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Chinese Public AI R&D Spending: Provisional Findings

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Executive Summary

China aims to become “the world’s primary AI innovation center” by 2030.¹ Toward that end, the Chinese government is spending heavily on AI research and development (R&D). This memo provides a provisional, open-source estimate of China’s spending.

We assess with low to moderate confidence that **China’s public investment in AI R&D was on the order of a few billion dollars in 2018**. With higher confidence, we assess that **China’s government is not investing tens of billions of dollars annually in AI R&D**, as some have suggested.²

Significant data gaps prevent us from producing a more precise estimate of China’s spending at this time, especially with respect to defense R&D. However, our rough estimate and the underlying analysis do allow us to rule out higher estimates with moderate to high confidence.

Additional findings include:

- **China’s government probably isn’t dramatically outspending the U.S. government on AI R&D.** While we did not analyze U.S. AI R&D spending in any depth for this paper, our results indicate that China’s spending in 2018 was on the same order of magnitude as U.S. planned spending for FY 2020, as documented elsewhere.³
- **Chinese public AI R&D spending probably tilts heavily toward applied research and experimental development**, not basic research. This is consistent with China’s overall public R&D spending.⁴
- **China’s government may be investing a few billion dollars a year (at most) in private-sector AI activity through guidance funds**—essentially, state-backed venture capital funds. However, guidance fund spending is not properly considered R&D spending and is likely overstated, as we explain in Appendix 1.

This paper describes our analysis in detail. To estimate the Chinese government’s civilian R&D spending, we integrated spending figures from China’s Ministry of Finance with open-source data on two key Chinese science and technology (S&T) programs: the National Natural Science Foundation (国家自然科学基金委员会) research funding program and the

National Key R&D Programs (国家重点研发计划) initiative. Our estimate of defense R&D spending, which is rougher than our civilian estimate, is based on spending in the MOF data that is not attributed to specific line items; like other analysts, we presume at least some of this spending was military spending.⁵

Our findings rely on sparse and uneven open-source data, and our analysis involves many assumptions. Consequently, **our findings are preliminary**, as are the numerical figures we produced for various specific programs and sub-categories of R&D. These figures, which are compiled in Section 4, were calculated solely as inputs to a high-level, order-of-magnitude estimate and should not be cited on their own.

Deriving estimates of Chinese public investment in AI-related research and development is challenging for several reasons:⁶

- The information on Chinese public spending that is publicly available (e.g., Ministry of Finance annual reports) is often aggregated to present a high-level overview and does not specifically call out AI-related spending. Chinese defense-related public spending is particularly opaque as compared to civilian spending, or even compared to U.S. defense spending.
- Identifying AI-related spending requires a level of detail that is usually not found even in publicly available U.S. budgetary documentation—and is even rarer in publicly available Chinese documents.
- Even when a line of spending can be associated with AI, identifying the R&D portion of that spending is challenging. This is a problem even in U.S. government spending documents, where spending on an AI-enabled surveillance system (for example) is likely to include development and acquisition of surveillance platforms and supporting systems, spending on associated communications equipment, and pay for personnel and/or contractor support; the portion of spending that is AI-related research and development is rarely identified. The same problem occurs in Chinese documents.
- While the primary Chinese documents related to AI R&D spending are readily available and have been translated, a large corpus of Chinese documents remains untranslated—and may contain documents that have not yet been identified as relevant to this problem.

CSET plans to continue studying China's AI R&D spending and refining the estimates presented in this paper in the coming months. We will explore secondary sources of information on Chinese public spending on AI-related R&D, test proxy measures that can be used to confirm and refine the estimates here, and develop methods to better categorize AI and AI-relevant programs. CSET is also expanding its efforts to translate Chinese-language documents that may shed further light on Chinese public spending in general and AI-related R&D in particular.

We welcome feedback on our research agenda. Please contact Zachary Arnold (zachary.arnold@georgetown.edu) and Igor Mikolic-Torreira (Igor.MikolicTorreira@georgetown.edu) with any suggestions.

Section 1. Overview of methodology

Our analysis is based on aggregate “science and technology” (S&T; 科学技术) spending data from Section V of China’s 2018 Ministry of Finance (MOF) national expenditure report. We use these data to estimate civilian and military AI R&D spending, then add the two for an overall estimate of China’s AI-related public R&D spending in 2018.

For civilian spending, we isolate line items in MOF’s data corresponding to basic research, applied research, and experimental development. We then select representative public programs for these categories: National Natural Science Foundation of China (NSFC; 国家自然科学基金委员会) grant funding for basic research, and the National Key R&D Programs (NKP; 国家重点研发计划) initiative for applied research and experimental development. Next, we estimate the AI-related proportion of activity within each representative program (expressed as a range of plausible values). For the NSFC, we estimate this proportion using funded project descriptions and NSFC’s own statistics. For NKPs, we use project descriptions in NKP funding calls. Finally, we multiply these estimated AI-related proportions by MOF’s topline figures for basic research, applied research, and experimental development to estimate China’s total public investment in civilian AI R&D.

For military spending, we calculate the amount of S&T spending that was included in MOF’s topline figures but not described in MOF’s spending line items. Following prior scholarship, we presume this undisclosed spending may have been defense-related and about 60 percent R&D.⁷ Lacking data on the distribution of China’s defense R&D across technologies, we then assume that the AI-related proportion of defense R&D was about the same as it was for civilian spending. We then multiply that same proportion (expressed as a range) by the undisclosed spending in MOF’s data to estimate China’s total public investment in defense AI R&D.

We limit our analysis to a single year—2018—because of missing data in other years. Specifically, we rely on NKP funding calls to estimate China’s spending on applied research and experimental development, but we only have access to funding calls from a limited period of time.⁸ Future research efforts may include extending our analysis backward and forward in time using other sources.

Section 2. Estimating civilian R&D spending

To estimate overall Chinese civilian public spending on AI research and development, we begin with MOF's aggregate S&T spending figures.⁹ According to MOF, China's government spent 832.7 billion RMB (\$120.7 billion) on S&T in calendar year 2018.¹⁰ MOF divides this spending into several categories: basic research, applied research, "technical research and development" (技术研究与发展), administrative costs, "technological conditions and services,"¹¹ social science, S&T "popularization," and S&T "exchanges."¹² The first three categories correspond to basic research, applied research, and experimental development—commonly accepted sub-categories of R&D.¹³ We rely on MOF's categorizations¹⁴ and assume China's 2018 R&D spending was the sum of reported spending in those three categories: 436.7 billion RMB (\$63.3 billion).

MOF reports that China spent 64.9 billion RMB (\$9.4 billion) of this 436.7 billion RMB on basic research(基础研究), 175.7 billion RMB (\$25.5 billion) on applied research (应用研究), and 196.0 billion RMB (\$28.4 billion) on experimental development (技术研究与发展)¹⁵ in 2018.¹⁶ (Again, we rely on MOF's labels, but we caution that in some cases, MOF may draw different boundaries between these categories than U.S. or OECD standards.¹⁷) We select two specific Chinese government programs, the National Natural Science Foundation of China (NSFC)'s grant program and the National Key R&D Programs initiative, as proxies for these spending categories, and estimate the proportion of each proxy program's spending that was meaningfully related to AI. We then multiply those proportions by the total spending MOF reported in the relevant categories to estimate AI spending across all reported R&D.

Basic Research

To estimate the AI-related portion of the 64.9 billion RMB (\$9.4 billion) that MOF says China spent on basic research in 2018, we examine the grant program of one specific research agency, the National Natural Science Foundation of China (NSFC), for which project descriptions are available. We use NSFC grant funding to stand in for China's overall investment in basic research because the agency is China's largest funder of basic research and has historically tended to fund pre-commercial, scientist-led projects.¹⁸

We estimate the AI-related portion of the NSFC's 2018 grant funding two different ways; both give similar results.

