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Executive Summary

China has ambitions to become a global leader in artificial intelligence (AI). Accordingly, the Chinese government, at the central and local levels, has announced large planned expenditures to support AI activities. This, in turn, has led Western analysts to compare Chinese and U.S. expenditures on non-defense AI research. However, we are unaware of any persuasive discussion about whether such comparisons are credible, in light of uncertainties about the Chinese estimates. This document investigates publicly announced Chinese non-defense AI expenditures made through four funding mechanisms and assesses the comparability of each expenditure with U.S. Federal expenditures on non-defense AI research and development (R&D).

The four Chinese funding mechanisms are the National Natural Science Foundation of China (NSFC), National Key R&D Programs (NKP), Megaprojects, and Government Guiding Funds (GGF). They all are reported to support AI activities. Expenditure data for each of the funding mechanisms was gathered primarily from official Chinese government sources. For a Chinese expenditure to be comparable to U.S. Federal expenditures in AI R&D, it must be: made by the central government; focused on AI; focused on R&D; and likely that the Chinese government will actually provide the funds. To support assessments of these four criteria, we address eight critical aspects of each expenditure, which are based on a previously published report describing our methodology (Colvin 2019). The critical aspects are: depth of available data; source of the funds; final recipient of the funds; how the funds flow from source to recipient; the timeframe of the expenditure; any support for activities other than AI; any support for activities other than R&D; and potential evidence that the funding mechanism may not operate as advertised. To assess whether an expenditure is focused on AI, we developed and applied a heuristic based on the methodology used by the Networking and Information Technology Research and Development (NITRD) program, which was used for the official estimate of U.S. Federal non-defense AI R&D expenditures.

We identified $138 million in Chinese non-defense AI R&D expenditures from 2018 that are potentially comparable to U.S. expenditures on non-defense AI R&D. We found that publicly available data are only sufficient to make credible or partially credible comparisons under a set of narrowly scoped conditions. As summarized in the table below, using this narrow scope, only the NSFC expenditures can be credibly compared with U.S. non-defense AI R&D expenditures. Partially credible comparisons can be made with NKP and Megaproject expenditures. GGFs are the mechanism responsible

for the largest announced expenditures to support AI; however, GGF expenditures are not comparable with U.S. Federal Government expenditures. Our estimate of $138 million is a lower bound, taken from the sum of comparable and partially comparable expenditures; it does not include expenditures made primarily on adjacent R&D topics (e.g., robotics) that may also include an unspecified amount of AI R&D.

Our expenditure estimates are lower than others from the literature, when viewed as a percentage of total expenditures examined within each funding mechanism. The Center for Security and Emerging Technology (CSET) and Development Solutions Europe Ltd. (DSE) have also investigated Chinese expenditures on AI R&D through these four mechanisms. Our results and theirs are summarized in the table below. The focus of DSE's research was to demonstrate to European researchers that opportunities exist for them to apply for AI research funding from China; the expenditure amounts were not central to their thesis and were only roughly estimated. Compared to CSET, we investigated a larger pool of NSFC awards and found expenditures that are in line with their lower bound as a percentage of total expenditures—approximately 1 percent. For NKPs, we examined approximately 50 percent more total expenditures than CSET, yet we found substantially smaller expenditures on AI-focused R&D on an absolute basis. This difference is mainly due to our use of a heuristic for classifying R&D projects as AI, based on the definition used by the U.S. Federal Government to estimate non-defense AI R&D expenditures, instead of classifying projects as AI that claim to fund AI.

Comparison of Expenditures Found by Different Analyses for Each Funding Mechanism* in 2018. Dollar Values are Provided in Millions of USD.

Mechanism	Comparable	Expenditure	STPI	CSET	DSE
NSFC	Yes	AI Focused	$32	$18 – $54	$106
		Total Examined	$3,250	$1,663	-
		Percentage of Total	1.0%	1.1% – 3.2%	-
NKP	Partially	AI Focused	$24	$62 – $267	-
		Total Examined	$3,325	$2,056	-
		Percentage of Total	0.7%	3.0% – 13%	-
Megaproject	Partially	AI Focused	$82	$131	$131
		Total Investigated	$131	$131	$131
TOTAL		**AI Focused**	**$138**	**$211 – $452**	**$237**

* GGFs are not credibly comparable, but we estimate an upper bound of $6 billion for GGF investments in 2018. The GGF estimate is not listed above because the other STPI estimates are not upper bounds.

Considering the challenges of data availability associated with the funding mechanisms we have investigated, **we find that it is not possible to credibly estimate the amount of China's broader government expenditures on non-defense AI R&D**. We investigated funding mechanisms that publicly compete their awards; thus, they are among

the most transparent of Chinese funding mechanisms. Only NSFC and the NKPs make sufficient data publicly available to analyze their entire R&D portfolio. Data on expenditures for Megaprojects and GGFs are challenging to find; comprehensive data may not exist publicly. The NSFC and the NKPs are responsible for only about 10 percent of the $60 billion that the Chinese central and local government expended on non-defense R&D in 2018. Given the opacity of the publicly competed funding mechanisms, we find it unlikely that the remaining 90 percent of China's non-defense R&D portfolio can be analyzed at a similar fidelity as the 10 percent that we and CSET have investigated. Further, we have both investigated funding mechanisms where AI R&D is known to exist, which potentially biases any attempt at generalizing or extrapolating our results to the broader R&D portfolio of the Chinese government. For the above reasons, we find that the uncertainties associated with a *national-level* estimate of Chinese government expenditures on non-defense AI R&D would be too great to allow for a credible comparison with the total U.S. Federal expenditures on non-defense AI R&D.

Contents

1. Introduction

A. Background

China has ambitions to become a global leader in artificial intelligence (AI). The Chinese government, at the central and local levels, has announced large amounts of planned expenditures to support AI activities. It is challenging for Western analysts, media, and policy makers to understand the extent of these Chinese activities in support of artificial intelligence. The lack of credible information on Chinese government expenditures on AI research and development (R&D) can lead to confusion and uneven comparisons between Chinese and U.S. expenditures on AI, which in some cases have caused alarm among U.S. policy makers and observers.

For instance, the Tianjin Municipal Government has announced a $15 billion fund to support the development of the AI industry (Beijing Monitoring Desk 2018; Tianjin 2018). This announced expenditure has been compared unfavorably with historical U.S. Federal Government expenditures on AI R&D (Savage and Scola 2019). Such a comparison is likely to be misleading because, unlike the U.S. Federal Government expenditures with which it was compared, the announced expenditure from the Tianjin government does not appear to be annualized, focused on R&D, come from the central government, or consist of an actual outlay of money. It is not clear how much of the *planned* expenditures by the Chinese government is *actually* being expended, from where the money is coming (e.g., central government, local government, state-owned enterprises, or individuals), to whom the money is going, and on what the money is being spent.

B. Purpose

Western analysts have made comparisons between Chinese and U.S. Federal expenditures in AI; however, we are unaware of any persuasive discussions about whether such comparisons are credible. Information from Chinese government documents and reported in the Chinese media is often too poorly defined—in terms of timing, sources, and purpose—to support credible comparisons between U.S. Federal and Chinese central government expenditures on non-defense AI R&D. This document investigates a subset of publicly announced Chinese AI activities and assesses the comparability of each activity's expenditures with U.S. Federal expenditures on non-defense AI R&D. As part of the analysis, we estimate expenditure amounts for some Chinese activities, but our goal is not to estimate China's total expenditures on non-defense R&D for AI.

