4

The Innovation-Driven Development Strategy, 2015-Present

China launched a new wave of industrial policies in 2015-2016. The opening maneuvers in this new campaign were the important stand-alone plans, "Made in China 2025" and the "Internet Plus Program," both made public in 2015. Then, in May 2016, the government approved a new integrating vision, a kind of master plan, entitled the "Innovation-driven Development Strategy" (IDDS) (CCP Party Center and State Council 2016). At about the same time, the existing Strategic Emerging Industries (SEI) plan was reconfigured to make it more operational, coherent, and consistent with the IDDS. Thus, within a couple of years, China adopted a portfolio of industrial policies, tied together with a vision statement. This new wave of industrial policy was a new departure, because it was focused on an emerging technological revolution. It was also an acceleration of existing industrial policies, substantially stepping up the overall resource effort. The high-level policy commitment to the new strategy was accompanied by the launch of a new funding device, government industrial guidance funds.

The first section of this chapter looks at the technological orientation of the new cluster of policies. It is sometimes said that Chinese planners were shocked into recognizing the power and significance of artificial intelligence by the 2015-2016 games in which the AlphaGo Artificial Intelligence program triumphed over the world's top-ranked Go players. In this version of events, AlphaGo served as a kind of "Sputnik moment" for Chinese planners, many of whom consider the game of Go to be more complex and more subtle than chess, and were thus shocked that a program, designed in the West, could beat the world's best players.[1] The chronology shows that China was already ramping up new policies when the shock of AlphaGo occurred, but this event can still serve as a symbolic moment in the creation of a new policy package. Ultimately, it is the orientation toward an emerging technological revolution that most sharply distinguishes Chinese industrial policy today from all other cases of industrial policy. The following section sketches out the scale of resource effort in the new policies, arguing that the magnitude of the current wave is much larger than any precedents. The third section discusses the implied economic strategy of current policies. The two final sections consider the impact of 2020 "New Infrastructure" policies, and provide a preliminary economic evaluation.

4.1. Targeting a Technological Revolution

The technological conception behind the IDDS marks it off from earlier Chinese industrial policies (and indeed, from earlier industrial policy in Japan or Korea). As described in the preceding chapter, the initial drafts of industrial policy in 2006 targeted a limited range of technologies and laid out a fairly traditional agenda of industrial catch-up. The sixteen 2006 "megaprojects" were, generally speaking, straightforward attempts to replicate existing

1 The crucial event came in March 2016, when Korea's Lee Sedol, arguably the world number two player, lost 4 games to 1 to AlphaGo. AlphaGo was created by DeepMind, subsequently acquired by Google.

industrial capabilities in advanced economies. The large civilian airliner and the Beidou geographic positioning system are good examples. In this sense, the initial version of Chinese industrial policy was a reincarnation of the classic latecomer catch-up strategy. This approach has two obvious advantages. First, the technological solutions adopted in advanced economies can be copied, replicated, or, when necessary, worked around. There are a number of "latecomer advantages" that can possibly be exploited, ranging from the market for cheap knock-offs to incremental improvements. Most important, policy-makers have certainty that a certain type of production can be achieved, so risk is concentrated in a limited range of achievable cost and quality dimensions. Second, industrial policy-makers can use the developmental trajectories of advanced economies to identify industries that are ripe for promotion. Japan's MITI famously targeted industrial sectors where the income elasticity in the middle income range was greater than one, including automobiles and chemicals. The (correct) assumption was that Japan would replicate the structural transformations of early developers.

The SEIs began the break with a traditional approach. The entire conception of "Strategic Emerging Industries" as elaborated in 2010 was that China could get in on the ground floor of entirely new industries in which there were no powerful entrenched incumbents. In 2010, Chinese policy-makers began to speak of "occupying the commanding heights of the technology revolution."[2] Individual sectors seemed to offer the potential not just to catch-up, but to surpass the others. However, beyond this commonality of theme, the SEIs were a grab bag of sectors selected for hope-for breakout potential. There was no internal logic that tied individual sectors together; they included high-impact

2 This was in part due to the impact of the Global Financial Crisis (GFC). As part of their stimulus programs during the crisis, the advanced economies, including the U.S., targeted newly emerging industries, like solar energy, intelligent electric grid, and improved batteries. For Chinese policy-makers, this confirmed the potential significance of their long-sought goal of skipping stages and moving directly into new industries.

drugs and electric vehicles, along with mobile internet and oceanic machinery.

The IDDS, by contrast, is built around the idea that a very specific wave of technological change is beginning. The configuration of this wave of technological change thus gives increasingly a definite form to policy. It also means that, in the IDDS, the opportunity to move directly to the technological frontier and surpass other economies is no longer a wished-for feature of a few random sectors, but rather a fundamental feature of the current global moment. Increasingly, Chinese industrial policy is based on the idea that China has a once-in-a-lifetime opportunity to get in on the ground floor of a technological revolution and vault into the leading ranks of economic and technological powers. As the IDDS itself states:

> A new round of global technological revolution, sectoral change and military change is accelerating, and scientific exploration is unfolding at every scale from the microscopic to the cosmological. A group of revolutionary new technologies that are intelligent, green and ubiquitous are reshaping the global competitive landscape and changing the relative strength of nations (CCP Party Center and State Council 2016).

The changing "relative strength of nations" implies the opportunity to "surpass," as well as the danger of falling farther behind.