First, we use the Dimensions academic grant database¹⁹ to estimate the proportion of funded grants that were related to AI. Dimensions includes detailed information for NSFC grants totaling \$3.8 billion in calendar year 2018,²⁰ roughly consistent with NSFC's own disclosures.²¹ A search across the titles and abstracts of these grants for keywords related to AI²² returned 1,268 grants, worth \$118 million altogether: that is, 3.1 percent of all Dimensions-tracked NSFC grant spending in 2018.²³

Second, we referred to NSFC's own analysis of its 2018 spending. According to NSFC, "general program" funding, or funding for its principal basic research program totaled 139 million RMB (\$20 million) for "AI" and 219 million RMB (\$30 million) for "automation."²⁴ NSFC spent 11.15 billion RMB (\$1.62 billion) across all general program areas in 2018.²⁵ Therefore, by NSFC's accounting, it directed 1.2 and 3.2 percent of its general program funding toward "AI" and "AI" plus "automation," respectively.²⁶

Measured two different ways, then, AI appears to comprise no more than a few percent of NSFC research spending in 2018. We assume this distribution was roughly representative of all basic research spending reported by MOF for 2018.²⁷ Under this assumption, we estimate that in 2018, China's public spending on basic research into AI was on the order of 1 to 3 percent of 64.9 billion RMB, MOF's topline figure for basic research—in other words, no more than about 2 billion RMB (\$290 million), and possibly as low as about 650 million RMB (\$90 million).

Applied research and experimental development

To estimate the AI-related portion of the 371.8 billion RMB (\$53.9 billion) that MOF says China spent on applied research and experimental development²⁸ in 2018, we examine a subset of this funding, the National Key R&D Programs, for which we have more detailed information. We assume that the proportion of AI-related funding for this subset applies to the overall applied research and experimental development budgets.

The National Key R&D Programs (also known as National Key Programs or NKPs) are publicly funded research and development initiatives that,

according to a recent European Commission report, “[reflect] a top-down and industry-university-research cooperation design which integrates basic research, technology application, demonstration and commercialization.”²⁹ Although some NKPs and NKP sub-projects entail some basic research, on the whole, we understand NKPs as efforts to develop scientific and technological solutions for practical problems of economic, political, and military importance, and to commercialize those solutions. As such, we consider NKPs to be a subset of MOF’s applied research and experimental development spending categories.³⁰

We estimated the AI-relevant portion of NKP spending by calculating the prevalence of apparently AI-relevant sub-projects within NKP funding calls. The central government designates NKPs and issues central funding for each NKP through open calls. These calls invite proposals from the public for specified sub-projects. With few exceptions, NKPs focus on broad domains of technological application. Some of these domains are broadly AI-related, such as “intelligent robots,” “IoT and smart cities,” and AI-enabled transportation.³¹ Other NKPs are not consistently focused on AI, but their funding calls include sub-project descriptions that appear to relate to AI or would be likely to involve AI tools. For example, the NKP on “service industry technology” includes a sub-project on “AI-based innovation and entrepreneurship service technologies.”³²

We estimated the AI portion of overall NKP spending in 2018 by using sub-project descriptions to measure the proportion of proposed sub-projects related to AI. This approach involves significant assumptions. First, we assume that NKP sub-projects are entirely AI-relevant or entirely not AI-relevant. Second, we assume the spending proposed in the calls we were able to review, ranging from October 2018 to August 2019, is representative of *actual* spending during calendar year 2018 (the spending year for our broader analysis).³³ We also assume the keywords used in brief, often vague sub-project descriptions shed light on actual activities that will be funded. Despite these assumptions, we believe our approach is an imprecise but reasonable first cut at the data. The information in NKP funding calls is more detailed and probably more reliable than data on other Chinese applied research and experimental development initiatives.³⁴

We began with a publicly available database of NKP funding calls.³⁵ We reviewed calls issued between October 26, 2018 and August 1, 2019—40

calls in total, corresponding to 13.6 billion RMB (\$1.97 billion) in proposed spending.³⁶ From the 594 sub-projects described, we compiled a subset of 303 sub-projects whose descriptions suggested any potential relation to AI.³⁷

Next, we isolated AI-relevant sub-projects. Because the sub-projects do not identify themselves as AI-related, we developed two alternative standards, one somewhat generous (representing an upper bound on AI-related spending) and the other rather strict (a lower bound).

For the generous, upper-bound standard, we designated sub-projects as AI-relevant if their descriptions or their corresponding NKP's descriptions used keywords related to artificial intelligence, "smart" systems, autonomy or robotics.³⁸ Under this generous standard, 85 sub-projects, or 14.3 percent of all sub-projects we reviewed, appeared AI-related.

For the stricter, lower-bound standard, we designated sub-projects as AI-relevant only if their descriptions (a) explicitly mentioned artificial intelligence or intelligent systems or (b) used keywords related to AI methods, such as neural networks.³⁹ Under this strict standard, only 22 sub-projects, or 3.7 percent of all sub-projects we reviewed, appeared to be AI-related.

However, the above calculations count sub-projects, not sub-project funding. Unfortunately, the funding calls don't indicate planned funding at the sub-project level. Lacking this information, we assume each sub-project within an NKP receives an equal share of the NKP's funding. Under this assumption, using the strict standard, AI-related projects accounted for 3 percent of NKP funds, and under the generous standard, 13 percent. However, much of the funding meeting the generous standard was associated with robotics, "smart" industry, or "smart" infrastructure projects; these likely involved significant spending on developing hardware and potentially little to none on core AI advances. Given the uncertainty over the distribution of funds to sub-projects, the gap between our strict and generous estimates, and the over-inclusiveness of our generous estimate, we simplify and round off our result: between 3 and 10 percent of proposed NKP spending in our sample of calls, assumed to be representative of actual 2018 NKP spending,⁴⁰ is AI-relevant.

We then further assume this NKP spending is representative of *all* of China's 2018 spending on applied research and experimental development, such that the same 3 to 10 percent proportion applies to that larger spending

pool.⁴¹ Under this admittedly crude assumption, China's government spent on the order of 3 to 10 percent of its 371.8 billion RMB outlays on applied research and experimental development. In other words, somewhere between 11 billion RMB (\$1.6 billion) and 37 billion RMB (\$5.4 billion)⁴² went toward applied research and experimental development in AI in 2018.

Proxies not chosen: SKLs and Megaprojects

Although we believe NSFC and the NKPs are reasonable proxies for the Chinese government's civilian R&D spending, other potential proxies exist. In 2014, China's State Council announced a reorganization of most centrally funded R&D initiatives into five "pillars:"

- the NSFC;
- NKPs;
- government "guidance funds" (政府引导基金), which are essentially state-backed venture capital funds;
- a "Megaprojects" (重大专项) program to accelerate innovation in a small number of industries deemed strategically important;⁴³ and
- a "Bases and Talents" (基地和人才) program to establish centrally supported labs and research teams.⁴⁴

As discussed above, we estimated the AI-related proportion of China's total civilian R&D spending using data from the NSFC and NKP only. We presume MOF's overall 2018 R&D figures, which form the basis of our estimates, account for all public R&D spending, including any R&D spending under the other three pillars. In other words, we believe our estimates cover AI R&D spending for all five pillars (to the extent they involved R&D) and any other civilian R&D funding sources, but we developed our estimate of the AI-related portion using data from only two of the pillars.