C. Methodology

This analysis *does not* attempt to provide a holistic look at Chinese AI activities and their associated expenditures. Instead, it dives deeply into the expenditures made by four R&D funding mechanisms for which data at the program or project level is publicly available and that can be used to explore the comparability of U.S. and Chinese expenditures on non-defense AI R&D. This chapter defines some of the concepts needed for this analysis, limits the scope to a small number of non-defense and competitively awarded sources of AI expenditures made by the Chinese central government, and then describes the analytic approach used to assess the comparability of U.S. and Chinese government expenditures.

1. Definitions and Scope

This section defines the concepts that will be used in our assessment of Chinese R&D expenditures for AI.

a. Definition of R&D

For this analysis to be useful to U.S. policy makers, a single definition needs to be employed and applied consistently to both U.S. and Chinese expenditures. We chose the Office of Management and Budget (OMB) and National Science Foundation (NSF) definitions because they are the basis for authoritative data on U.S. Federal Government and business expenditures on R&D, respectively.

OMB Circular A-11 states that "research and experimental development activities are defined as creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of people, culture, and society—and to devise new applications using available knowledge." The construction of Federal R&D facilities may be considered R&D expenditures if they "are necessary for the execution of an R&D program"; however, construction of other facilities, such as office space, is excluded (OMB Circular A-11). For businesses, the NSF's National Center for Science and Engineering Statistics (NCSES) defines R&D activities similarly. Like OMB, it also excludes construction of facilities that are not solely used for an R&D project. Further, NSF's definition also excludes product development[1] from being an R&D expenditure (NCSES 2018). In other words, if a company expends money to refine a service or product that it offers commercially and is doing so to meet an externally imposed requirement (potentially from a customer), then that is not considered an R&D activity.

[1] This is defined as "adaptation of an existing capability to a particular requirement or customer's need as part of a continuing commercial activity."

b. Expenditures on AI versus Other Research Areas

We recognize that many definitions of AI exist, which are the subject of debate (Tarraf et al. 2019). Because our goal is to explore the comparability of Chinese and U.S. expenditures on AI, we use the Networking and Information Technology Research and Development (NITRD) Program's recently released budget estimate for U.S. Federal non-defense expenditures on networking and information technology R&D, including AI (NITRD 2019). Using the NITRD definition to classify Chinese activities as AI helps to make an apples-to-apples comparison between U.S. and Chinese expenditures on AI.

In its budget estimate, NITRD defines 11 different Program Component Areas (PCAs) for which it estimates Federal expenditures. The PCAs are:

- AI - Artificial Intelligence;
- CHuman - Computing-Enabled Human Interaction, Communication, and Augmentation;
- CNPS - Computing-Enabled Networked Physical Systems;
- CSP - Cyber Security and Privacy;
- EdW - Education and Workforce;
- EHCS - Enabling-R&D for High-Capability Computing Systems;
- HCIA - High-Capability Computing Infrastructure and Applications;
- IRAS - Intelligent Robotics and Autonomous Systems;
- LSDMA - Large-Scale Data Management and Analysis;
- LSN - Large-Scale Networking; and
- SPSQ - Software Productivity, Sustainability, and Quality

The definition of the AI PCA is intimately tied to the definitions of the other 10 PCAs: "AI R&D advances the ability of computer systems to perform tasks that have traditionally required human intelligence; this includes R&D in machine learning, computer vision, natural language processing and understanding, intelligent decision support systems, and autonomous systems, as well as the novel application of these techniques to various domains, *where not principally covered by other PCAs*." Thus, to classify an expenditure into the AI PCA, one must also determine that the expenditure does not principally fall under one of the other 10 PCAs. Appendix A provides the official definitions of each PCA and a heuristic for operationalizing the NITRD definitions to classify Chinese expenditures as primarily supporting AI or not. An expenditure that is not classified with the AI PCA may nonetheless support some level of AI R&D. For example, the NITRD budget estimate for fiscal year 2020 identified $654.4 million of funding for projects within the AI PCA, while there was $319.1 million of further AI-focused funding in the other PCAs.

c. Sets of Economic Actors in China and the United States

Money for China's AI activities comes from a variety of sources. To make comparisons with the United States, an appropriate grouping of the sources of money should roughly mirror the sources of R&D expenditures in the U.S. economy. STPI views Chinese expenditures on AI as originating from the following three sets of actors: central government, local government, and enterprises. The corresponding sets of U.S. actors are Federal Government, non-Federal Government, and businesses, respectively.

China's central government has several branches that are partially analogous to the three U.S. Federal Government branches. Of concern for this report are the State Council and its subordinate organizations. The State Council includes the Ministry of Science and Technology (MOST), the Ministry of Industry and Information Technology (MIIT), and others. Expenditures made by the Chinese central government flow through the State Council and the ministries below it, similar to how most expenditures made by the U.S. Federal Government flow through the departments and agencies of the executive branch. Statements (e.g., policies) made by these bodies or their subordinates are considered authoritative and indicate central government involvement in any activities they have initiated.

We designate local governments as any mainland-Chinese government body that is not the central government. Provincial and municipal governments are considered local. They are grouped together because it is difficult and often impossible to separate their expenditures on R&D. Some municipal governments are placed in the same category as provincial governments, such as Beijing, Shanghai, and Tianjin. The analogous sector for the United States would be all government bodies that are not the U.S. Federal Government, e.g., State, municipal, and Tribal governments.

Private enterprises in China are similar in many ways to businesses in the United States, but state-owned enterprises in China exhibit substantial differences. A Chinese enterprise in which government ownership is substantial is called a state-owned enterprise (SOE). Although SOEs tend to seek profits, the government involvement creates incentives to support government policy objectives that override the pursuit of profits. Additionally, even private enterprises are subject to substantial influence from the Chinese government (McMahon 2018), a level of influence that is greater than the influence of Western governments on businesses in their countries. Because government money and influence are intimately tied to the operations of many Chinese enterprises, we recognize that at times expenditures by an SOE might be considered in some part a government expenditure.

For an analysis of Chinese expenditures, based on currently available data and with the caveats listed above, we find that it is better not to incorporate expenditures by SOEs on AI R&D into Chinese central government expenditures. It is difficult, if not impossible, to determine when a given SOE expenditure may be the result of coercion by the central

government or what fraction of that money should be counted as a government expenditure. An analysis that applies a non-zero percentage to enterprise AI R&D expenditures would require a justification for the fraction chosen for each SOE—probably even each expenditure made by each SOE. We found such an analysis infeasible. Consequently, for our analysis, we categorize Chinese enterprises, both private and state-owned, as being analogous to U.S. businesses.

d. Chinese Funding Mechanisms

In 2014, the State Council announced a reform and reorganization of China's innovation system (State Council of China 2015). The reform consolidated hundreds of overlapping, redundant, and underperforming science, technology, and innovation programs into five funding mechanisms (DSE 2018a). While these five funding mechanisms do not cover all Chinese expenditures on non-defense AI R&D, awards made through these mechanisms are publicly competed; thus, open-source data should exist for use in our assessment. The five funding mechanisms are:

- The National Natural Science Foundation of China, which is focused on basic and applied research;
- National Key R&D Programs, which are focused on highly-targeted R&D projects to improve the social and economic welfare of the people;
- National Science and Technology Megaprojects, which are focused on producing breakthroughs in key technologies;
- Guiding Funds, which provide capital to start-ups and growth-oriented small-and-medium enterprises to stimulate innovation and technology transfers; and
- The Bases and Talents Program, which encourages the creation of research centers and partnerships, and attracts talented scientists and engineers to work in China.

In this analysis, we investigate only activities whose expenditures are provided by the first four of the above funding mechanisms. The Bases and Talents mechanism is less centrally organized than the other four. Consequently, its associated data is so dispersed that a comprehensive analysis would have to be the subject of potential future work.

