signposts for China's progress toward becoming an AI superpower. It called for China to reach the top tier of AI economies by 2020, achieve major new breakthroughs by 2025, and become the global leader in AI by 2030.

If AlphaGo was China's Sputnik Moment, the government's AI plan was like President John F. Kennedy's landmark speech calling for America to land a man on the moon. The report lacked Kennedy's soaring rhetoric, but it set off a similar national mobilization, an all-hands-on-deck approach to national innovation.

BETTING ON AI

China's AI plan originated at the highest levels of the central government, but China's ambitious mayors are where the real action takes place. Following the release of the State Council's plan, local officials angling for promotion threw themselves into the goal of turning their cities into hubs for AI development. They offered subsidies for research, directed venture-capital "guiding funds" toward AI, purchased the products and services of local AI startups, and set up dozens of special development zones and incubators.

We can see the intricacy of these support policies by zooming in on one city, Nanjing. The capital of Jiangsu province on China's eastern seaboard, Nanjing is not among the top tier of Chinese cities for startups—those honors go to Beijing, Shenzhen, and Hangzhou. But in a bid to transform Nanjing into an AI hotspot, the city government is pouring vast sums of money and policy resources into attracting AI companies and top talent.

Between 2017 and 2020, the Nanjing Economic and Technological Development Zone plans to put at least 3 billion RMB (around $450 million) into AI development. That money will go toward a dizzying array of AI subsidies and perks, including investments of up to 15 million RMB in local companies, grants of 1 million RMB per company to attract talent, rebates on research expenses of up to 5 million RMB, creation of an AI training institute, government contracts for facial recognition and autonomous robot technology, simplified procedures for registering a company, seed funding and office space for military veterans, free company shuttles, coveted spots at local schools for the children of company executives, and special apartments for employees of AI startups.

And that is all in just one city. Nanjing's population of 7 million ranks just tenth in China, a country with a hundred cities of more than a million people. This blizzard of government incentives is going on across many of those cities right now, all competing to attract, fund, and empower AI companies. It's a process of government-accelerated technological development that I've witnessed twice in the past decade. Between 2007 and 2017, China went from having zero high-speed rail lines to having more miles of high-speed rail operational than the rest of the world combined. During the "mass innovation and mass entrepreneurship" campaign that began in 2015, a similar flurry of incentives created 6,600 new startup incubators and shifted the national culture around technology startups.

Of course, it's too early to know the exact results of China's AI campaign, but if Chinese history is any guide, it is likely to be somewhat inefficient but extremely effective. The sheer scope of financing and speed of deployment almost guarantees that there will be

inefficiencies. Government bureaucracies cannot rapidly deploy billions of dollars in investments and subsidies without some amount of waste. There will be dorms for AI employees that will never be inhabited, and investments in startups that will never get off the ground. There will be traditional technology companies that merely rebrand themselves as "AI companies" to rake in subsidies, and AI equipment purchases that simply gather dust in government offices.

But that's a risk these Chinese government officials are willing to take, a loss they're willing to absorb in pursuit of a larger goal: brute-forcing the economic and technological upgrading of their cities. The potential upside of that transformation is large enough to warrant making expensive bets on the next big thing. And if the bet doesn't pan out, the mayors won't be endlessly pilloried by their opponents for attempting to act on the central government's wishes.

Contrast that with the political firestorm following big bets gone bad in the United States. After the 2008 financial crisis, President Obama's stimulus program included plans for government loan guarantees on promising renewable energy projects. It was a program designed to stimulate a stagnant economy but also to facilitate a broader economic and environmental shift toward green energy.

One of the recipients of those loan guarantees was Solyndra, a California solar panel company that initially looked promising but then went bankrupt in 2011. President Obama's critics quickly turned that failure into one of the most potent political bludgeons of the 2012 presidential election. They hammered the president with millions of dollars in attack ads, criticizing the "wasteful" spending as a symptom of "crony capitalism" and "venture socialism." Never mind that, on the whole, the loan guarantee program is projected to *earn* money for the federal government—one high-profile failure was enough to tar the entire enterprise of technological upgrading.

Obama survived the negative onslaught to win another term, but the lessons for American politicians were clear: using government funding to invest in economic and technological upgrades is a risky business. Successes are often ignored, and every misfire becomes fodder for attack ads. It's far safer to stay out of the messy business of upgrading an economy.