We chose not to use guidance fund, Megaproject, or Bases and Talents spending data to help infer overall proportions of AI-related R&D spending for several reasons. As we explain in Appendix 1, although guidance fund spending is significant, it is generally not R&D spending in any meaningful sense.⁴⁵ In contrast, Megaprojects do appear to involve genuine R&D activity to some degree, but public data on Megaproject spending are too limited and uneven for us to derive estimates of the AI-portion.⁴⁶ Likewise, there is scant public data on the initiatives within the Bases and Talents pillar.⁴⁷ The

best-documented of these initiatives, the State Key Laboratories (SKL) funding program for university and corporate research centers,⁴⁸ probably spent about 8.2 billion RMB (\$1.2 billion) in 2018, but it's not clear how this money was distributed.⁴⁹ This prevents us from credibly estimating the AI-related R&D proportion of recent SKL activity, and in turn, from using that estimate to infer the AI-relevant proportion of China's R&D efforts overall.⁵⁰

Consolidated estimates: civilian spending

Our estimates of China's public, civilian AI R&D spending in 2018 are as follows:

	Lower bound estimate	Upper bound estimate	Notes
Basic research			
Overall spending	64.9 billion RMB (\$9.4 billion)		<i>As reported by MOF for "basic research" (基础研究).</i>
AI-related proportion	~1 percent	~3 percent	<i>Based on NSFC grant data.</i>
Total AI-related spending	~650 million RMB (\$90 million)	~2 billion RMB (\$290 million)	
Applied research and experimental development			
Overall spending	371.8 billion RMB (\$53.9 billion)		<i>As reported by MOF for "applied research" (应用研究) and "technical research and development" (技术研究与开发).⁵¹</i>

AI-related proportion	~3 percent	~10 percent	<i>Based on proposed spending and sub-project descriptions in NKP funding calls.</i>
Total AI-related spending	~11 billion RMB (\$1.6 billion)	~37 billion RMB (\$5.4 billion)	
Total			
All civilian AI R&D spending, 2018	~11.7 billion RMB (\$1.7 billion)	~39 billion RMB (\$5.7 billion)	

Section 3. Estimating military R&D spending

China’s defense R&D budget is not public, so any estimates of Chinese military R&D in AI will necessarily be indirect and extremely imprecise.⁵² However, because the Chinese military has expressed a strong interest in adopting and investing in AI,⁵³ we have generated a rough bounding estimate.

As with our civilian R&D estimate, we begin with aggregate science and technology (S&T) spending data from MOF. According to MOF, China’s government spent 832.7 billion RMB (\$120.7 billion) on S&T in calendar year 2018. Of this sum, 523.9 billion RMB (\$75.9 billion) was attributed to specific line items, and 308.8 billion RMB (\$44.8 billion) was not.⁵⁴ Following prior scholarship by Sun and Cao (2014), we presume at least some of the undisclosed spending was military spending.⁵⁵ If *all* of it was military spending, which we consider highly unlikely, then China’s 2018 defense S&T spending could have reached 308.8 billion RMB (about \$44 billion).⁵⁶

Next, building on Sun and Cao’s analysis, we assume around 60 percent of this military S&T spending (60.9 billion RMB in 2011) went to R&D activities

according to generally accepted definitions.⁵⁷ If so, China may have spent as much as about 185 billion RMB (\$27 billion) on defense R&D in 2018.⁵⁸

Estimating the AI-relevant proportion of this spending requires still more speculation. The Chinese military’s strong interest in AI is well-known, but it is also advancing on many other technological fronts. At a minimum, we lack evidence that the military allocates significantly more or less of its R&D budget to AI than do civilian S&T agencies. Given this, we assume that like those civilian agencies we assessed in the previous section, China’s defense agencies spent several percent of their 2018 R&D outlays on AI-relevant projects—likely between 1 and 10 percent, as rough bounds. Under this assumption, we estimate China spent no more than about 19 billion RMB (\$2.7 billion) on AI-related defense R&D in 2018⁵⁹—and possibly much less, depending on how much of the unattributed S&T spending went to defense projects.

Section 4. Consolidated estimates

Our aggregate results are as follows:

Civilian AI R&D - basic research	~650 million RMB (\$90 million) to ~2 billion RMB (\$290 million) (low to moderate certainty)
Civilian AI R&D - applied research and experimental development	~11 billion RMB (\$1.6 billion) to ~37 billion RMB (\$5.4 billion) (low certainty)
Defense AI R&D - all	~1.8 billion RMB (\$300 million) to ~19 billion RMB (\$2.7 billion) (very low certainty)
Total AI R&D	~13.5 billion RMB (\$2.0 billion) to ~57.5 billion RMB (\$8.4 billion) (very low certainty)

Given the pervasive uncertainties and assumptions in our analysis, we urge readers not to draw anything from these figures other than rough orders of magnitude. Our ultimate conclusion is that **based on assumptions and**

inferences we consider plausible, we believe China’s government probably spent a few billion dollars—and at most, closer to 10 billion dollars—on AI-related R&D in 2018, with basic research comprising a small fraction of the total.

Given this finding, we believe it is highly unlikely that China is investing tens of billions of dollars per year in AI R&D, as other sources suggest.⁶⁰ Although our findings and assumptions are tentative, inferring tens of billions of dollars in annual R&D spending from publicly available data would require much more extreme assumptions.⁶¹

Appendix 1. Assessing Chinese guidance fund spending

Overview of the guidance fund mechanism

Guidance funds (政府引导基金) are central to the Chinese government's strategy for supporting strategic industries. In a typical guidance fund, a central or local government entity pledges a small amount of its own capital and solicits a much larger amount of "social capital" from private venture capitalists, larger companies, and state-owned enterprises and/or institutional investors. The resulting fund is invested directly into commercial ventures.⁶²

Chinese guidance funds are inspired by successful initiatives in other countries to foster new industries via government-backed venture capital, including the U.S.'s SBIC and In-Q-Tel programs and Israel's Yozma program.⁶³ Starting around 2014,⁶⁴ the central government has prioritized guidance funds as a means of state support for key industries, attempting to replace older, inefficient subsidies and heavy-handed state involvement in the private sector. By the end of 2018, there were more than a thousand announced guidance funds with committed capital of about \$584 billion and eventual funding targets amounting to more than \$1.7 trillion.⁶⁵

Local governments created most of these funds to support local industry and infrastructure rather than high technology. However, a number of large funds (both centrally and locally funded) purport to focus on AI and related industries, such as semiconductors and optoelectronics.⁶⁶

Guidance funds vs. R&D spending

We chose not to use guidance fund spending data to help infer overall proportions of AI-related R&D spending because generally, public investment in guidance funds is not directly comparable to public R&D funding. Guidance fund investments are not, to our knowledge, specifically earmarked for R&D, and the targets likely spend only a fraction of what they receive on R&D activities. In our view, guidance fund investment is analogous to equity investment in AI businesses by private investors. An apples-to-apples comparison between the United States and China that included guidance fund spending would have to include this type of investment, as well. While

such a comparison is beyond the scope of this paper, given the scale and maturity of the U.S. equity investment market and the preeminence of the U.S. tech industry, we expect it would favor the United States.