We have already noted that not all Chinese support for non-defense AI R&D flows through the four mechanisms within our scope. Other sources of R&D financial support may come from stable funding provided to research institutions (e.g., institutes within the Chinese Academy of Science and public universities), tax incentives, subsidies, and other mechanisms of which we are currently unaware. We have also excluded all defense-related funding mechanisms. These exclusions are justified because it is not our intention to produce a complete estimate of Chinese non-defense expenditures on AI R&D. These four

mechanisms provide sufficient coverage of Chinese activities to assess the comparability of U.S. and Chinese expenditures on AI R&D.

2. Analytic Approach

For each of the chosen funding mechanisms, STPI has attempted to gather all of the data available about expenditures made through those funding mechanisms in the central government's fiscal year[2] 2018. Our coverage may be imperfect; however, it appears to be broader ranging than the studies performed by Development Solutions Europe Ltd. (DSE) (DSE 2018b) and the Center for Security and Emerging Technology (Acharya 2019), which are the only other analyses of Chinese R&D expenditures on AI that we have identified. We use the following process to support our analysis.

a. Four Assessment Criteria

For a Chinese expenditure to be comparable to U.S. Federal expenditures in AI R&D, the Chinese expenditure must be made by the central government, focused on AI, focused on R&D, and viable. We determine whether there is sufficient publicly available information about Chinese expenditures through our chosen funding mechanisms to make the four assessments above. If an expenditure does not meet all four of those criteria, then it is judged to be not comparable to an actual U.S. Federal Government expenditure on AI R&D.

For the assessments about central government, AI-focused, and R&D-focused expenditures, we state qualitatively whether sufficient information exists to determine the central government's contribution to the expenditure, the degree to which the target of the expenditure is focused primarily on AI, and whether the expenditure is primarily supporting R&D. For the viability of the expenditure, we assign one of the following four assessments, listed in order of descending viability: actual, estimated, budgeted, or aspirational. An *actual* expenditure is one that is a matter of historical record; the money has been fully spent at the time it was reported in our data. An *estimated* expenditure is one that is likely underway and reported as being the amount that will be spent by the end of the current year. A *budgeted* expenditure represents the budget for an established program for the coming year as reported by a government source. Finally, an *aspirational* expenditure is one that has been announced but is of dubious reliability due to the timeframe or its source. For example, the reported expenditure for a new and yet to be established program would likely be classified as aspirational. Similarly, reported expenditures that are upper bounds on the expenditures made over the course of the program's lifetime would be classified as aspirational.

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[2] In China, the fiscal year and calendar year are equivalent.

This research was conducted in 2019. Because China uses the calendar year as its fiscal year, only expenditures from 2018 and earlier could be assessed as *actual*. Similarly, only expenditures from 2019 or earlier could potentially be assessed as *estimated*, depending on the date of our data points. *Budgeted* and *aspirational* expenditures may be assessed for any year, but generally would not apply to expenditures earlier than 2018, because *actual* expenditure information should exist.

b. Critical Aspects that Support the Assessments

To support the four assessments, we have gathered information on eight critical aspects about the expenditure's associated funding mechanism. For many critical aspects listed below, the subjunctive "would" and "should" are used to indicate the way the funding mechanism is described in policy documents. This is to highlight that the implementation of the mechanism may not fully align with the official descriptions of how it "should" work. The critical aspects are the answers to the following questions; does information exist from official Chinese government sources that can be used to determine:

What is the source, volume, and depth of the data available on expenditures? This is intended to illustrate the degree to which the publicly available data are comprehensive and authoritative. Additionally, a description of the available data will support more in-depth discussions of the subsequent seven critical aspects.

What entities would provide the money? The answer to this question is at least a list of the economic actors that are known or likely to contribute money as a part of this funding mechanism. This information is primarily used to assess whether the expenditure is a central government expenditure. The source of the money also has ramifications for the viability of the expenditure, as expenditures announced by the central government are more viable than those announced by local governments.

Who would be the ultimate recipients of the money? The minimal answer to this question is a list of the economic actors that are known or likely to be the intended beneficiaries of the expenditure. This answer can inform the degree to which an expenditure may be R&D focused; for example, a university is likely to spend grant money on research activities, while money provided to a private company may be used for product development or other non-R&D activities. In cases where the awarded entity is required to provide matching funding, knowing whether the recipients are central government organizations is required to properly estimate the full value of the central government's expenditure.

How does money flow from the source to the final recipient? Answers to this question will vary substantially by funding mechanism. Some funding mechanisms are straightforward, others require matching funds to be provided by the awardee, and one of the mechanisms investigated channels money from the central government to ultimate

recipients through one or more layers of non-governmental intermediary organizations. This critical aspect is relevant to assessing the viability of expenditures and for determining what fraction of an expenditure is centrally derived.

What is the timeframe of the expenditure? Each of the funding mechanisms appear to make and release information about their expenditures at varying paces. The minimal answer to this question will provide sufficient information to estimate the year in which the expenditure was or will be made. Based on this information, it will be possible to assess whether the expenditure is actual, estimated, budgeted, or aspirational.

Does the expenditure support activities other than R&D? This will list any activities supported by the expenditure that are not directly R&D. The presence of non-R&D activities does not necessary disqualify an expenditure from being considered R&D-focused. For instance, U.S. R&D awards to professors are also used to partially cover the overhead costs of the professor's university.

Does the expenditure support activities other than AI? This will list any activities supported by the expenditure that do not meet a reasonable definition of AI or that only include AI as a relatively minor component. Examples of such activities may include: 5G, advanced manufacturing, cloud computing, integrated circuits designed for general applications, etc.

Is there evidence to suggest that the previously mentioned ways the mechanism should work are not the way it actually works? This answer will examine ways that the idealized understanding of the funding mechanism may not be reflective of its actual implementation. Information provided for this answer may be applied to any of the four assessments.

c. Estimates of the Central Government's Expenditure on AI R&D

If expenditures through a mechanism satisfy all four criteria, then we have the information necessary to provide an estimate of the portion of the associated expenditure that is comparable to U.S. Federal AI R&D. In this case, we provide an estimate of the amount of relevant expenditures made through the mechanism. For a funding mechanism that is judged as not being comparable to U.S. Federal AI R&D, we attempt to provide some level of illustrative analysis. This may be an estimated upper bound on the funding or a case study that illustrates the complexity of expenditures under the mechanism.

D. Structure of Report

The report is organized into six chapters and five appendices. Chapters 2–5 apply our methodology to each of the four Chinese funding mechanisms of interest. Chapter 6 provides a summary of our results and some overarching insights. Appendix A provides the heuristic we used to classify expenditures according to their likely NITRD PCA. For

each funding mechanism, there is also a corresponding appendix that provides more information used to support the assessments made in the main body of the report.

2. National Natural Science Foundation of China

A. Background

The National Natural Science Foundation of China (NSFC), established in 1986, focuses on supporting "research promotion, talent fostering, and infrastructure construction for basic research," with an annual budget that has grown from 80 million RMB ($0.025 billion USD) in 1986 to 30.7 billion RMB ($4.6 billion USD) in 2018 (NSFC 2019a). Most of NSFC's budget is directed to its research programs, the largest being the *General Program*, which accounted for 43 percent of NSFC's total expenditures in 2018 (NSFC 2019b). The NSFC accepts proposals for basic and applied research in AI primarily within the Third Office of the Department of Information Sciences under the following two category codes: F06 - artificial intelligence; and F07 - cross-disciplinary information sciences (NSFC 2019b).

The NSFC website lists all the awards granted each year, including titles, direct funding amount, grantees of the award, and a funding code corresponding to the department, office, and research topic area of the funds. We were not able to gather the abstracts corresponding to each award; however, we know that such information exists and is available through Dimensions—a subscription-based R&D analytics database. At the time we contacted Dimensions, their abstract-level data appeared to be a year behind the most recent awards.