These technologies, jointly, are conceived of as a single "general purpose technology" that will be implemented across the board in society, improving productivity in many industrial sectors, as well as agriculture and services. These technologies are familiar to anyone who follows science and technology today. They are founded on the triangle of communication, data, and artificial intelligence. China is already by far the world's largest mobile internet market. Now the arrival of fifth generation (5G) communications technology provides enormous new capabilities for networked communication. To be sure, 5G is faster than 4G, making it more convenient and efficient. But even more important is the fact that 5G allows the seamless integration of local and global networks. This creates the opportunity for numerous local networks with a latency close-to-zero, which allows things like remote surgery in real time. These local networks are also critical for the development of driverless vehicles and truly intelligent traffic control networks. Data are increasingly being generated by massive networks of sensors of all kinds, from satellites to street cameras. As sensors proliferate, data proliferates at an exponentially greater rate, since each sensor creates an ongoing stream of data. Techniques to process data are improving by leaps and bounds, and artificial intelligence provides the opportunity not just to manage data, but also to derive higher level conclusions and interactions from patterns in the data. Together, the three clusters of communication, data and A.I. constitute a triangle of interacting capabilities that reinforce each other and create a single general purpose (GP) technology that has implications in every area of society and the economy.

Because of the emphasis on GP technologies and a coming technological revolution, IDDS is less specifically defined by individual industrial sectors than earlier waves of Chinese industrial policies. Progress in many sectors will contribute to the relative success of the IDDS, and overall progress will make success in individual sectors more likely. For example, more sophisticated robotics and smart networks will allow China's traditional industries to become more efficient, allowing them to retain competitiveness in an environment in which Chinese worker wages are rising rapidly. Alternately stated, the complementarity of many different sectors builds on China's strengths and gives China a unique opportunity. Section 4.6 provides further discussion of this strategy and the potential complementarity of different industries.

Despite this complementarity, IDDS retains the basic feature of previous industrial policies in that it explicitly targets a range of specific sectors and steps up the resource commitment to those sectors. In that sense, the *name* of the *innovation*-driven development strategy is rather misleading. Nearly every country has an innovation strategy, and almost everyone thinks innovation is a good thing, and therefore it might seem that China is simply doing what other countries do. For most countries, though, innovation strategy is predominantly a horizontal policy that aims at improving the environment for innovation and entrepreneurship in general, without targeting specific sectors. In fact, the components of IDDS make it clear that the definition of "innovation" in use corresponds to "technological upgrading." Josef Schumpeter long ago introduced the distinction between invention (a novel idea for how to do things) and innovation (carrying it out into practice). According to Edler and Fagerberg (2017:4) "what matters economically and societally is not the idea itself but its exploitation in the economic and social system… innovation is… the introduction of new solutions in response to problems or opportunities that arise in the social and/or economic environment?… in low-tech as well as high-tech."[3] By contrast, the official Chinese use of "innovation" almost always refers to "technological upgrading," in which highly qualified and credentialed personnel, working in sophisticated environments, are integrating more sophisticated procedures into the production process. Businesses that pioneer low-tech innovations, for example, bicycle-sharing (although that uses sophisticated internet-based interfaces) are not the focus of policy. While this is a broader, bolder, and more integrative industrial policy, it still relies primarily on the traditional industrial policy framework of industrial targeting.

4.2. A Key National Policy

The IDDS encompasses more sectors and more sectoral policies than China's previous industrial policies. Moreover, more attention is focused on the cross-sectoral impact of policies. As a result, the IDDS is expected to affect every aspect of society and the economy. This important feature is built into the policy design of the IDDS.

3 Edler and Fagerberg (2017) characterize innovation policies as mission-oriented, invention-oriented, or system-oriented. Chinese policies are a mix of all three.

4.2.1. A Portfolio of Policies with an Integrating Vision

The IDDS is an umbrella policy that includes many specific industrial policies as components. The "Industrial Policy Timeline" below shows both the "Made in China 2025" (State Council 2015/a; Wubbeke et. al 2015) and the "Internet Plus" (State Council 2015/b) policies preceding the IDDS, rolling out in 2015. Both these policies emphasize the application of new technologies to existing industrial sectors. "Made in China 2025" resembles Germany's "Industry 4.0" in its technological conception (though it is much larger in resource effort), calling for the integration of robotics, precision engineering, and ubiquitous sensors into "smart manufacturing" networks. These policies are highly actionable, and arguably represent a response to a new opportunity, that is, to introduce new general purpose technologies into traditional industries, where such technologies might not be well-known. The subsequent release, in May 2016, of the "Innovation-driven

Table 4.1: Industrial Policy Timeline

2005	11th Five Year Plan
2006	ML Term Science & Technology Plan
2010	Strategic Emerging Industries
2011	12th Five Year Plan
2015	Made in China 2025 Internet Plus
2016	IDDS National Plan SEIs 13th Five Year Plan
2017	Military-Civilian Fusion Plan Artificial Intelligence Plan AI 3-Year Action Plan
2018	Other 3-Year Action Plans Intelligent Photovoltaics; Intelligent Shipbuilding Cloud Computing; Information Consumption
2019	Internet and Services

Sources: own elaboration compiled by the author from data supplied by Zero2IPO / Qingke Research Center (清科研究中心). Accessed at https://www.pedata.cn/. Some data may be behind paywalls.

Development Strategy" (IDDS), was clearly an effort to integrate previously disparate strands of policy-making into an over-arching vision of technological change.

At the same time, the SEI program was revised to become a component of the broader IDDS. In November 2016, the Strategic Emerging Industries (SEI) Plan for the 13th FYP period (2016-2020) was issued. It contained broad targets for industrial sectors and dis-aggregated implementation tasks to numerous government agencies (State Council 2016).[4] Moreover, the new SEI plan called for close coordination with the slightly earlier Made in China 2025 and Internet Plus plans, as well as with the Military Civilian Industry Fusion Plan that followed shortly thereafter (Xia and Li 2016). Within the SEI plan, five large sectors were designated for immediate action, while four large sectors are designated for "preparatory work for later action." Each of what we might call the Big 5 has a target for output value in 2020: IT industry (12 trillion RMB); high-quality industrial equipment (12 trillion RMB); bio and pharmaceuticals (8-10 trillion); new energy vehicles and clean energy (10 trillion); and digital media (8 trillion). The four sectors being nurtured for later do not have output targets: they are Space and Ocean Exploration; information networks; life sciences; and nuclear technology. The plan also includes a number of sections on the creation of industrial clusters.