In addition, from a strategic perspective, the guidance fund mechanism may be less effective than direct R&D funding. First, the quantity of Chinese guidance fund investment is uncertain and routinely overstated. Guidance fund announcements generally assume private investors will match public funds several times over, but both the public seed capital and the follow-on private investments are often implausibly large⁶⁷ and routinely fail to materialize.⁶⁸ Many observers also overlook that whatever capital is raised is spent gradually, not all at once. Most funds are meant to spend their capital over a period of up to 10 years.⁶⁹

Second, guidance fund investments are often poor quality. Guidance funds attract “social capital” by foregoing a portion of the returns, and often take on most of the risk when investments fail. As a result, fund managers have strong incentives to invest in safe bets rather than high-risk startups whose success won’t enrich them or their supervisors.⁷⁰ Often, these funds’ capital goes toward larger, established companies or infrastructure projects like industrial parks.⁷¹ Large funds competing to invest in particular sectors often do so inefficiently. China is trying to put far more capital to work in its guidance funds than other countries have done in analogous programs. With such massive resources available to the market and a limited pool of talent and value to invest in, fund capital may inflate prices and crowd out sophisticated private investors, support low-value companies, or simply sit idle.⁷²

Estimating guidance fund investment in AI

Although they are not comparable to R&D investment, guidance funds are an important component of China's AI innovation strategy, and Western observers often refer to them—especially in the context of claims that China is dramatically outpacing the United States in public AI investment.⁷³

In reality, we believe guidance funds have directed far less public funding toward AI activity than is commonly believed. Because data is scarce, it's difficult to measure their actual spending, but given the centrality of guidance funds in China's innovation efforts and their frequent use (and misuse) in analyses of those efforts, we believe a rough estimate is worthwhile. As discussed below, we estimate Chinese central and local governments could have spent as much as several billion dollars on AI-related activity through guidance funds in 2018. But although uncertainties in the data prevent us from ruling out this upper bound, we suspect actual spending was probably less, and spending on meaningful AI research and development was a small portion of that amount.

To produce our estimate, we begin with a list of major guidance funds compiled from several sources.⁷⁴ We then manually isolate 48 funds that (as of late 2018) appeared to focus on AI, strategic technologies, or emerging technology in consultation with subject matter experts. The funding targets of these 48 plausibly AI-related funds totaled \$628 billion. But public reports suggest that, as of late 2018, China's guidance funds as a whole had raised no more than a third of their announced funding.⁷⁵ Assuming this was also true of the 48 AI-related funds, they likely managed no more than \$209 billion as of late 2018. (In fact, they probably managed less, since several of the funds were only announced in mid-2018.⁷⁶)

To estimate the portion of this capital pool that may have been invested in 2018, we use the relatively well-documented "Big Fund" for integrated circuits as a rough proxy.⁷⁷ In recent years, the Big Fund invested 20 percent of its capital each year⁷⁸—an unusually rapid rate compared to the typical guidance fund. If the 48 selected funds invested at a similar clip, which we consider unlikely, they would have invested about \$40 billion in 2018.⁷⁹

Finally, we estimate the portion of these funds invested in AI-related activity. As with China's public R&D support generally, most of the funds on our list aim to invest in a wide range of strategic technologies. Our best estimate, discussed above, is that China's NSFC and NKP programs spend several percent of their overall funding on AI. If we generously assume that China's guidance funds were about twice as focused on AI than the other funding streams, then they would have invested between two and eight billion dollars in AI-related business activity in 2018.⁸⁰

Again, we emphasize that this upper bound estimate—a product of very generous assumptions—is **not** an estimate of AI-related R&D spending (which would be a fraction of this at best). And as discussed above, even if guidance funds invested this amount in AI in 2018, the investment was probably allocated sub-optimally and crowded out private capital to some extent.

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Endnotes

¹ See Graham Webster et al., “Full Translation: China’s ‘New Generation Artificial Intelligence Development Plan’ (2017),” *DigiChina*, August 1, 2017, <https://www.newamerica.org/cybersecurity-initiative/digichina/blog/full-translation-chinas-new-generation-artificial-intelligence-development-plan-2017>.

² Most prominently, in 2018, U.S. Air Force General VeraLinn Jamieson stated: “[W]e estimate the total spending for artificial intelligence systems in China for 2017 was \$12 billion. We also estimate it will grow to at least \$70 billion by 2020.” See VeraLinn “Dash” Jamieson, speech at Air Force Association event, July 26, 2018, <https://www.afa.org/content/dam/afa/news-images/Jamieson%20Breakfast%20Transcript.pdf>. Although General Jamieson did not specifically refer to AI R&D or even public spending, and the methodology behind her estimate is not public, the \$70 billion figure is frequently conflated with public R&D spending in popular commentary. See, e.g., Dan Wood and Bradley Bowman, “America is in an AI fight for its life,” *The Hill*, July 31, 2019, <https://thehill.com/opinion/cybersecurity/455484-america-is-in-an-ai-fight-for-its-life> (“[I]t is estimated that China’s spending on AI will grow to at least \$70 billion by 2020. In contrast, the Pentagon reportedly plans to invest about \$4 billion in AI and machine learning research and development in fiscal year (FY) 2020.”); Oriana Pawlyk, “China Leaving US Behind on Artificial Intelligence: Air Force General,” *Military.com*, July 30, 2018, <https://www.military.com/defensetech/2018/07/30/china-leaving-us-behind-artificial-intelligence-air-force-general.html> (“While ‘great instigator’ Russia has the desire to do ambitious experiments with A.I., China already has the means. . . . For example, China is building several digital artificial intelligence cities in a military-civilian partnership to understand how A.I. will be propagated. . . . ‘We estimate the total spending on artificial intelligence systems in China in 2017 was \$12 billion. We also estimate that it will grow to at least \$70 billion by 2020,’ Jamieson said during an Air Force Association breakfast Thursday.”)

³ See, e.g., Michael Kratsios, speech at Center for Data Innovation Forum on AI, September 18, 2019, <https://www.datainnovation.org/2019/09/remarks-by-michael-kratsios-u-s-cto-at-center-for-data-innovation-forum-on-ai/> (announcing “nearly \$1 billion in non-defense AI R&D” across civilian federal agencies in the FY 2020 budget); Chris Cornillie, “Finding Artificial Intelligence Money in the Fiscal 2020 Budget,” *Bloomberg Government*, March 28, 2019, <https://about.bgov.com/news/finding-artificial-intelligence-money-fiscal-2020-budget/> (“The Defense Department plans to allocate \$4 billion toward artificial intelligence and machine learning R&D activities in fiscal 2020,” up from about \$1.4 billion in FY 2019).

⁴ See, e.g., Dennis Normile, “Surging R&D spending in China narrows gap with United States,” *Science*, October 10, 2018, <https://www.sciencemag.org/news/2018/10/surging-rd-spending-china-narrows-gap-united-states>.

⁵ See Yutao Sun and Cong Cao, “Demystifying central government R&D spending in China,” *Science* 345, no. 6200 (August 29, 2014): 1006-1008, <https://science.sciencemag.org/content/sci/345/6200/1006.full.pdf>

⁶ For a discussion of the difficulties of estimating these expenditures, and guidance on how to approach them, see Thomas J. Colvin et. al, “A Tentative Framework for Examining U.S. and Chinese Expenditures for Research and Development on Artificial Intelligence” (Institute for Defense Analyses, September 2019), <https://www.ida.org/research-and-publications/publications/all/a/at/a-tentative-framework-for-examining-us-and-chinese-expenditures-for-r-and-d-on-ai>.

⁷ This figure is borrowed from a recent analysis of nondisclosed central S&T spending by China’s defense agencies in 2011. Sun and Cao, “Demystifying central government R&D spending in China,” and supporting materials thereto (available at <https://science.sciencemag.org/content/sci/suppl/2014/08/27/345.6200.1006.DC1/1253479.Sun.SM.pdf>). Sun and Cao attribute 105.865 billion RMB in nondisclosed central S&T spending to China’s defense agencies in 2011, and estimate that 60.937 billion RMB of this spending, or 57.5 percent, was R&D.

⁸ See discussion at notes 34-37 and accompanying text.