NSFC publishes a *Guide to Programs* every year in December that describes the research programs to which applicants may apply in the coming calendar year as well as eligibility and application requirements. It also provides a summary of direct funding awarded in the current and previous calendar year for each research program and department within NSFC. For instance, the 2019 Guide to Programs was published in December 2018 and it reports that the Third Division of the Department of Information Sciences provided nearly 140 million yuan in direct funding to 231 projects for "artificial intelligence and intelligent systems" within the General Program;[3] however, the NSFC's definition of AI may not fully accord with the NITRD AI PCA.

[3] We note that the 2019 Guide to Programs contains a substantial typographical mistake. It incorrectly attributes the 231 projects to "Systems science and system engineering" (code: F03)—an error that is partially revealed by a comparison with the 2018 Guide to Programs and further confirmed through the use of project-level data taken from the NSFC's online database.

NSFC also publishes an *Annual Report* to publicize the accomplishments of its grantees and more detailed summary statistics of its expenditures from the previous year. Expenditures for each department and program can be extracted from the *Annual Report*. The most recent *Annual Report* was released in 2019 and contains information for calendar year 2018 (NSFC 2019a).

B. Analysis

The NSFC is a central government agency and is sole contributor of funds for the R&D awards it administers, with few exceptions. Its *Guide to Programs* lists the direct and indirect expenditures for each of its 18 programs; thus, it is possible to estimate an overhead ratio for each program. Direct funding information is available on the NSFC website at the grant level for each program, which can be used to roughly estimate the total amount of direct funding for each category code (e.g., F06) and its corresponding sub-codes. We find that publicly available information is sufficient to estimate the central government's direct and indirect expenditures through NSFC for any category code.

We find that publicly available information exists on the NSFC awards database that allow a rough classification of activities that are likely to be aligned with the AI PCA. AI could be funded by divisions other than the Third Office of the Department of Information Sciences, for example, but we conclude that such expenditures are unlikely to be classified as AI by our heuristic; the expenditures would be more likely to fall into another NITRD category or have only a minor relevance to AI R&D.

NSFC is designed to support basic science, research, and development. Most of the awards go to scientists at universities and government research institutions for "research promotion, talent fostering, and infrastructure construction for basic research." These activities, including the development of infrastructure to support R&D programs, appear to align with the OMB R&D definition; thus, we find that its expenditures are R&D-focused.

Unlike the NSF in the United States, expenditures made through the NSFC cannot be used to partially support the salary of the principal investigator or other senior researchers; NSF awards allow up to 2 months of salary support for such researchers. There are indications that the salary of junior researchers (e.g., graduate students and post-docs) are not allowed to be fully covered by an individual award (Embassy of Switzerland in China 2014; NSFC 2015; NSFC 2016; Cao 2018). No such restrictions exist regarding the funding of junior researchers under NSF awards. The qualitative differences in how NSFC and NSF support the labor of researchers complicate a comparison of the expenditures made by the two organizations.

NSFC publishes its retrospective funding summaries in its annual *Guide to Programs* and *Annual Report*. We have independently verified some of its aggregate numbers by

scraping grant-level award data from the NSFC database. We find that sufficient information exists to determine NSFC's *actual* expenditures for the 2018 funding cycle.

We find that publicly available information is sufficient to estimate an NSFC expenditure that is comparable to U.S. Federal expenditures on the AI PCA. However, we find that it is *not possible* to compare NSFC expenditures with U.S. NSF expenditures, because the two organizations take different approaches to providing salary support for researchers. Further details that support our NSFC assessments are in Appendix B.

C. Expenditure Estimate

While the Dimensions database contains abstracts for all research grants that would allow an analyst to classify the NSFC awards according to their approximate NITRD PCA, we do not have access to this database. Further, the assignment of NITRD codes to NSFC's thousands of awards would be prohibitively difficult. Instead, our estimate at classifying research expenditures by NITRD PCA relies mainly on the titles of the funding codes (Table 1). We assess that F0601–F0605 are likely to be AI. We assess that F0606 and F0607 are mostly not aligned with the AI PCA. Only two sub-codes under F0606 are likely AI, while the remaining nine are a mix of IRAS, CNPS, CHuman, or unclassifiable (X).4 Similarly F0607 contains only a single sub-code that is likely AI, with the remaining eight being EHCS or CHuman. We find that effectively none of the expenditures made under the F07 code are AI. Specifically, all sub-codes under F0701 appear to be best classified as EdW. Only a single sub-code under F0702 mentions AI, with the rest being tangentially related at best (e.g., automation) or completely unrelated at worst (e.g., optics).

[4] See Appendix A for a discussion of the NITRD PCAs.

Table 1. NSFC Funding Codes Thought to Include AI Classified by NITRD PCA

Code	Chinese	English	NITRD
F0601	人工智能基础	Artificial intelligence foundation	AI
F0602	机器学习	Machine Learning	AI
F0603	机器感知与模式识别	Machine perception and pattern recognition	AI
F0604	自然语言处理	Natural language processing	AI
F0605	知识表示与处理	Knowledge representation and processing	AI
F0606	智能系统与应用	Intelligent systems and applications	Mixed
F0607	认知与神经科学启发的人工智能	Cognitive and neuroscience-inspired artificial intelligence	EHCS
F0701	教育信息科学与技术	Educational Information Science and Technology	EdW
F0702	信息与数学交叉问题	Information and Math Cross Problems	X

Using data scraped from the NSFC's public-facing awards database, we investigated the expenditures of seven NSFC programs that accounted for approximately 70 percent of NSFC's total expenditures on direct research funding in 2018. We were able to validate the completeness of our data for three of the programs by comparing the total number of projects and award amounts within the F06 research code with data from the 2018 Annual Report (Table 2).

Using our assessment that only funding codes F0601–F0605 would likely be classified with the AI PCA, **we find that NSFC made expenditures of approximately 210 million RMB ($32 million USD) on direct funding for projects aligned with the AI PCA** in these programs (Table 3). The sum of the budgets for these seven programs represents about 70 percent of NSFC's direct funding expenditures.

Table 2. Validation of NSFC Website Scrape. The Scraped Data Closely Matches the Statistics Provided in the 2018 Annual Report. All Expenditures in Millions of RMB.

	Annual Program F06		Scrape F06	
Name	Projects	Expenditures	Projects	Expenditures
General Program	231	13,908	222	13,432
Key Projects	-	-	-	-
Major Projects	-	-	-	-
Major Research Plans	-	-	-	-
Joint Funds	-	-	-	-
Youth Funds	223	5,494	217	5,344
Fund for Less Developed Regions	40	1,519	40	1,519

Table 3. Amounts of Direct Funding from NSFC That Appears Aligned with the AI PCA. All Quantities in Millions of RMB.

Name	Program Budget	F0601	F0602	F0603	F0604	F0605	Sum of F06
General Program	11,153	18	13	48	11	12	102
Key Projects	2,054	6	6	0	3	9	23
Major Projects	687	0	0	0	0	0	0
Major Research Plans	883	3	0	0	0	4	6
Joint Funds	1,406	0	0	18	6	0	23
Youth Funds	4,176	8	8	19	4	4	41
Fund for Less Developed Regions	1,103	3	2	5	3	1	14
TOTAL	**21,463**	**37**	**28**	**90**	**26**	**29**	**210**

3. National Key R&D Programs

A. Background

A National Key R&D Program (NKP) is a cluster of R&D projects that target key technologies aimed at social welfare and improving people's livelihoods (DSE 2018a). The NKP funding mechanism was created in 2014 to consolidate previously independent funding mechanisms, such as the *863 Program* (State High-Technology Development Plan), the *973 Program* (National Basic Research Program), and others (DSE 2018a). New NKPs are announced each year; they generally expire after 5 years. For the lifetime of each active NKP, MOST releases an annual program guide that describes the projects available in that year's funding call.