Between 2015 and 2017, then, policy-makers sought to integrate existing initiatives and produced a full panoply of interlocking plans. The IDDS sat at the apex, with at least five major programs under its broad umbrella. Four of these were targeted sectoral plans, and the fifth, the SEI itself encompassed a broad range of production sectors. Clearly, the span of industrial policy was substantially increased by this complex of policies.

4 The SEI plan for the previous five-year period, adopted July 9, 2012, can be accessed at http://www.gov.cn/zwgk/2012-07/20/content_2187770.html.

4.2.2. Authoritative National Policy

The IDDS is an unusually authoritative document. Because China has a hierarchical governmental system, the exact level of government that issues a policy is of great importance. If a ministry issues a document, for example, it is not binding on other ministries.[5] The IDDS is issued jointly by the Communist Party Center and the government State Council, giving it the highest possible political imprimatur: this document is binding on everybody in the political system. The IDDS is thus far more authoritative than policies that are issued by the State Council alone, or else drafted by Ministries and promulgated by the State Council Office. In addition, the IDDS is designed for the long term. It is formulated in "three stages": becoming an "innovative nation" by 2020; relying on innovation for economic growth and emerging as a leading innovative nation by 2030; and becoming a technological superpower by 2050. It is not clear that these stages have much concrete significance, but together they consolidate the expectation that this is a long-term strategy, not to be subject to the short-term whims of policy-makers. It is also not accidental that 2050 is one year after the one-hundredth anniversary of the establishment of the People's Republic of China in 1949.

The long-term and highly authoritative character of the IDDS helps explain the relationship between IDDS and "Made in China 2025." News reports in the U.S. sometimes give the impression that all of Chinese industrial policy is part of "Made in China 2025." This is not precisely true, but really, no harm is done.[6] Made in China 2025 did indeed signal the roll-out of a far more intrusive, comprehensive, and well-funded approach to industrial policy in

5 Moreover, provinces have the same administrative rank as ministries. The relationship between provinces and ministries is more collaborative, and less competitive, than that between ministries, but ministries still cannot issue commands to provinces.

6 Indeed, one of the defenses of China's industrial policy often made is the assertion that Made in China 2025 has been misunderstood, and that it is a relatively low-level document that is not authoritative enough to impose binding targets on any specific industry. This is a half-truth.

China. Moreover, Chinese government sources themselves sometimes fall into the habit of referring to the whole complex of policies as the "manufacturing super-power strategy."[7] By contrast, as explained earlier, the title of IDDS is somewhat misleading because of the way the word "innovation" is used. In fact, the IDDS, as a portmanteau policy, includes all the specific components of the sectoral industrial policies. Thus, the title "Made in China 2025," rather accurately reflects the goals of the entire range of Chinese industrial policies.

4.2.3. Cycles and Waves of Policymaking

The timeline of industrial policy shows the impact of the five-year planning process as well, albeit not in a mechanical way. Toward the end of each five-year period (that is, in 2005, 2010, 2015, and 2020), an effort to evaluate and re-think the existing policy approach gets under way. This process usually doesn't culminate in a new plan until the next year, the first year of the new Five Year Plan period. Thus, we saw the IDDS and a new SEI plan in 2016, the first year of the 13th Five Year Plan. Concurrent with the Five Year Plan, though, individual ministries and agencies are preparing their own plans, and these are usually finalized after the main FYP is issued. Sometimes, a sector or area needs additional strategic elaboration, and this may well occur in the following year. Thus, it is not surprising to see the Military-Civilian Fusion Plan and the Artificial Intelligence Plan emerging in 2017.

This policy cycle is constantly being adapted to new realities, though. Since the IDDS, in 2016, led to a strategic reorientation across-the-board, other sectors are being led to re-think their approach. From 2018, therefore, this has led to urgent 3-year action

7 In Chinese, *zhizao qiangguo zhanlue.* For example, the National Development and Reform Commission (NDRC 2018) issued a call to "fully bring into play the core and leadership role of state-owned enterprises in realizing the innovation-driven development strategy and manufacturing super-power strategy."

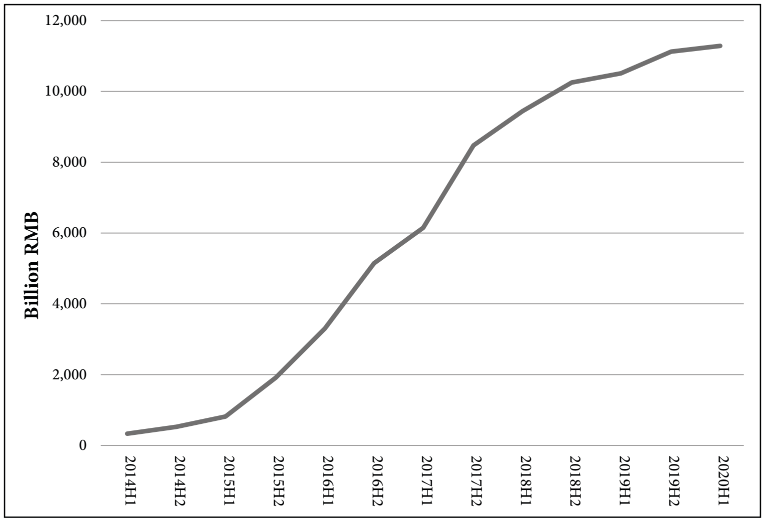
plans, essentially to bring the strategic guidance up to the end of the Five Year Plan in 2020. During 2020, as this is written, exercises are underway to evaluate the existing policy approach and suggest new guidelines for the 14th Five Year Plan (2021-2025). This plan will likely appear during 2021, and we do not have much indication, as of this writing, what changes will be made. However, under the dual impact of heightened strategic competition with the United States, and the disruption of the coronavirus pandemic, it is unlikely that any major shifts in direction will take place. When that plan is produced, it will serve as the foundation for scores of sectoral and regional Five Year Plans, which will be elaborated during 2021 and 2022.