⁹ See Section V of Ministry of Finance of China (MOF), “2018 National General Public Budget Expenditure,” http://yss.mof.gov.cn/2018czjs/201907/t20190718_3303195.html. China’s National Bureau of Statistics (NBS) also publishes data on R&D spending. Some analysts use NBS numbers, including the OECD in its analysis of China’s R&D activity. See “Gross domestic expenditure on R&D by sector of performance and source of funds,” OECD.Stat, Organisation for Economic Cooperation and Development, https://stats.oecd.org/Index.aspx?DataSetCode=GERD_SOF (reporting 2017 and 2018 government R&D numbers identical to the “government funds” for “expenditure on R&D” figures in section 20-1 of National Bureau of Statistics of China, 2017 China Statistical Yearbook (Beijing: China Statistics Press, 2017), available at <http://www.stats.gov.cn/tjsj/ndsj/2017/indexeh.htm> and National Bureau of Statistics of China, 2018 China Statistical Yearbook (Beijing: China Statistics Press, 2018), available at <http://www.stats.gov.cn/tjsj/ndsj/2018/indexeh.htm>); see also Jingping Li et al., 2018 “The Status Quo and Issues of R&D Statistics in China,” paper presented at 16th Conference of the International Association for Official Statistics, Paris, France, September 2018, http://www.oecd.org/iaos2018/programme/IAOS-OECD2018_Item_2-D-2-Gao-Guan-Li-Zhang.pdf (discussing NBS’s application of OECD reporting standards). We use MOF numbers instead for two reasons. First, MOF has published calendar year 2018 figures, but NBS figures are currently available through calendar year 2017 only. Second, MOF data provide a more detailed cross-section of government spending by category, helping us to extract potentially AI-relevant spending from aggregate numbers. See also Sun and Cao, “Demystifying central government R&D spending in China” (using MOF numbers). The topline NBS and MOF public R&D spending figures in 2017, the last year with data from both sources, differed by about 13 percent (349 billion RMB (\$50.6 billion) and 396 billion RMB (\$57.4 billion), respectively). Given this, we expect that our analysis would yield

roughly similar results if we had been able to use NBS numbers. For the 2017 MOF figure, see Section V of Ministry of Finance of China, “2017 National General Public Budget Expenditure,” http://yss.mof.gov.cn/qgczjs/201807/t20180712_2959592.html (total government spending in 2017 was 60.5 billion RMB (\$8.8 billion) on basic research, 157.6 billion RMB (\$22.8 billion) on applied research, and 178.0 billion RMB (\$25.8 billion) on experimental development, per the MOF’s definitions, or 396.2 billion RMB (\$57.4 billion) total). For the NBS figure, see National Bureau of Statistics of China, 2018 China Statistical Yearbook, Section 20-1 (reporting 349 billion RMB (\$50.6 billion) in “government funds” R&D expenditure in 2017).

¹⁰ This includes both local and central expenditures, as reported by MOF. We use a conversion rate of 6.9:1 USD here and elsewhere.

¹¹ We believe this term probably refers to S&T digital infrastructure, such as online platforms for sharing research between government and industry. According to MOF, the Chinese government spent 34.2 billion RMB (\$5 billion) on “technological conditions and services” in 2018. See MOF, “2018 National General Public Budget Expenditure.”

¹² MOF, “2018 National General Public Budget Expenditure.”

¹³ See National Center for Science and Engineering Statistics, *Definitions of Research and Development: An Annotated Compilation of Official Sources* (Alexandria, VA: National Science Foundation, 2018), <https://nsf.gov/statistics/randdef/rd-definitions.pdf>. From our review of MOF’s reports and related scholarship, we believe MOF’s “technical research and development” term, 技术与开发, is interchangeable with the Chinese phrase for “experimental development,” 试验发展. See, e.g., Zhu Yingchun 朱迎春, “创新型国家基础研究经费 配置模式及其启示” (“Basic Research Funds Model and Its Enlightenment of Innovation-Oriented Countries”), *中国科技论坛* (*Forum on Science and Technology in China*) 2018, no. 2 (2018): 20, <http://www.casted.org.cn/channel/download/vzyQNkqqW> (equating 基础研究, 应用研究和 技术与开发 collectively with “R&D”).

¹⁴ This is a simplifying assumption. China’s S&T and R&D accounting standards are not perfectly aligned with international standards, such as the OECD’s Frascati Manual. See, e.g., Normile, “Surging R&D spending in China narrows gap with United States.” The sub-allocations provided by MOF give us some confidence that the numbers reported for these categories include most of China’s “true” R&D spending and exclude to a significant extent S&T spending that is clearly not R&D. We also note that in 2017 (the last year that both agencies reported data), MOF’s topline numbers aligned fairly well with the National Bureau of Statistics R&D figures, which outside observers including the OECD consider credible. See discussion in note 9.

¹⁵ See discussion of this term in note 13.

¹⁶ See MOF, “2018 National General Public Budget Expenditure.”

¹⁷ See discussion in note 14.

¹⁸ NSFC does fund some applied research, however. See, e.g., Hepeng Jia, "China Reshuffles Science Governance," *C&EN*, April 25, 2018, <https://cen.acs.org/policy/research-funding/China-reshuffles-science-governance/96/i18>; see also "NSFC at a Glance," National Natural Science Foundation of China (NSFC), 2017, http://www.nsf.gov.cn/english/site_1/about/6.html ("Since its establishment, NSFC has comprehensively introduced and implemented a rigorous and objective merit-review system to fulfill its mission of supporting basic research, fostering talented researchers, developing international cooperation and promoting socioeconomic development."); Zhonghe Zhou and Weijie Zhao, "Funding System Reform for Excellence in Science: an Interview with Jinghai Li, President of NSFC," *National Science Review* 6, no. 1 (January 2019), <https://academic.oup.com/nsr/article/6/1/177/5304651>; MOF, "2018 National General Public Budget Expenditure" (listing about 30 billion RMB (\$4.3 billion) in "natural science funding" (自然科学基金), which may refer to NSFC, under basic research). However, recent bureaucratic reforms may shift this balance. See Jia, "China Reshuffles Science Governance."

¹⁹ See generally Christian Bode, Christian Herzog, Daniel Hook, and Robert McGrath, "A Guide to the Dimensions Data Approach," (Dimensions, April 2019), <https://www.dimensions.ai/resources/a-guide-to-the-dimensions-data-approach/>.

²⁰ Specifically, \$3.8 billion is the aggregate funding amount for grants in Dimensions that have NSFC as a funder and 2018 as the starting year. We assume that this amount was actually disbursed in 2018.

²¹ In a March 2019 statement, NSFC said that in calendar year 2018, it received 27.7 billion RMB (\$4 billion) from the government (the term used is "coordinated the use of financial resources" (统筹使用财政经费)) for grant activities, and actually spent 26 billion RMB (\$3.8 billion) in "direct funding" of research projects and an additional 4.7 billion RMB (\$700 million) in "indirect funding." See Zhang Qian, "自然科学基金委公布2018年资助账单," *中国青年报* (*China Youth Daily*), March 27, 2019, <http://www.nsf.gov.cn/publish/portal0/tab440/info75532.htm>. This 26-30.7 billion RMB (\$3.8-4.4 billion) range accounts for 40-47 percent of the 64.9 billion RMB (\$9.4 billion) in public basic research spending catalogued by the MOF in 2018.

²² The specific query: ("artificial intelligence") OR ("machine learning") OR (one shot learning) OR ("reinforcement learning") OR ("supervised learning") OR ("transfer learning") OR ("unsupervised learning") OR (zero shot learning) OR (computer vision) OR (natural language processing) OR (natural language understanding) OR (artificial neural network) OR (convolutional neural network) OR (recurrent neural network) OR ("deep learning") OR (generative adversarial network) OR ("graphical model") OR ("random forest") OR (restricted Boltzmann machine) OR (support vector machine)".

²³ 3.1 percent may be high; a manual review of the top grants by value reveals several that do not seem meaningfully related to AI, despite using one of our keywords. On the other hand, our search may miss papers that don't use our keywords but are meaningfully related to AI nonetheless.