Projects within the NKPs may be awarded competitively or non-competitively through "directional application" (DSE 2018a). Awards for projects are publicly announced, accompanied by a brief period for public comment to contest the award. The award announcements list the recipient and award size, but do not list the total amount of additional funding for those projects that require matching funds nor the project proposal submitted by the successful applicant.

We collected publicly available program guides and award announcements from the MOST website.[5] We searched for the relevant documents based on a list of active NKPs compiled by DSE (DSE n.d.). Of the 65 NKPs that were initiated between 2015 and 2018, we were able to locate the program guides for 64 in the 2018 cycle of solicitations. We were able to collect the corresponding award announcements for 62 of the NKPs, totaling 21.98 billion RMB ($3.3 billion USD) across 1,216 projects. Awardees in our database tended to be universities, government research institutes, and enterprises.

B. Analysis

NKPs are a central government program, and the central government is a contributor for each project. While MOST administers NKPs and releases the solicitations, they sometimes do so in conjunction with other entities, such as the Chinese Academy of Sciences (CAS), the Ministry of Finance (MOF), and local governments (DSE 2016). Entities involved in the formulation of the solicitations may also be responsible for contributing funds; in some cases local governments appear to be among the primary sponsors of the R&D. The program guides are inconsistent in their descriptions of

[5] MOST documents can be searched for at https://service.most.gov.cn/2015tztg_all/.

participating and sponsoring entities and the award announcements do not reference primary sponsors at all. Therefore, we find that it is not possible to confidently estimate the central government's direct expenditures to each project as we cannot conclusively determine the sponsors for most of the NKPs.

Expenditures made by central government sponsors do not represent the totality of central government expenditures on the NKPs. The program guides prescribe a minimum ratio of matching funds that must be provided by the awardee. However, matching funds provided by awardees that are members of the central government or are primarily government supported would also be central government expenditures. The award announcements do not list the amount of matching funding provided by the awardees; it is possible that the true amount of matching funds could be substantially more or less than the minimum ratio, precluding a confident estimate of central government expenditures through matching funds.

There are no active NKPs that are dedicated directly to AI; however, there are projects within some NKPs that focus on or involve AI. Program guides include a description of each research task, which includes the research goals along with assessment indicators for the evaluation of a project. We find that the program guides contain sufficient information to assign a NITRD PCA to each project within the NKPs.

We find that NKPs are likely R&D activities, but it is possible that some of the projects within NKPs could be considered product development if they were awarded to an enterprise. The performance of most projects is judged by the ability to develop technologies that meet or exceed specified technological parameters. Enterprises were awarded 21.5 percent of the projects. [6] If it is the case that an enterprise is receiving money to improve a product it already sells, then the expenditure might not be considered R&D, per NCSES's definition, but instead be classified as product development for a government customer.[7] The list of awardees is available for each project, but we did not attempt to assess the extent of this possibility. This is due to the time and resources required to determine if the awarded enterprise already sells a substantially similar capability. In the absence of such information, we assume that NKPs are an R&D-focused expenditure.

We find that expenditures made by MOST and other sponsors through the NKP mechanism should be classified as *estimated* expenditures. The award announcements provide a short period of time for the award to be contested; however, we were unable to determine whether awards were adjusted in response to objections from losing applicants.

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6 We characterized enterprises as entities that included "有限公司" in the name, which can be translated as "limited liability company."

7 Product development, defined as the "adaptation of an existing capability to a particular requirement or customer's need as part of a continuing commercial activity," is excluded from business R&D statistics.

We find that publicly available information is insufficient to estimate an expenditure that is comparable to U.S. Federal expenditures on the AI PCA. This is because the sponsors are only vaguely specified for some NKPs and completely unspecified for others. Using the assumption that all NKP sponsors are central government entities expenditures allows for a partially comparable expenditure estimate to be produced.

C. Expenditure Estimate

The 62 NKPs from the 2018 solicitation cycle for which we have a program description and an award announcement contain a total estimated expenditure of 21.98 billion RMB. To find NKP research projects that could potentially be classified with the AI PCA, we first search for research projects that contain keywords that are broadly related to AI within the program guides. The keywords are expected to identify all of the projects that are aligned with the AI PCA along with additional projects that do not align with the AI PCA. The keywords used can be found in Appendix C. The keyword search identified 61 projects spanning 22 NKPs.

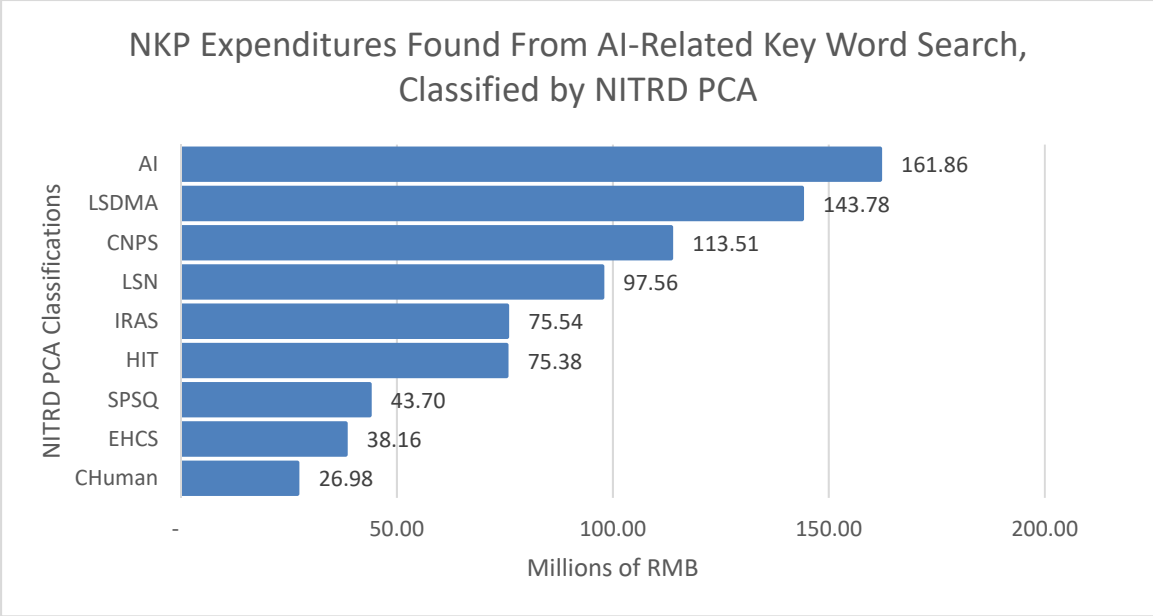

Figure 1. NKP Expenditures Found from AI-Related Keywords Search, Classified by NITRD PCA (see Appendix A). Each Project Is Assigned a Single PCA.

We then assigned each project a single NITRD PCA based on our assessment of its project description, using the heuristic in Appendix A. The 61 project descriptions reveal many projects that contain words like "artificial intelligence" but that have little or nothing to do with AI. We find that only 11 projects—worth 162 million RMB ($24 million)—**that may be partially comparable to U.S. Federal expenditures on the AI PCA** (Figure 1).

Of the 11 projects, a few straddle the line between AI and other PCAs; in these instances, we conservatively classified them as AI. A subsequent 33 projects may reasonably be classified with the remaining NITRD PCAs, worth 610 million RMB ($92 million). As a reminder, projects within non-AI PCAs may contain some AI R&D, but it is not the major focus of the research and there is no way to estimate the amount of AI from publicly available data. Also, these estimates pertain only to the sponsors' expenditures through the NKPs; they do not include matching funds from the awardees, who may also be contributing central government funds in unknown amounts.