4.3. Magnitude of the Policy

The preceding discussion implies that China is increasing its resources effort for industrial policy. This does indeed seem to be the case. It is extremely difficult to measure the total volume of resources going into Chinese industrial policy today. Resources flow through many channels, including direct investment by state-owned entities, tax breaks for R&D, as well as favored sectors and technology-intensive firms, regulatory preferences, and (usually short-term) protected markets. Policy instruments are discussed in the next chapter. Some are common instruments, used by many countries around the world. Others are unique, and exist only in the Chinese context. As it happens, one very large channel for industrial policy resources is a recent, distinctive invention of the Chinese government, the Government Industrial Guidance Funds.[8] The widespread introduction of this distinctive instrument coincides broadly with the roll out of the IDDS and can serve as an index of the increase in government effort associated with this third round of industrial policy.

8 Very little has yet been written about these funds (Huang 2019).

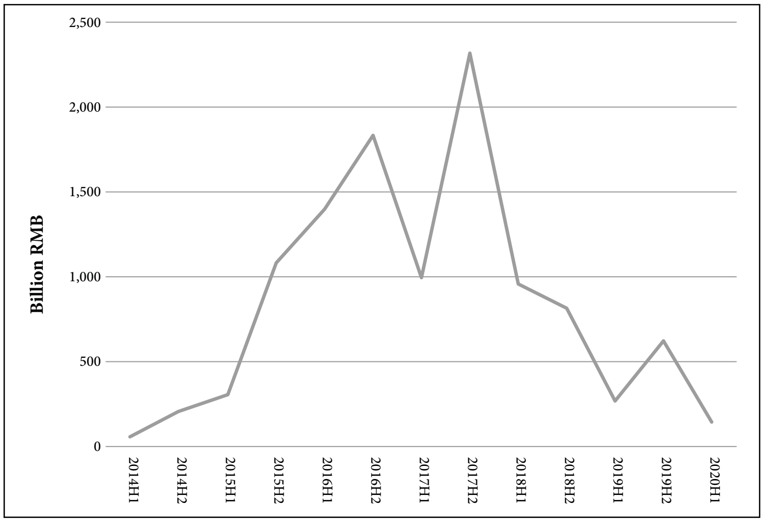
Figure 4.1: Government Industrial Guidance Funds: Cumulative Fund-Raising Scope



Sources: own elaboration compiled by the author from data supplied by Zero2IPO / Qingke Research Center (清科研究中心). Accessed at https://www.pedata.cn/. Some data may be behind paywalls.

As Figure 4.1 shows, Industrial Guidance Funds (IGF) took off after 2014. They grew rapidly through the end of 2018, and by June 30, 2020, the total designated fund-raising scope of all these funds was an astonishing 11,275 *billion* RMB —that is, 11.27 trillion RMB, or roughly USD $1.6 trillion. Figure 4.2 displays the time pattern of IGF development from a different perspective. A trickle of IGFs, starting in 2006, amounted cumulatively to only 317 billion RMB by the middle of 2014. Establishment of new funds then accelerated, and then took off in the second half of 2015, with over a trillion RMB in funds established in six-months, more than the cumulative total up until then. This extraordinary pace was sustained through the end of 2018, so that by that time a cumulative total of 10.2 trillion RMB (roughly USD $1.5 trillion) in IGFs had been established, representing over 11% of China's GDP. From the end of 2018, the pace of new fund establishment slowed substantially, even before the coronavirus in 2020. In three years, 2016 through 2018, China set aside well over a trillion dollars (8.3 trillion RMB) of fund-raising quota for IGFs.

Figure 4.2: New Government Guidance Funds: Designated Fund-Raising Scope



Sources: own elaboration compiled by the author from data supplied by Zero2IPO / Qingke Research Center (清科研究中心). Accessed at https://www.pedata.cn/. Some data may be behind paywalls.

To be sure, the numbers in the preceding figure represent the sum of the registered fund-raising plans of all of the IGFs. This is the first step in a process that includes actually raising the funds, and then making investments. Actual fund-raising lags behind plans, of course, and according to scattered 2019 press reports, amounts to about 60% of registered scope. Even so, that would be over 6% of GDP. There are substantial time-lags between when these programs are announced and when we expect them to have important economic effects.

The overall picture sketched by the numbers for IGFs is clear. Up until 2013 or 2014, China was making a substantial industrial policy effort, as indicated by the cumulative commitment to Megaprojects, SEIs, and other programs. Nonetheless, this effort was dwarfed by the resource commitment to the IDDS. Even if we confine our attention to the Industrial Guidance Funds, it is almost certain that the IDDS represents the greatest single commitment of government resources to an industrial policy objective in history. Moreover, many other instruments are in play, and it is likely that the resource effort suggested by their implementation has also increased since the inception of the IDDS. This IDDS seems to be a remarkable and unprecedented government effort.

4.4. Industrial Policy for a Technological Revolution: General Purpose Technologies

The inter-sectoral impacts of the IDDS are significant, but planners work with a fairly general conception of what those impacts will ultimately be, appropriately, since it is hard to predict specific applications. To understand how China's current industrial policy works, it is useful to look more concretely first at downstream sectors, where the new technologies will be applied, and then at upstream sectors that will produce high-technology inputs. A subsequent section looks at the relationship between China's industrial policy and the role of physical infrastructure investment.