²⁴ See “信息科学部面上项目近两年资助情况一览表,” NSFC, 2019, <http://www.nsf.gov.cn/nsfc/cen/xmzn/2019xmzn/01/06xx/index.html>. NSFC uses the term “general program” to refer to its main funding streams for basic research. General program spending accounted for about 40 percent of all NSFC spending in 2018. See NSFC, *National Natural Science Fund Guide to Programs 2019* (2019), 1, http://www.nsf.gov.cn/english/site_1/pdf/NationalNaturalScienceFundGuidetoPrograms2019.pdf (“direct cost” of general program spending was 11.15 billion yuan in 2018); MOF, “2018 National General Public Budget Expenditure” (total NSFC spending was about 30 billion RMB (\$4.3 billion) according to Ministry of Finance statistics). Other NSFC funding streams, including NSFC “key programs,” appear to also support significant basic research, but NSFC has not (to our knowledge) disclosed the “AI” and “automation” proportions of these streams.

²⁵ NSFC, “National Natural Science Fund Guide to Programs 2019,” page 33.

²⁶ That is, 139/1115 and (139+219)/1115, respectively.

²⁷ To test this assumption, we also searched the Dimensions database for 2018’s Chinese *publications* with the AI keywords listed in note 23, on the rough presumption that academic publication trends reflect public basic research funding from all sources over the preceding several years. According to our search, 3.2 percent of all Chinese academic articles published in 2018 included keywords related to AI in their titles or abstracts; in turn, we presume that roughly 3.2 percent of all of China’s public basic research funding went to AI in the several years prior to 2018. We think AI’s share has probably increased significantly since then; for example, additional Dimensions searches (using the same method and keywords outlined above) indicate that NSFC’s AI-related grant spending roughly doubled from 2014 to 2018. But even if 2018’s rate of AI-focused public basic research funding from all sources was somewhat higher than 3.2 percent, it would be on a similar order of magnitude with our rough “few percent” estimate derived from NSFC spending alone.

²⁸ As discussed above, MOF’s terminology for these categories differs from other authorities. See note 13.

²⁹ See “National Key R&D Programmes,” chinainnovationfunding.eu, European Commission, <http://chinainnovationfunding.eu/national-key-rd-programmes/>; “Interim Measures for the Management of National Key R&D Programmes,” chinainnovationfunding.eu, European Commission, June 28, 2017, http://chinainnovationfunding.eu/dt_testimonials/interim-measures-for-the-management-of-national-key-rd-programmes-2/.

³⁰ We also note that based on our review of NKP funding calls, individual NKP sub-projects generally have precise technical specifications, often including numerical targets of cost per unit, size, and efficiency of physical components, and scalability, speed, and reliability of algorithms and networks. A final type of target is scale of implementation, operationalized not just in papers published, but often in patent applications or implementations in a given industry. These targets demonstrate that NKPs are generally targeted at direct practical application, not blue-sky research. See also European Commission, “National Key R&D

Programmes” (NKPs “feature several well-targeted and defined objectives and deliverables to be achieved in a period ranging from three to five years”).

³¹ All three calls were announced on the MOST website on June 2019; see Ministry of Science and Technology of the People’s Republic of China (MOST), *科技部关于发布国家重点研发计划“智能机器人”等重点专项 2019 年度项目申报指南的通知*, 国科发资 [2019] 205号, June 14, 2019, <http://most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2019/201906/t20190621147261.htm>. Further details on these AI-related NKPs are provided in annexes to the announcement. On the Intelligent Robots 2019 call, see MOST, ““智能机器人”重点专项 2019 年度 定向项目申报指南,” 2019, <http://www.most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2019/201908/W020190801566650620304.pdf>, and “NKP – Intelligent robots (2019 annual call),” chinainnovationfunding.eu, European Commission, June 21, 2019, <http://chinainnovationfunding.eu/project/nkp-intelligent-robots-2019-annual-call-2/>. On the IoT and Smart Cities 2019 call, see MOST, ““物联网与智慧城市关键技术及示范”重点专项 2019 年度项目申报指南,” 2019, <http://most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2019/201906/W020190621571078438548.pdf>, and “NKP – IoT and smart cities (2019 annual call),” chinainnovationfunding.eu, European Commission, June 21, 2019, <http://chinainnovationfunding.eu/project/nkp-iot-and-smart-cities-2019-annual-call/>. On the Smart Transportation 2019 call, see MOST, ““综合交通运输与智能交通”重点专项 2019 年度项目申报指南,” 2019, <http://most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2019/201906/W020190621571077032479.pdf>, and “NKP – Comprehensive and intelligent transports (2019 annual call),” chinainnovationfunding.eu, European Commission, June 21, 2019, <http://chinainnovationfunding.eu/project/nkp-comprehensive-and-intelligent-transportation-2019-annual-call/>.

³² See MOST, ““现代服务业共性关键技术研发及应用示范”重点专项 2019 年度项目申报指南,” 2019 <http://most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2019/201906/W020190621571076252007.pdf>; “NKP – Modern service industry key technologies (2019 annual call),” chinainnovationfunding.eu, European Commission, June 21, 2019, <http://chinainnovationfunding.eu/project/nkp-modern-service-industry-key-technologies-2019-annual-call/>.

³³ At this time, we have no reliable data on actual NKP spending in 2018 and how it may have differed from proposed spending in our sample.

³⁴ We also note that our analysis only uses NKP spending figures to produce an AI-relevant proportion of spending, which we then apply to MOF R&D figures to obtain a dollar/RMB result. That is, the (budgeted, 2018-2019) NKP spending data isn’t directly included in our final result.

³⁵ See “Chinese Funding Database,” chinainnovationfunding.eu, European Commission, <http://chinainnovationfunding.eu/chinese-funding-database/>; on the source, see generally

"R&D and innovation funding in China: project introduction," chinainnovationfunding.eu, European Commission, <http://chinainnovationfunding.eu/rd-innovation-funding-china-project/>. The database is sponsored by the European Commission (EC) and the European Union. It draws on the original calls published by China's Ministry of Science and Technology. MOST publishes the original calls online, but they are difficult to locate and compile directly. From a cursory review of MOST's website, we believe the EC database is fairly comprehensive and rely on it here. Follow-on research efforts may entail a more comprehensive review of original MOST data.

³⁶ The August 2019 round of calls was the most recent round posted when we conducted our research; the October 2018 calls were the earliest collected by the EC. The EC states that projects receive final approval three to five months after calls are announced, so an exhaustive analysis of 2018-relevant NKP announcements would include project calls as far back as July or August 2017. See European Commission, "National Key R&D Programmes," at "project cycle and application process" (application deadlines are four to five weeks after tender publication, followed in one to two months by second-round evaluations, which are followed by project announcements after another one to two months).

³⁷ Specifically, we collected each sub-project whose description referred to artificial intelligence, "smart" technologies, computing-relevant hardware (e.g., integrated circuits and semiconductors), computer science, robotics, sensors, telecommunications, data acquisition, data analysis, telecommunications, technologies related to media, neurology, and modeling. We collected this sample, rather than all of the sub-projects in the EC database, in the interest of time. We plan to validate our sample-based result against all of the sub-projects, but given the breadth of the concepts we used to build our sample, we believe the sample includes essentially all sub-projects with a significant AI dimension.

³⁸ We used the following keywords: AI, intelligence, intelligent, smart, robot, robotic, robotics, autonomous, autonomy.

³⁹ We used the following keywords: AI, artificial intelligence, data mining, (intelligent OR intelligence OR smart) AND system, (intelligence OR intelligent OR smart) AND control. Consistent with our Dimensions keyword searches (see note 23), we also included a large number of machine learning keywords (including neural network, reinforcement learning, etc.), but these yielded zero search hits because the NKP sub-project headlines did not specify the desired technique. Example queries yielding zero hits: machine learning, one shot learning, reinforcement learning, supervised learning, transfer learning, unsupervised learning, zero shot learning, computer vision, natural language processing, natural language understanding, artificial neural network, convolutional neural network, recurrent neural network, deep learning, generative adversarial network, graphical model, random forest, restricted Boltzmann machine, support vector machine.