4. Megaprojects

A. Background

National Science and Technology Megaprojects originated with the Outline of the National Medium- and Long-term Program for Science and Technology Development (2006–2020) (国家中长期科学和技术发展规划纲要(2006–2020 年)) and were integrated into the 2014 reform of China's Innovation System (DSE 2017a). This plan initiated 16 Megaprojects, which are considered to be China's largest and most ambitious R&D tasks for medium- and long-term development. The 13 civilian Megaprojects were publicly acknowledged; however, there are three military Megaprojects for which public information is not available. Some were largely focused on technology development, such as the development of China's first domestically produced large aircraft (the C919) or the development of China's crewed space station (Tiangong-2) and robotic lunar lander (Chang'e-3) (DSE 2017a; McGregor 2010).[8] Other Megaprojects, while still applied, were more science-focused, such as efforts to breed genetically modified plants or for research on vaccines. New Megaprojects known as 2030 Innovation Megaprojects (科技创新 2030 重大项目), such as the New Generation of Artificial Intelligence (新一代人工智能) Megaproject, were initiated in 2016 by the *13th 5-Year Plan for National Science and Technology Innovation*, to be active by 2020 with an implementation period until 2030 (State Council 2016).

Funding for Megaprojects is publicly competed and eligibility requirements for applicants are specified in individual solicitations. Requirements generally include matching funds provided by local government departments and that the applicant be in good financial standing (e.g., the applicant's capacity to provide additional funding), and, while not required, "industry-university-research cooperation" is encouraged (DSE 2017a). The central government determines the relevant research tasks and allocates funds to support projects, which are intended to last 3 to 5 years. The project declaration guides provide detailed descriptions of the project content and goals for each relevant research task contained within a Megaproject. In many cases the central government expenditure will also be need to be supplemented by outside funding at a ratio of 1:1 or higher.

Award recipients have included universities, enterprises, and research institutes. Funds can also be awarded to a consortium of recipients, coordinated by a project lead. Project units can apply independently, in which case the evaluation committee may group

[8] Information regarding old megaprojects can be found at http://www.nmp.gov.cn/

them into consortia. Previously formed consortia must submit detailed technical and financial proposals when applying (DSE 2017a).

Data on Megaprojects were collected primarily from project declaration guides, available on the MOST website. Project declaration guides describe the goals of the project and the specific research tasks that will be supported by the Megaproject in that funding cycle. STPI was able was to collect four project declaration guides: New Generation of Artificial Intelligence (2018); Clean and Efficient Use of Coal (2018); Advanced CNC Machines (2016); and Water Pollution Control and Treatment Science and technology (2018). Other researchers have noted similar difficulties gathering information about Megaprojects; the program guides are not consistently available (DSE 2017a). Some of the declaration guides, including the New Generation of AI Megaproject, also provide an estimated budget.

B. Analysis

Publicly available information is insufficient to make a comprehensive AI R&D expenditure estimate across this funding mechanism; most of the megaprojects do not have publicly available program guides and award announcements. The remainder of this analysis will focus exclusively on the New Generation of Artificial Intelligence Megaproject, as both of the necessary documents are available.

The program guide for the New Generation of AI Megaproject contains 16 total research tasks, each of which can fund multiple projects. Expenditures on these research projects are clearly central government expenditures; however, publicly available information is insufficient to determine the size of the expenditure per project. Neither the program guide nor the award announcement provides details about how much each project has been awarded nor what the level of awardee-provided matching funds is.

Sufficient documentation is available for the New Generation of AI Megaproject to assign NITRD PCAs to each of its 16 research tasks. The program guide contains a few sentences per research task that describe the goal of each task. The descriptions also use keywords that can be used to understand specific techniques that are in scope (e.g., swarm intelligence or reinforcement learning).

The National Science and Technology (S&T) Megaprojects are meant to tackle major bottlenecks in technology (DSE 2017a). For the Megaproject dedicated to AI, the bottleneck identified was early-stage R&D, as shown by the major technical directions and research tasks outlined in the project guide, which relate to fundamental theories of AI and key technologies. Of the projects supported in the 2018 awards, all but two were led by either universities or government research institutes. We find that expenditures made through the New Generation of AI Megaproject are focused on R&D activities, rather than product development or other non-R&D activities.

The project declaration guide for the AI Megaproject provides the sum of MOST's planned expenditure across all 16 research tasks. While it is clear that the central government will be expending funds through this megaproject, we find that the amount of the expenditure can only be classified as *budgeted* at this time. The project award recipients have been released but it is unknown how much funding was awarded to each project—precluding this expenditure from being considered *actual* or *estimated*.

We find that it is not possible to make a credible comparison between expenditures from the New Generation of AI Megaproject and U.S. Federal expenditures on non-defense AI R&D. This is because there is insufficient data to understand the actual amount of funding provided for the overall effort and for the individual projects. A partially credible estimate may be made by assuming that the actual expenditures are equal to the budget and that funds are distributed evenly across all research tasks.

C. Expenditure Estimate

As noted above, it is not possible to provide a credible estimate of AI expenditures for this mechanism, nor even for the New Generation of AI Megaproject. Regardless, we provide a very rough estimate of total central government expenditures on AI R&D through the Megaproject.

The program guide for the 2018 New Generation of Artificial Intelligence Megaproject announced a total budget of 870 million RMB. This budget would be spread across 16 research tasks in unspecified proportions. Assuming that the total budget is distributed evenly across research tasks, this equates to 54 million RMB per research task. As noted above, we assume this budget covers the entire period of performance and is not an annual funding amount.

Based on the descriptions of each research task, we find that only 10 of the 16 research tasks are likely to be classified with the AI PCA (Table 4). **Assuming that budgeted funds are distributed evenly across all research tasks leads to approximately 540 million RMB ($82 million) of expenditures aligned with the AI PCA**. This is a rough approximation, as we have no reason to suspect that MOST will distribute the money evenly across all 16 tasks, nor that the actual expenditure closely matches the budget. While the program guide published *minimum* ratios for awardee-provided matching funds, the award description listed only the recipients of awards for each research task, not the size of the award nor the *actual* ratio of matching funds that they must provide. Our estimate of 540 million RMB does not include any potential matching funds.

Table 4. Research Tasks to Be Supported by the 2018 New Generation of Artificial Intelligence Megaproject, Classified by NITRD PCA (see Appendix A)

Task	Name	PCA
1.1	A New Generation of Neural Network Models (新一代神经网络模型)	AI
1.2	Adaptive Perception for Open Environments (面向开放环境的自适应感知)	AI
1.3	Cross-media Causal Inference (跨媒体因果推断)	AI
1.4	Game Decision under Incomplete Information Conditions (非完全信息条件下的博弈决策)	AI
1.5	Group Emergence Mechanism and Calculation method (群智涌现机理与计算方法)	AI
1.6	People in the Loop of Hybrid Enhanced Intelligence (人在回路的混合增强智能)	CHuman
1.7	Collaborative Control and Decision Theory Method in Complex Manufacturing Environment (复杂制造环境下的协同控制与决策理论方法	CHuman
2.1	Generalized Domain Knowledge Learning and Calculation Engine (可泛化的领域知识学习与计算引擎)	AI
2.2	Cross-media Analysis and Reasoning Technology System (跨媒体分析推理技术系统)	AI
2.3	Scene Active Perception Technology under Cognitive Tasks (认知任务下的场景主动感知技术)	AI
2.4	Group-inspired Clustering Research for Group Behavior (面向群体行为的群智激发汇聚研究)	AI
2.5	Research on Human-Computer Cooperation Software and Hardware Technology (人机协同软硬件技术研究)	CHuman
2.6	Unmanned System Independent Intelligent Accurate Sensing and Manipulation (无人系统自主智能精准感知与操控)	IRAS
2.7	Smart and Precise Operation Learning of Autonomous Agents (自主智能体的灵巧精准操作学习)	IRAS
3.1	New Sensing Devices and Chips (新型感知器件与芯片)	EHCS
3.2	Neural Network Processor Key Standards and Verification Chips (神经网络处理器关键标准与验证芯片	AI

5. Guiding Funds

A. Background

The Chinese central government created government guiding funds (GGFs) (政府引导基金) to increase the supply of investment and spur private venture capital investment (Lin 2017; Lee 2018). GGFs raise capital from government entities and other co-investors, then make equity investments in companies in government-prioritized industries. Investments can be made directly by the GGF or through one or more layers of sub-funds to which the GGF has contributed capital. The government investors forgo their share of the returns to increase the return on investment for the co-investors without removing the risk. The first GGF is believed to be Zhongguancun Venture Capital Guiding Fund, set up in 2002 (Noble 2018). Since then, the number of GGFs has proliferated, with a large wave of GGFs established in 2015 to jump-start innovation-led growth and shift away from manufacturing-led growth (Lin 2017).