4.4.1. Downstream: Three Areas of Application

The most attractive immediate applications of this new GP technology are in industry, transport, and military sectors. Industrial robots are already very important in the automobile and electronics industries, and they have the potential to spread much further. Indeed, the use of industrial robots and numerically controlled machine tools exemplifies a generation of industrial technology that has already been implemented in advanced economies, so-called "Industry 3.0." China is just a beginner in Industry 3.0, compared to countries like Germany, Japan and Korea which have already more-or-less universalized robots and digital control devices in automobile and electronics manufacturing. Now, China seeks to leapfrog into Industry 4.0, and join the leaders. This means creating, implementing, and integrating clusters of industrial robots tied together with intelligent networks in order to automate entire manufacturing processes. This will be a big jump for China's manufacturing industry, which has been until recently heavily dependent on China's low-cost labor and often undertakes labor-intensive processes in preference to more expensive capital-intensive processes. This jump is the focus of the "Made in China 2025" component of the IDDS.

Transportation looks well-placed to be fundamentally transformed by the new GP technology package. Even before true autonomous vehicles (AV), transportation efficiency should be improved by various "Smart Cities" technologies: tuning traffic lights to respond to changes in traffic flows, for example. Moreover, fleets of trucks can be dispatched far more efficiently when each vehicle is tracked by sensors and integrated into a complete logistic effort. China is comparatively well advanced in these efforts. Hangzhou, the headquarters of Alibaba, is a candidate to be the smartest city in the world. Alibaba's "City Brain" program provides several layers of intelligent networking to facilitate transport and emergency services in the city. China's very high rate of infrastructure investment obviously provides China enormous opportunities to be an "early adopter" of transportation-related smart technologies (Naughton 2020).

Military applications for the technology triangle are also potentially enormous, and deeply destabilizing. Ever since the US victory in the first Iraq War ("Desert Storm"– February 1991), it had been clear that a "revolution in military affairs" was occurring. Desert Storm technologies were like Industry 3.0, based on individual smart weapons, which only the US at that time possessed. Today's AI-enabled technologies create a range of difficult-to-foresee situations in the Industry 4.0-type networked battlefield, including such things as massive intelligent swarms of drones. The completion of one of China's Megaprojects, the Beidou global positioning system, means China has now put in place one essential building block of contemporary military technologies. The 35th and final satellite of the system was placed in orbit in June 2020, providing complete global coverage. Military aspects of industrial policy are outside the scope of this essay, but it should be acknowledged that military and strategic concerns are key drivers of industrial policy decisions. In China, that means that the Military - Civilian Indus-try Fusion Program is an important constituent element of the IDDS.

4.4.2. Upstream: Key Sectors for the Technology Triangle

While the new GP technologies have broad effects downstream on every sector, it remains true that their mastery requires control of certain specific industrial sectors. It is no accident that Made in China 2025, with its emphasis on industrial robots, was the first salvo of the IDDS. More broadly, though, two sectors are essential for the new technological revolution: semiconductors (integrated circuits) and artificial intelligence. The two are very different.

Semiconductors are essential for each of the vertices of the triangle. Modern communications depend entirely on semiconductors, especially three key types: the processing chips in phones and other end-use terminals; the communications chips that link terminals and networks; and the server chips that power the nodes in the communications networks. Other smart networks are analogous to the phone network. Modern data storage is carried out entirely on semiconductors, in the ubiquitous memory chips that make everything else possible. Artificial intelligence obviously requires processors to work at all, and specialized processors to implement distributed AI, that is, efficient, low-electricity chips that provide just-enough "intelligence" required to make special-purpose local intelligent networks feasible. It is fair to say that the emergence of the AI-triangle is the result of the long-term increase in capability and decline in cost of ICs, following the fifty-plus years of Moore's Law.[9]

Semiconductor production capacity is not widely spread throughout the world. A small number of "fabs" produce the most advanced of the actual physical chips, notably Taiwan Semiconductor Manufacturing Corporation (TSMC), Samsung, and Intel. An equally small number of chip designers define the frontier of the most sophisticated chips, including Intel (again), Qualcomm, Samsung, and China's Huawei. Production of semiconductor manufacturing equipment is likewise concentrated in a handful of firms —American, Japanese and Dutch. However, there has been, until recently, a relatively open and free global market in most types of integrated circuits. Thus, most producers have had relatively equal access to the components needed for most types of electronic manufacturing. China has long been uncomfortable with its position in this industry. Large-scale semiconductor production was the last state-invested project standing when Zhu Rongji reduced industrial policy, and semiconductors were the first priority sector included in the revival of industrial policy. At the same time, the US (and, importantly, Taiwan) maintain export controls on semiconductor production technology to China, designed to keep China about two generations (i.e., 2-3 years) behind the technology frontier. To China's frustration, despite the expenditure of enormous sums of money, that gap has not been narrowed over the past thirty years.

The AI sector is very different. Knowledge production is concentrated: Google is the global leader by quite a bit. However, breakthroughs in A.I. programs are quickly published and available to a global audience. Advances in machine learning have steadily democratized the field of artificial intelligence. Almost anybody can participate, although developing deep expertise in specific applications is of course still extremely difficult and time consuming.

9 Moore's Law refers to the observation made by Gordon Moore in 1965 that the number of transistors packed into a given space would double every two years, doubling processing power, and/or reducing costs by half. Since 1965, this doubling has occurred regularly in less than two years, leading to the observation being dubbed a "law."

However, there are few barriers that prevent an ambitious newcomer like China from advancing rapidly in A.I. It depends entirely on the quality of human resources and the support they get.

4.4.3. Chinese Strategy: Upstream and Downstream Together

The Chinese strategy in the face of the new technological revolution is to invest in both upstream and downstream applications. Industrial policy-makers tend to take the "value chain" as a unit of analysis. (Chinese policy-makers absorbed the lessons of Global Production Networks into their own industrial policy framework.) For example the National Government IC Guidance Fund invests in the best indigenous firms at each stage of the semiconductor value chain (design, fab, packaging, equipment). Their objective from early on has been to grow domestic capability for each of the stages of the industrial value chain. A massive flow of resources into investment in the upstream stages of the value chain —for example in semiconductor design and production— is designed to increase capability and develop domestic supply.