⁴⁰ See discussion in text accompanying note 34 above.

⁴¹ We believe this sub-assumption is reasonable for present purposes, since NKPs are a prominent R&D initiative, forming one of the so-called "five pillars" of central science and technology funding established by the State Council in December 2014. See "The reform of

the Chinese national STI funding system," chinainnovationfunding.eu, European Commission, <http://chinainnovationfunding.eu/the-reform-of-the-chinese-national-sti-funding-system/>

⁴² 175.8 billion RMB + 196.0 billion RMB = 371.8 billion RMB; 20 billion RMB is about 5 percent of 371.8 billion RMB.

⁴³ See generally 国家科技重大专项, MOST, accessed November 2019, <http://www.nmp.gov.cn/>.

⁴⁴ See European Commission, "The reform of the Chinese national STI funding system." Ongoing programs not covered by the "pillars" include the Thousand Talents recruitment program, some ministry-specific research programs, and core central funding for public research universities.

⁴⁵ Because of this, we expect guidance fund investment does not factor into MOF's R&D figures (and, in turn, it does not factor into our AI R&D estimates).

⁴⁶ Reported Megaproject funding has been extremely variable in recent years, and currently seems to be in a lull as the past batch of 2020-targeted Megaprojects reaches completion and the new 2030 Innovation Megaprojects are not yet underway. The 2030 New Generation Artificial Intelligence Megaproject, which announced 870 million RMB (\$126 million) in funding across up to 39 projects in October 2018, is indicative of China's growing interest in artificial intelligence, but there is little information available on spending for other Megaprojects; based on searches of the MOST Information System (<https://service.most.gov.cn/2019zr1/>) and the EU Commission's Program Database (<http://chinainnovationfunding.eu/chinese-funding-database/>), only a few Megaprojects seem to have reported spending in 2018. To the extent that the New Generation Artificial Intelligence Megaproject was in fact an outsize contributor to overall Megaproject spending in 2018, we expect the balance will shift significantly in future years as the new Megaprojects begin allocating funds. See generally "'2030 Megaproject' – New Generation Artificial Intelligence (2018 annual call)," chinainnovationfunding.eu, European Commission, October 12, 2018, <http://chinainnovationfunding.eu/project/2030-megaproject-new-generation-artificial-intelligence/>; MOST, 科技部关于发布科技创新2030—“新一代人工智能”重大项目2018年度项目申报指南的通知, 国科发资〔2018〕208号, October 12, 2018, http://www.most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2018/201810/t20181012_142131.htm.

⁴⁷ The Bases and Talents pillar incorporates a hodgepodge of pre-existing initiatives. See generally "The reform of the Chinese national STI funding system."

⁴⁸ See "Chinese State Key Labs," Datenna, July 17, 2014, <https://www.datenna.com/2014/07/17/chinese-state-key-labs/>; "China to have 700 national key labs by 2020," *China Daily*, June 6, 2018, <http://www.chinadaily.com.cn/a/201806/26/WS5b323775a3103349141deebf.html>.

⁴⁹ MOF reported R&D expenditures of about 8.2 billion RMB (\$1.2 billion) on “key laborator[ies] and related facilities” in 2018. MOF, “2018 National General Public Budget Expenditure.” We believe this mostly consists of SKL spending.

⁵⁰ A very crude estimate can be calculated from data compiled by Datenna, a Dutch research consultancy. In June 2018, Datenna collected names and descriptions of 230 SKLs from Chinese government and academic sources, particularly the Platform for the National Science and Technology Infrastructures at [escience.gov.cn](http://www.escience.gov.cn/) (inaccessible as of this writing; see archived versions in Chinese and English: <https://web.archive.org/web/20160112112259/http://www.escience.gov.cn/>; <https://web.archive.org/web/20150424041528/http://www.escience.gov.cn/eng/index.html>). Datenna’s source data is available at https://datenna.carto.com/tables/skl_297_entries_v1_final_version_on_june_06/public. On an informal review, fewer than 10 percent of the SKLs on Datenna’s list included AI-relevant keywords in their names or descriptions. This broadly corroborates our AI relevance estimates from NSFC and NKP data.

⁵¹ See discussion at note 13.

⁵² See generally “What does China really spend on its military?”, *China Power*, <https://chinapower.csis.org/military-spending/>.

⁵³ See, e.g., Kristin Huang, “Will China’s embrace of military AI trigger a new arms race?”, *South China Morning Post*, May 4, 2019, <https://www.scmp.com/news/china/military/article/3008745/will-chinas-embrace-military-ai-trigger-new-arms-race>.

⁵⁴ See MOF, “2018 National General Public Budget Expenditure.”

⁵⁵ Sun and Cao, “Demystifying central government R&D spending in China.”

⁵⁶ As discussed above, MOF’s figures include both central and local government spending. See note 9. The 308.8 billion RMB (\$44.8 billion) figure for presumed S&T spending includes 88 billion RMB (\$12.8 billion) in unattributed central S&T spending and 300 billion RMB (\$43.5 billion) in unattributed local S&T spending. Although Sun and Cao did not address unattributed local spending in their analysis, which was expressly limited to central government R&D activity, their inference about unattributed central spending could plausibly be applied to local spending as well, and our analysis does so in the interest of producing a comprehensive upper bound estimate. We also note that the allocation of some ‘local’ funds to defense would help explain the apparent stagnation of defense R&D over time. After accounting for inflation, Sun and Cao’s estimate of 105 billion RMB for the central government’s defense S&T spending in 2011 is considerably greater than the 88 billion RMB (\$12.8 billion) undisclosed in MOF’s 2018 central S&T spending numbers. See Sun and Cao, “Demystifying central government R&D spending in China,” and supporting materials thereto (available at <https://science.sciencemag.org/content/sci/suppl/2014/08/27/345.6200.1006.DC1/1253479.Sun.SM.pdf>). We think Chinese defense S&T spending probably hasn’t actually

shrunk overall since 2011. Instead, we suspect that at least some of MOF's unattributed local S&T spending in 2018 was defense-related.

⁵⁷ See Sun and Cao, "Demystifying central government R&D spending in China," and supporting materials thereto (available at <https://science.sciencemag.org/content/sci/suppl/2014/08/27/345.6200.1006.DC1/1253479.Sun.SM.pdf>) (estimating that 57.5% of central S&T spending by China's defense agencies in 2011 was R&D).

⁵⁸ Given Sun and Cao's estimate of 60.9 billion RMB of military R&D spending in 2011, this would imply that Chinese military R&D spending tripled in nominal RMB terms between 2011 and 2018, with an annualized growth rate of 17 percent. However, Chinese public R&D spending reported to the OECD roughly doubled in a similar period, growing at an annualized rate of about 12.7 percent between 2011 and 2017. For comparison, applying a 12.7 percent annual growth rate to the 2011 defense R&D spending identified by Sun and Cao would suggest Chinese military R&D expenditures of around 140 billion RMB (\$20.5 billion USD) in 2018.) Given this, the implied growth rate for military R&D seems within the realm of plausibility.

⁵⁹ That is, about 10 percent of 185 billion RMB.

⁶⁰ See discussion at note 2.