The sponsoring government entity announces the creation of a GGF with its intended total capitalization, the amount of matching funds that the sponsoring entity will provide, and the goals of the fund. Fund management companies or sub-funds (generally venture capital [VC] firms) either competitively apply to the sponsoring entity to be designated as a GGF or they are appointed by the sponsoring entity. Before applying to become a GGF, a fund management company must first raise capital from various limited partners that it intends to invest on behalf of the GGF. If the fund management company has raised enough capital and has a good business track record, then the sponsoring agency may accept the application to become a GGF and also provide some amount of matching funds.

A sub-fund may make direct equity investments in portfolio companies or may operate as a fund-of-funds, distributing its money to more specialized VC firms that directly invest in companies. In principle, the general partner or manager of the sub-fund should be a well-established investment firm, who makes investment decisions on the basis of market principles, as other VC firms do (Noble 2018). If the portfolio companies of the sub-fund ultimately fail, all the partners lose their investment, including the government (Lee 2018). If, however, portfolio companies succeed, the investments of all the partners will increase in value, but the sub-fund manager will cap the government's return from the fund at a predetermined percentage, and may use private money to buy the government's shares out at that rate (Lee 2018). In this way, the Chinese government tries to attract capital from private entities and individuals to foster targeted emerging industries. Despite being designed to emulate conventional VC funds, several reports demonstrate that GGFs operate

differently from conventional VC funds (Noble 2018). Local governments often intervene in fund management operations for local government-supported GGFs, appointing specific fund managers, and mandating that certain companies or locations be funded (Noble 2018; Lin 2017).

Nearly all of the data and information we use is sourced from policy reports, journal papers, and various news articles. We do have some primary sources, such as announcements of new GGFs taken from government websites, although these primary sources relate to local GGFs. While these sources do provide insights on the structures, goals, and challenges of GGFs, they do not provide data on any central and local government GGFs nor their expenditures. For example, China Money Network publishes a list and ranks GGFs, but does not provide information on whether any GGFs have reached their capitalization goals, nor does it provide information on how much the associated central or local government entity has contributed to the GGF (China Money Network n.d.). Zero2IPO Group also provides information and research on the investment and VC industry, but does not provide publicly available data on specific GGFs and their investments. We were unable to identify or create a comprehensive dataset on GGF expenditures from publicly available data.

B. Analysis

For centrally administered GGFs, the contribution made by the central government is variable; it may range from approximately 20 to 100 percent, depending on the status of the co-investors (Noble 2018; DSE 2017b). The literature suggests that local governments use the GGF mechanism more than the central government, with local governments having created a greater number of GGFs with a greater total target capitalization (Lee 2018; Noble 2018). We find that GGFs are generally not central government expenditures and that publicly available information is only partially sufficient to determine the central government's contribution to a given management firm.

We find that publicly available information is insufficient to identify AI-focused activities. We were unable to find any centrally administered GGFs that are focused predominantly on AI as a policy objective; however, it should be noted that some local government-supported GGFs are marketed as AI-focused. To determine the amount of AI-focused expenditures through GGFs would require information on each recipient of investment to assess the degree to which they are AI-focused. Public reporting of these investments is only partial (DSE 2017b; Acharya 2019), so it would not be possible to use this approach to comprehensively estimate the amount of investments in AI companies. Finally, equity investments in an AI-focused company will likely be spent on all business functions and not solely be spent on AI.

We do not consider expenditures made through GGFs as R&D-focused because GGFs make equity investments in enterprises (Lee 2018). Enterprises can use funding

from equity investments for any business functions, with a highly variable portion of the funding to be spent on R&D. To determine the portion spent on R&D would require financial data from every enterprise that received funding from a GGF to estimate its expenditures on R&D.

GGFs advertise their capitalization goals; however, there is only sparse data on their true capitalization. GGFs and their sub-funds appear to have trouble reaching their capitalization goals and using their existing capital to make investments in enterprises given the oversupply of capital (Lee 2018; Ren 2018). At best, the target capitalization of GGFs are *aspirational* or *budgeted*, because even if the fund does meet its target capitalization, it may take many years to invest the money. To determine the actual expenditures from a GGF would require data on each investment, which may exist in publicly available data; however, we were unable to locate sources of data with sufficient information.

We find that publicly available information is insufficient to make a credible comparison between expenditures made by GGFs and U.S. Federal expenditures on AI R&D. Expenditures made by GGFs are effectively neither central government expenditures nor are they AI-focused or R&D-focused. There is also not enough publicly available information to determine the actual investments of GGFs for any given year.

C. Expenditure Estimate

Although it is difficult, perhaps impossible, to estimate total R&D expenditures by AI-focused enterprises financed by GGFs, there is sufficient information to estimate the total amount of VC investments in AI-focused companies in China. CB Insights, a financial technology platform that aggregates VC data, approximates the global total amount of investment for AI start-ups was $20 billion[9] with 1,805 deals for 2018 (CB Insights 2019). Data from Pitchbook, another financial technology platform, is reported to show that Chinese firms received 29 percent of all AI-focused VC funding in 2018 (Footnote 93 from Castro 2019). Using the two numbers, we calculate that Chinese AI-related firms received approximately $6 billion in investment in 2018. Alternatively, the Center for Data Innovation, which uses data from CB Insights, estimates the total amount of funding for AI start-ups in China was $13.5 billion across 2017 and 2018; that is $6.75 billion per year on average (Castro 2019). Similarly, the Organisation for Economic Cooperation and Development (OECD), which uses data from Crunchbase, provides a visual representation that shows the total amount of investment for AI-related activities to be approximately $6 billion in China for 2017 (OECD 2018).

[9] We do not have access to the full analysis from which this number is taken. Instead, this is the sum of the funding for 2018 as shown in the bar chart provided in the preview for the analysis.

Total VC investment in AI-focused companies represents an upper bound on total GGF investments in AI-focused companies, because the former total includes the latter. The three estimates above for total VC funding of AI-related companies are all in the $6 to $7 billion range for each of the years 2017 and 2018. **Thus, total central government expenditures on AI-focused companies through GGFs is an unknown fraction of the approximately $6 billion AI-focused investments in China in 2018**.

6. Conclusion

The four Chinese funding mechanisms we investigated are the NSFC, NKP, Megaprojects, and GGF. They were chosen because they are reported to support AI activities. Expenditure data for each of the funding mechanisms was gathered primarily from official Chinese government sources. For a Chinese expenditure to be comparable to U.S. Federal expenditures in AI R&D, it must be made by the central government, focused on AI, focused on R&D, and viable. To support assessments of these four criteria, we address eight critical aspects of each expenditure, which are based on a previously published report describing our methodology (Colvin 2019). The critical aspects include: depth of available data; source of the funds; final recipient of the funds; how the funds flow from source to recipient; the timeframe of the expenditure; any support for activities other than AI or R&D; and potential evidence that the funding mechanism may not operate as advertised.