At the same time, Chinese policy-makers are actively working to expand demand. Chinese government investment in infrastructure and information control provides it with an important early source of demand. It is no accident that Chinese firms like Hikvision have jumped to the lead in facial recognition technology: they have a patient and generous customer in the form of Chinese security services. We have already mentioned the business opportunities presented by Chinese government investment in "Smart Cities" infrastructure. Moreover, policy-makers believe the China has a unique ability to combine unified management of the Internet, ubiquitous sensors, telecommunications and smart transport/city networks, along with artificial intelligence. The US may be ahead in every one of these individual sectors, but the prospect for the US combining management and control of these networks is virtually zero. Therefore, China has the potential to reap the overall benefits of these general purpose technologies, catapulting it into a position parallel to, or ahead of, the United States. At the same time, the negative externalities of these technologies in enabling enhanced government surveillance and top-down control are welcomed by the Chinese government and have so far evoked little opposition among Chinese citizens.

The breadth of the strategy means that it is easily adapted to bring in additional elements. As described earlier, the SEI program has been modified to bring it more smoothly into the IDDS framework. The SEI program now focuses on five large industrial sectors, IT industry; industrial machinery; bio and pharmaceuticals; new energy vehicles and clean energy; and digital media. These are mostly downstream sectors where the projected economic opportunities and benefits of the new GP technologies are likely to be largest and quickest to materialize. With the obvious exception of semiconductors, the SEIs are generally not the core sectors technologically, but rather early adopters of new technologies. To be sure, their strengthened industrial capacities will also contribute to cost-effective implementation of new GP technologies more broadly. Military-civilian industry fusion is another case where cross-sector spillovers are a key justification for the policy: in this case, government as customer drives the growth of entire industrial sectors, with spill-on from civilian industry to the defense sector.

4.5. The Latest Component: New Infrastructure

The wave of new general purpose technologies interacts strongly with the provision of new types of infrastructure. Communications networks are an obvious example, and the current build-out of 5G telecom infrastructure is the focus of a great deal of attention worldwide. Transportation infrastructure needs to be built, and perhaps more importantly, upgraded to take advantage of new technologies. Energy infrastructure needs to be converted into "smart grids," in order to increase efficiency and reduce risks, and to drive transition to cleaner fuels. Infrastructure is extremely expensive, and the pace at which infrastructure should be built and upgraded will be a major determinant of economic gains going forward.[10] China has sustained a very high rate of infrastructure construction for over twenty years, and now the global economic crisis created by the coronavirus pandemic provides both new opportunities and new challenges.

The global economic recession in 2020 in the wake of the coronavirus economic crisis caused a shift in the cost-benefit calculus with respect to Chinese infrastructure policy. New types of infrastructure were already an integral part of the current wave of industrial policies. As countries around the world responded to the coronavirus crisis with various kinds of stimulus, it was not surprising that China also contemplated a stimulus program, but one built around the provision of "new infrastructure." While use of the term goes back at least to the end of 2018, a tentative round of new policies —potentially quite large— emerged during the first half of 2020, in response to the virus-induced recession. It is important to distinguish between strictly-defined "new-style infrastructure" and the broader definitions that could be employed to justify a large stimulus program. A narrower definition was laid out by Wu Hao of the National Development and Reform Commission (NDRC) on April 20, 2020 (Yang 2020). By this definition, new-style infrastructure would consist of:

1. The information infrastructure (or digital infrastructure). The communications network, including 5G telecom base stations, the internet of things, industrial internet and satellite communications; new technology infrastructure, including

10 In the past, China lacked infrastructure across-the-board, so a strategy of building infrastructure out ahead of demand was technically rather easy to execute, as long as the resources could be found. Now that an interregional grid of high-speed rail and expressways is nearing completion, and modern cities have largely been built, the question of where and how much infrastructure to be built is much more difficult to answer appropriately. More local knowledge and decision-making is likely indicated to make these decisions appropriately.

A.I., computing, and Blockchain; and computing infrastructure, including data centers and processing centers.
2. Integrated infrastructure. This means upgrading traditional infrastructure with the addition of internet, big data, and A.I. Examples include intelligent transport networks and intelligent energy infrastructure.
3. Innovation infrastructure. Science, technology, development, and research facilities.

While the first of these categories is relatively well-defined, many different kinds of activity can be included in the second category, upgrading traditional infrastructure. Moreover, these are the real big ticket items, on which hundreds of billions of dollars can be spent. While that may be acceptable if stimulus is urgently needed, it may be wasteful in the long-term if plans are not carefully laid out. In fact, policy-makers also floated a list of seven major sectors of "new infrastructure" that is more concrete than the NDRC definition (Wind Consulting 2020). These included:

1. 5G base stations and networks
2. Data centers
3. Artificial intelligence
4. Industrial internet of things
5. Electric vehicle charging stations
6. Ultra-high voltage (UHV) electric transmission lines
7. Intercity rail transit and urban subways

It can easily be seen that the first four of these are easily within the scope of the IDDS framework outlined in this chapter. The fifth, electric vehicle charging stations, is an effort to provide a piece of electric vehicle policy that has often been missing (repeatedly called for but rarely implemented). The last two areas of traditional infrastructure present opportunities for "smart" upgrading, although simple solutions are not necessarily readily available.

The possibilities of "new infrastructure" are impressive, but it is not a cure-all. In the first place, there is disagreement on the scope of stimulus needed: some policy-makers are wary of the expansion of debt that would be required for a major effort in this area. Infrastructure planning has long lead-times, even in China, and building infrastructure is a much less effective way to get money into the hands of households than other policies. Even those committed to a large program are looking for ways to get private sector buy-in that would lower the cost for the government. Second, there are technological issues still to be overcome. While the electricity company has already spent billions on UHV transmission, the technology has by no means been proven to be superior to existing technologies, nor does the use of UHV transmission automatically imply that grids are "smart." Indeed, they may be the opposite of "smart," since they have the potential to destabilize the overall grid. There is thus substantial debate and uncertainty surrounding the size and concrete implementation of the "new infrastructure." However, the decisions made with respect to "new infrastructure" are likely to be important influences on industrial policy over the next few years. As Chapter 1 stated, infrastructure construction multiplies the impact of industrial policy choices.