⁶¹ Consider, for example, that China's *total* reported public R&D spending in 2018 was about \$63 billion. See discussion in Section 2. Tens of billions of dollars in AI R&D spending would count for a very large portion of this figure, implying that China is either investing orders of magnitude more in AI than in other strategic technologies or massively underreporting its R&D spending. Neither scenario is likely: China is known to be investing heavily in a wide range of technologies, and its R&D reporting is widely considered plausible, albeit not fully aligned with international accounting standards. (If anything, the Chinese government's ongoing push to raise R&D investment would tend to cause overreporting, not underreporting.) See discussion at notes 9 and 14.

⁶² See, e.g., Tianlei Huang, "Government-Guided Funds in China: Financing Vehicles for State Industrial Policy," *Peterson Institute for International Economics*, June 17, 2019, https://www.piie.com/blogs/china-economic-watch/government-guided-funds-china-financing-vehicles-state-industrial-policy#_ftnref2.

⁶³ Lance Noble, "Paying for Industrial Policy," (GaveKal Dragonomics, December 4, 2018), <https://research.gavekal.com/gavekal-dragonomics> (copy on file with CSET).

⁶⁴ In December 2014, the State Council issued a plan to reform science and technology funding, establishing guidance funds as one of the "five pillars" of S&T support. See "The reform of the Chinese national STI funding system," chinainnovationfunding.eu, European Commission, <http://chinainnovationfunding.eu/the-reform-of-the-chinese-national-sti-funding-system/>.

⁶⁵ See Huang, "Government-Guided Funds in China"; Sophy Yang, "China's 2,041 Government Guidance Funds' Size Reaches \$530B: Report," *ChinaMoneyNetwork*, November 12, 2018, <https://www.chinamoneynetwork.com/2018/11/12/chinas-2041-government-guidance-funds-size-reaches-530b-report>.

⁶⁶ See, e.g., Huang, "Government-Guided Funds in China."

⁶⁷ See, e.g., Pan Yue, "China's \$798B Government Funds Redraw Investment Landscape, Here Are The Largest Funds You Must Know," *ChinaMoneyNetwork*, October 31, 2017, <https://www.chinamoneynetwork.com/2017/10/31/chinas-798b-government-funds-redraw-investment-landscape-largest-funds-must-know>. ("Very often, the aimed for 'total leveraged social capital' is so great that it would be impossible to achieve. For example, Hubei province's Yangtze River Industry Fund, currently the largest government guidance fund and a rare three-tier fund structure, is targeting RMB 1 trillion in total leveraged social capital. That is around one third of the whole province's 2016 GDP of RMB 3.2 trillion. Xinjiang Uyghur Autonomous Region PPP Government Guidance Fund is aiming to establish a RMB 100 billion fund-of-funds, and reach 'total leveraged social capital' of 'trillions of RMB,' while the province's 2016 GDP is less than RMB 1 trillion.")

⁶⁸ See, e.g., Yue, "China's \$798B Government Funds Redraw Investment Landscape."

⁶⁹ Noble, "Paying for Industrial Policy." Even the national "Big Fund" for integrated circuits took about five years to invest its initial endowment. See "China announces measures to boost IC industry," *ChinaDaily USA*, June 25, 2014, http://usa.chinadaily.com.cn/business/2014-06/25/content_17613997.htm (initial target size of 120 billion RMB in June of 2014); Zhao Jianwei, "国家大基金二期正募集千亿布局集成电路产业链," *Xinhua*, May 4, 2018, http://m.xinhuanet.com/ln/2018-05/04/c_1122781205.htm (by the end of 2017, three and a half years later, it had invested 81.8 billion RMB, or 61 percent of its initial endowment); Wei Sheng, "China's 'Big Fund' raises RMB 200 billion to fuel chip industry," *TechNode*, July 26, 2019, <https://technode.com/2019/07/26/chinas-big-fund-raises-rmb-200-billion-to-fuel-chip-industry/> (in July 2019, five years after its announcement, the fund received a second funding round). The "Big Fund" is a direct investment vehicle for the central government and is structured differently from guidance funds. However, it has been held out as a representative example and a success story for China's public investment efforts generally. See generally Li Tao, "How China's 'Big Fund' is helping the country catch up in the global semiconductor race," *South China Morning Post*, May 10, 2018, <https://www.scmp.com/tech/enterprises/article/2145422/how-chinas-big-fund-helping-country-catch-global-semiconductor-race>.

⁷⁰ Noble, "Paying for Industrial Policy." This risk aversion problem was also described in an August 2018 article about guidance funds from state news outlet *Xinhua*. See Xu Zhouchao, "国内共成立1171只政府引导基金 总目标规模达5.85万亿元," *Xinhua*, August 21, 2018, http://www.xinhuanet.com/fortune/2018-08/21/c_1123299570.htm.

⁷¹ Noble, "Paying for Industrial Policy."

⁷² See, e.g., Shuli Ren, "China's \$856 Billion Startup Juggernaut Is Getting Stuck," *Washington Post*, December 16, 2018, https://washingtonpost.com/business/chinas-856-billion-startupjuggernaut-is-gettingstuck/2018/12/16/7babccda-0186-11e9-958c-0a601226ff6b_story.html. This might be especially true of smaller and less developed provinces trying to move into AI. For discussion of many local governments' plans to foster AI development, including some smaller ones that seem less AI-ready, see Jaqueline Ives and Anna Holzmann, "Local governments power up to advance China's national AI agenda," *MERICCS Blog – European Voices on China*, April 26, 2018, <https://www.merics.org/en/blog/local-governments-power-advance-chinas-national-ai-agenda>.

⁷³ A representative example is Thomas H. Davenport, "China is overtaking the U.S. as the leader in artificial intelligence," *MarketWatch*, March 7, 2019, <https://www.marketwatch.com/story/china-is-overtaking-the-us-as-the-leader-in-artificial-intelligence-2019-02-27>.

⁷⁴ Our sources included Yue, "China's \$798B Government Funds Redraw Investment Landscape," and a May 2018 Chinese-language report by CCID Consulting (available at <http://xqdoc.imedao.com/164f00e92bb573fd4b9e6ce1.pdf>). We also used unpublished lists compiled by experts in contact with CSET. We augmented these published sources with funds collected from news reports and conversations with subject matter experts. The full list is on file with CSET and is available upon request.

⁷⁵ See Yang, "China's 2,041 Government Guidance Funds' Size Reaches \$530B: Report."

⁷⁶ See "Shanghai to set up multi-billion-dollar fund to develop AI," *China Daily*, September 18, 2018, <http://www.chinadaily.com.cn/a/201809/18/WS5ba0ade9a31033b4f4656be2.html> (Shanghai's 100 billion RMB AI guidance fund was announced in September 2018); Meng Jing, "Tianjin city in China eyes US \$16 billion fund for AI work, dwarfing EU's plan to spend US \$1.78 billion," *South China Morning Post*, May 16, 2018, <https://www.scmp.com/tech/innovation/article/2146428/tianjin-city-china-eyes-us-16-billion-fund-ai-work-dwarfing-eus-plan> (Tianjin's 100 billion RMB AI fund was announced in May 2018); MOST, "北京科创基金正式启动" ("Beijing Science and Technology Fund officially launched"), June 28, 2018, http://www.most.gov.cn/kjbgz/201806/t20180628_140332.htm (Beijing's 30 billion RMB science and technology innovation fund was announced in June 2018). Shanghai's AI fund began operations this August with only a tenth of its targeted \$15 billion in funding. See He Wei, "Shanghai launches AI investment fund," *China Daily*, August 31, 2019, <http://www.chinadaily.com.cn/a/201908/31/WS5d6a6bd3a310cf3e35568fc9.html>

⁷⁷ As noted above, the "Big Fund" is not a guidance fund, but has been held out as a representative example and a success story for China's public investment efforts generally. See discussion at note 69.

⁷⁸ See sources cited in note 69.

⁷⁹ That is, 20 percent of \$209 billion.

⁸⁰ That is, ~five to 20 percent of \$40 billion.