SELF-DRIVING DILEMMAS

That same divide in political cultures applies to creating a supportive policy environment for AI development. For the past thirty years, Chinese leaders have practiced a kind of techno-utilitarianism, leveraging technological upgrades to maximize broader social good while accepting that there will be downsides for certain individuals or industries. It, like all political structures, is a highly imperfect system. Top-down government mandates to expand investment and production can also send the pendulum of public investment swinging too far in a given direction. In recent years, this has led to massive gluts of supply and unsustainable debt loads in Chinese industries ranging from solar panels to steel. But when national leaders correctly channel those mandates toward new technologies that can lead to seismic economic shifts, the techno-utilitarian approach can have huge upsides.

Self-driving cars make for a good example of this balancing act. In 2016, the United States lost forty thousand people to traffic accidents. That annual death toll is equivalent to the 9/11 terrorist attacks occurring once every month from January through November, and twice in December. The World Health Organization estimates that there are around 260,000 annual road fatalities in China and 1.25 million around the globe.

Autonomous vehicles are on the path to eventually being far safer than human-driven vehicles, and widespread deployment of the technology will dramatically decrease these fatalities. It will also lead to huge increases in efficiency of transportation and logistics networks, gains that will echo throughout the entire economy.

But alongside the lives saved and productivity gained, there will be other instances in which jobs or even lives are lost due to the very same technology. For starters, taxi, truck, bus, and delivery drivers will be largely out of luck in a self-driving world. There will also inevitably be malfunctions in autonomous vehicles that cause crashes. There will be circumstances that force an autonomous vehicle to make agonizing ethical decisions, like whether to veer right and

have a 55 percent chance of killing two people or veer left and have a 100 percent chance of killing one person.

Every one of these downside risks presents thorny ethical questions. How should we balance the livelihoods of millions of truck drivers against the billions of dollars and millions of hours saved by autonomous vehicles? What should a self-driving car "optimize for" in situations where it is forced to choose which car to crash into? How should an autonomous vehicle's algorithm weigh the life of its owner? Should your self-driving car sacrifice your own life to save the lives of three other people?

These are the questions that keep ethicists up at night. They're also questions that could hold up the legislation needed for autonomous-vehicle deployment and tie up AI companies in years of lawsuits. They may well lead American politicians, ever fearful of interest groups and attack ads, to pump the brakes on widespread self-driving vehicle deployment. We've already seen early signs of this happening, with unions representing truck drivers successfully lobbying Congress in 2017 to exclude trucks from legislation aimed at speeding up autonomous-vehicle deployment.

I believe the Chinese government will see these difficult concerns as important topics to explore but not as a reason to delay the implementation of technology that will save tens if not hundreds of thousands of lives in the not-too-distant future. For better or worse — and I recognize that most Americans may not embrace this view — Chinese political culture doesn't carry the American expectation of reaching a moral consensus on each of the above questions. Promotion of a broader social good — the long-term payoff in lives saved — is a good enough reason to begin implementation, with outlier cases and legal intricacies to be dealt with in due time. Again, this is not a call for the United States and Europe to mimic the techno-utilitarian approach utilized in China — every country should decide on its own approach based on its own cultural values. But it's important to understand the Chinese approach and the implications it holds for the pace and path of AI development.

Accelerating that deployment will feature the same scramble by local government officials to stand out on AI. Along with competing to attract AI companies through subsidies, these mayors and provincial governors will compete to be the first to implement high-profile AI projects, such as AI-assisted doctors at public hospitals or autonomous trucking routes and "city brains" that optimize urban traffic grids. They can pursue these projects for both the political points scored and the broad social upside, spending less time obsessing over the downside risks that would scare away risk-sensitive American politicians.

This is not an ethical judgment on either of these two systems. Utilitarian government systems and rights-based approaches both have their blind spots and downsides. America's openness to immigration and emphasis on individual rights has long helped it attract some of the brightest minds from around the world — people like Enrico Fermi, Albert Einstein, and many leading AI scientists today. China's top-down approach to economic upgrades — and the eagerness of low-level officials to embrace each new central government mandate — can also lead to waste and debt if the target industries are not chosen well. But in this particular instance — building a society and economy prepared to harness the potential of AI — China's techno-utilitarian approach gives it a certain advantage. Its acceptance of risk allows the government to make big bets on game-changing technologies, and its approach to policy will encourage faster adoption of those technologies.

With these national strengths and weaknesses in mind, we can construct a timeline for AI deployment and look at how specific AI products and systems are set to change the world around us.