4.6. The Broad Development of Industrial Policy and Economic Strategy

Comparing these descriptions in this and the previous chapter, it is easy to see a pattern in the way in which Chinese central government industrial policy has evolved. In 2006, industrial policy began tentatively, at the "top" of the economy and at the bottom, or grass roots. At the top, the MLP suggested a broad range of possible directions in which the economy could be nudged; while at the bottom, the Megaprojects were a relatively small number of expensive projects funded by the government. In the years since 2006, industrial policy has expanded out both from the top and the bottom. Industrial policy has moved into the middle, and now permeates industrial investment and technology space.

From the top, policy increasingly is backed up with real resources —substantial and growing financial and other resource flows— so that policy becomes a way for the government to steer the real economy. Policy has evolved from something we can characterize as either "development strategy" or "indicative planning," into something that is clearly "industrial policy." Central policy is no longer merely a statement about possible evolutionary trends, primarily providing information to decentralized actors. It is today a statement of government intent to achieve certain outcomes based on the new technology opportunity set. Those outcomes can be defined very precisely (as in Made in China 2025), or they can be defined very loosely ("occupy the commanding heights of the new technological revolution"), but they are meant to be taken seriously.

From the bottom, government intervention has expanded from a few fully-funded projects, to sectoral interventions, and now to the point that government has sectoral policies for virtually every industrial sector. There are lists of target technologies to be mastered in emerging sectors; and the government expends and indirectly controls substantial resources for bottom-up restructuring of a vast range of sectors. The number of plans has multiplied perhaps a hundred-fold (and certainly many times tenfold), considering all the sectoral plans that are promulgated in the wake of the national five year plans. Thus, the space in the middle —between broad policy and selective investment— has increasingly been filled with a complex but comprehensive set of government steerage policies.

At the same time, industrial policy has become more broadly conceptualized as the application of advanced technology to many industrial sectors. That is, policies like Made in China 2025 and Internet Plus clearly envisage the application of new technologies to a broad range of sectors, including traditional industrial sectors. The same is true for the Artificial Intelligence Action Plan adopted in 2017. This gives a greater sophistication to industrial policy that in and of itself would be welcome. Policies have spread across a broader spectrum of the economy, meaning they have the potential to be less selectively targeted, and more "horizontal," encouraging the diffusion of new technologies without prejudging specific applications. This evolution was driven in part by recognized shortcomings within the earlier waves of industrial policy, and particularly of the SEI plan as originally promulgated. In reviews of the policy conducted around 2014-2015, it was recognized that many unrealistic targets had been promulgated, and a great deal of money had been wasted, and that a somewhat more "horizontal" approach to innovation would be more efficient. It was conceivable that recognition of these problems might have driven industrial policy toward a less targeted approach, or a "lighter touch" industrial policy.

Instead, the excitement generated by the increasing recognition of the potential revolutionary impact of the cluster of new general purpose technologies drove policy towards a more activist and increasingly interventionist stance. This was essentially a historic coincidence that fed the growing perception that rather than individual sectoral opportunities (as in the SEIs), China in fact faced a more general opportunity presented by the new technological revolution. Thus, the recognition of the broad applicability of these GP technologies was accompanied by an increased sense of urgency, and even greater priority given to fostering these technologies. As a result, recognition of the broad applicability of new technologies has not been followed by a "lighter touch" approach to specific sectors, quite the contrary. It has led to the cumulative targeting of broad technological changes *and* specific sectors. For example, industrial robotics has been targeted even as upgrading of traditional industrial sectors has been emphasized.

The result has been a greater sophistication of industrial policy, combined with a much broader scope of industrial policies. Industrial policy now permeates the Chinese economic landscape. The conception of technological and economic upgrading is more sophisticated and potentially more cost-effective than ever before. However, this sophistication is to a certain extent offset by the fact that government interventions have become more intrusive and more pervasive. The increased amplitude of these interventions is likely to be more distortionary. Moreover, due to the sheer multiplicity of intervention, it is extremely difficult to discern the size or net impact of these interventions. The indirect costs, doubtless substantial, are diffused through the economy and hard to perceive.

A parallel process of broadening the scope of industrial policy is discernable with regard to the attitude of policy-makers toward private businesses. Today, policy-makers have no problems supporting private businesses as part of industrial policies. This pragmatism is driven in part by a basic reality: much of the expertise in artificial intelligence and operating smart networks lies in the private sector. Salaries and profits are high, and the likelihood that the government can attract the talent it needs away from companies like Alibaba and Tencent is very low. It is far better, from the government's standpoint, to enlist these private firms in the national effort. It is now clear to everybody that Alibaba, Baidu, Tencent, and Huawei are all parts of the "national team," and that they must comply with "government guidance" to continue to be successful. Realistically, private firms have little choice, and substantial opportunity to benefit if they go along. The government is quite happy to spend money to further its objectives, and does not object if some of the money increases the profits of high tech companies. Alibaba's founder and CEO Jack Ma has even said that if the nation wants his company, they can have his company, implying that he will follow guidance in just about every aspect.

Even in defense industries, new policies are designed to open up as much as possible to private companies. The guiding philosophy of Military-Civilian fusion is to encourage civilian and private firm participation in military contracting. The objective is to tap into civilian high-tech expertise to strengthen the defense sector, and this necessitates greater openness to private business. To be sure, the bulk of resources in the defense industrial sector are still controlled by state-owned enterprises (SOEs). This highlights an important fact: while policy is probably closer to neutral toward private firms than it has been, the overall impact of industrial policies still favors SOEs. This is because SOEs are more easily assigned "missions" and given resources in pursuit of national goals. There has been a great deal of rhetoric about the importance of SOEs and their role as part of the "national team" supporting the IDDS lately. This reflects reality. However, support has gone to private companies as well, and overall this is a potential strength of the IDDS (State Council Office 2017).[11]

4.7. Key Success Factors

Whether the Chinese approach makes sense will be determined by the strength of two offsetting factors. On the positive side, AI and related technologies are becoming "general purpose" technologies that will revolutionize all production. Technological convergence —the increasing overlap of the component technologies that offer productivity-improving solutions to a wide range of sectors— is an external, largely exogenous, factor that increases the potential payoff from industrial policy. A general purpose technology, such as electricity, is an advance that comes to be incorporated throughout the economy, driving up productivity growth for a generation or more. The occurrence of such an exogenous technological event strongly supports the fundamental rationale for industrial policy, which is that certain investments will generate spillovers (based on knowledge diffusion or other factors) that would not be captured by any private investor, and should thus be subsidized by government. As Pack and Saggi emphasize, "The ideal but rarely attained goal of industrial policy is the development of a general-purpose technology… [but] the discovery of such "general purpose technologies" is a rare event" (Pack and Kamal 2006:11). That means that the spill-over benefits (positive externalities) from these technologies are unusually large, potentially justifying government intervention to accelerate adoption.

11 This document specifically encourages private participation in railroad equipment, Internet Plus, Big data and robotics, on the ground that these sectors involve long and complex production chains. It also welcomes private participation in "Made in China 2025" demonstration zones and projects.

Whenever the technological externalities are larger and more significant, the case for government intervention is stronger. Market forces cannot be relied upon to produce optimal outcomes if the market cannot capture external economies. To the extent that a few key technologies might have economic benefits across a broad swathe of economic sectors, it may be reasonable for the government to promote those technologies. Certainly, this is what Chinese policy-makers are implicitly arguing. Moreover, because convergence in technologies is taking place, nobody is able to predict future technological configurations very well. The Chinese know they do not know what they are doing, but they are attempting to position themselves so that, when the revolution comes, they will have the skills to be a half step ahead, or at least not behind. Their gamble is that when new systems shake out, they will be well positioned to quickly adopt the most effective solutions, reap the productivity benefits, and develop newly competitive products and a more prosperous economy.

On the negative side, targeting industries at the technological frontier greatly increases risk and cost. There are no front-runners to emulate, and there is enormous uncertainty about which specific technological solutions will emerge as cost-effective and therefore dominant. There is significant risk of prematurely committing to a set of apparently superior technologies that are suddenly rendered obsolete by rapid technological change. It is worth stressing that China is not the science and technology leader in any of the component industries of the new technological revolution (with a few small, but important, exceptions such as quantum communications). It is hard to see that government targeting has any obvious advantages in a discrete case of industrial innovation. Indeed, it has generally been assumed that one of the reasons both Japan and Korea moved away from industrial policy when they did was that the importance and effectiveness of government targeting declined as their economies drew closer to the technological frontier. The task of developing specific technological solutions at the frontier was best diversified and left to individual companies. China's recent policy choices run in exactly the opposite direction, and completely counter to expectations based on the experience of forerunner economies (and industrial policy practitioners). The justification for this must lie almost entirely in whether or not there are complementarities among these emerging technologies which justify subsidizing early adopters.

It is conceivable that Chinese confidence in a new wave of transformative general purpose technologies will turn out to be wishful thinking. Past experience indicates that new GP technologies take decades to spread through the economy, and their impact often comes in ways that were poorly anticipated at the beginning. Whatever the future turns out to bring, China's current policy orientation will be extremely difficult to change, because it is backed by a strong enforced consensus. Overall, the IDDS is long-term and baked into a vast panoply of plans. It has been elaborated in many arenas, intertwined with various economic, military, and other objectives. The different approaches are like different "brands," that appeal to different constituencies, but are all part of a broad industrial policy initiative. To some constituencies, Military-Civilian Fusion is the most important component, a key to defensive strength. To other constituencies, research and the expansion of education are the most important components. Given the high degree of policy priority, and the strong interrelatedness between many aspects of these industrial policies, the whole complex is virtually impossible to change. Policy in China has a tendency to overshoot, generating destructive "great leaps." We cannot exclude that this will be the case with the IDDS as well. It is an enormous gamble, and the risk of overshooting is significant.

At the same time, as argued in Chapter 1, China is generally well positioned to be a global technological power. Many individual industrial policies may fail, and China may yet end up as a successful economy and a modern, influential global power. What is certain today, however, is that the process of China's emergence will be determined primarily by the interaction between an aggressive and interventionist government, on the one hand, and a robust business sector on the other, rather than through primarily market forces on their own. The gamble that China is taking today can best be understood in terms of the technological revolution. However, the probabilities of winning that gamble are likely more dependent on the specific instruments and policy tools that China adopts. That is the subject of the following chapter.

4.8. Conclusions

The adoption of the IDDS completed the dramatic transformation of Chinese industrial policy that began in 2006. China had already shown its willingness to adopt interventionist policies, and then to fund them generously. Now, China had found a broad and transformative rationale that further elevated the national significance of industrial policy. In this new conception, China's industrial policy had become part of a response to a technological revolution. Industrial policy was justified by the enormous potential externalities of a new general purpose technology. In a broader sense, it was also a way to combine China's vast human resources with traditional Chinese diligence and respect for education. As China's comparative advantage in (unskilled) labor-intensive manufacturing was fading, China hoped to move toward a new comparative advantage in high-skill and technology-intensive sectors. These broad and powerful rationales consolidated the support that top policy-makers were already giving to industrial policy, and put China firmly on a new path. Indeed, the attractiveness of this vision was such that it began to shape the type of institutions that China wanted to create. As the next chapter shows, the shaped of "economic reform" and institutional change has increasingly been shaped by China's industrial policy ambitions.