To assess whether an expenditure is focused on AI, we developed and applied a heuristic based on the methodology used by the NITRD program, which was used for the official estimate of U.S. Federal non-defense AI R&D expenditures. NITRD defines 11 PCAs, one of which is the AI PCA. An expenditure is classified within the AI PCA if the activity it supports is AI R&D and is not principally covered by another PCA. We note that expenditures classified within the AI PCA do not capture all non-defense expenditures on AI R&D. Expenditures within other PCAs—e.g., intelligent robotics and autonomous systems—may contain some amount of AI R&D; however, publicly available information is insufficient to determine the approximate percentage of such expenditures that support AI R&D. For example, NITRD has specified the U.S. Federal non-defense AI R&D budget request for fiscal year 2020 at $654.4 million for projects within the AI PCA and $319.1 million of AI-focused funding within the other PCAs. Thus, our assessments of the comparability of Chinese government expenditures (Table 5) should be understood within the narrow scope of expenditures that are aligned with the AI PCA, where AI R&D is the main focus of the supported research activity.

NSFC's expenditures aligned with the AI PCA can be credibly estimated and compared with U.S. Federal non-defense expenditures on AI R&D. However, a credible comparison cannot be made with U.S. NSF expenditures, due to qualitative differences in how its expenditures are spent on labor. We investigated 70 percent of NSFC's expenditures for direct funding of R&D during the 2018 fiscal year and found 210 million RMB ($32 million USD) of funding that is likely to be comparable to U.S. expenditures on AI through the NITRD AI PCA.

Table 5. Comparability of Chinese Expenditures with U.S. Federal Expenditures That Support the AI PCA

Mechanism	Can we determine how much is: Central	AI PCA	R&D	Viable	Comparable
NSFC	Yes	Yes	Yes	Yes	Yes
NKP	Partial	Yes	Yes	Yes	Partial
Megaproject	Yes	Yes	Yes	Partial	Partial
Guiding Fund	Partial	No	No	No	No

NKP expenditures aligned with the AI PCA are only partially comparable with U.S. Federal non-defense expenditures on AI R&D. We have seen that local governments and other government entities can be the primary sponsors of these projects—MOST is not the only sponsor. Publicly available data is insufficient to confidently identify the sponsors of each NKP or their respective expenditures; thus, we cannot confidently estimate the central government's expenditure. Regardless, we identified 22 billion RMB ($3.3 billion) in NKP expenditures for the 2018 funding cycle, of which we conclude 162 million RMB ($24 million) is likely comparable to the AI PCA. Our identification of active NKPs was limited to only those identified by DSE, and we have reason to believe that DSE's coverage is incomplete; thus the total expenditure through NKPs on all topics in the 2018 funding call may be greater than 22 billion RMB.

Where data is available, **Megaproject expenditures aligned with the AI PCA are only partially comparable with U.S. Federal non-defense expenditures on AI R&D.** We were only able to identify program information for four Megaprojects, which indicates that it is likely impossible to generate a comprehensive estimate of AI spending through this mechanism. We assessed only the New Generation of Artificial Intelligence Megaproject and found that it is only partially comparable with U.S. Federal AI R&D expenditures. This is because we do not know how the proposed 870 million RMB ($131 million) budget will be distributed among the 10 of 16 research tasks that we conclude are aligned with the AI PCA. The Megaproject has released the names of the 33 awardee institutions; however, no funding information was provided. Thus, we cannot say how closely the sum of the awarded amounts aligns with the proposed budget.

GGFs clearly fail to meet at least three of our assessment criteria for comparability. This is noteworthy because they are also the sources of the largest *reported* expenditures on AI in China. They fail mainly because the money they provide to a company may be used on any aspect of the business, e.g., marketing or janitorial services, and need not be spent on R&D. Even if the money is spent on R&D, it is unconstrained by topic with no way to estimate how much may be spent on AI. Most challenging of all is that GGF are not viable expenditures; they have been shown to have difficulties with both raising and spending capital. Publicly available data is insufficient to trace the investments made by these guiding funds to the companies in which they have invested. Such data may

technically exist in the public domain; however, we were unable to find or create such a dataset.

We identified $138 million in Chinese non-defense AI R&D expenditures from 2018 that are potentially comparable to U.S. expenditures on non-defense AI R&D. Our estimate of $138 million (Table 6) is a lower bound, taken from the sum of comparable and partially comparable expenditures, which does not contain expenditures made primarily on adjacent R&D topics (e.g., robotics) that may also contain an unknown amount of AI R&D. For comparison, U.S. expenditures in the AI PCA capture only two-thirds of the total non-defense expenditures on AI R&D made by the U.S. Federal Government; the final third is distributed among the other PCAs.

Table 6. Comparison of Expenditures Found by Different Analyses for Each Funding Mechanism* in 2018. Dollar Values are Provided in Millions of USD.

Mechanism	Comparable	Expenditure	STPI	CSET	DSE
NSFC	Yes	AI Focused	$32	$18 – $54	$106
		Total Examined	$3,250	$1,663	-
		Percentage of Total	1.0%	1.1% – 3.2%	-
NKP	Partially	AI Focused	$24	$62 – $267	-
		Total Examined	$3,325	$2,056	-
		Percentage of Total	0.7%	3.0% – 13%	-
Megaproject	Partially	AI Focused	$82	$131	$131
		Total Investigated	$131	$131	$131
TOTAL		**AI Focused**	**$138**	**$211 – $452**	**$237**

* GGFs are not credibly comparable, but we estimate an upper bound of $6 billion for GGF investments in 2018. The GGF estimate is not listed above because the other STPI estimates are not upper bounds.

As part of our methodology, we have considered only central government expenditures as comparable, but what if local government expenditures should be considered comparable to U.S. Federal expenditures? Indeed, Chinese local governments may outspend the central government in terms of AI R&D, because they are often responsible for implementing national policy initiatives. Local officials are responsible for implementing central government policies to achieve national development goals, and they have great incentive do so. Because their promotions are based on the Communist Party's internal human resources department, ambitious local officials compete to advance the national development goals laid out by the State Council (Lee 2018). In fact, local governments are the leading actors in China's national science and technology innovation system, because the central government compels local governments to compete for R&D investments and funding (He et al. 2018).

If local government expenditures are considered comparable to U.S. Federal expenditures, that affects only our NKP assessment. NKP expenditures aligned with the

AI PCA would become fully comparable to U.S. Federal expenditures on non-defense AI R&D; however, it would still not be possible to estimate the total expenditures on AI R&D through the NKP mechanism and would not change our estimate of expenditures aligned with the AI PCA. Expenditures made through local guiding funds are not R&D and would be decidedly not comparable. Further, upon closer inspection the AI Guiding Funds established in Tianjin and Shanghai may not even be AI-focused. For instance, the Tianjin AI Development Fund appears mostly focused on robotics and explicitly carves out 30 percent of its capitalization to support smart manufacturing, which fall under IRAS rather than AI, as well as the transition of traditional industries to smart manufacturing processes (Wang 2018; Tianjin Municipal Government 2018). These guiding funds are among the largest reported Chinese investments in "AI," yet they would likely still fail our AI-focused criteria despite some guiding funds claiming to target AI. More generally, the mechanisms used to fund AI R&D at the local level appear to be far less standardized than at the central level, making an analysis of their expenditures complicated. More research is required to determine whether sufficient information exists on local government websites to establish the extent to which local expenditures meet our other three assessment criteria of AI-focused, R&D-focused, and viability.

Our expenditure estimates are lower than others from the literature, when viewed as a percentage of total expenditures examined within each funding mechanism. The Center for Security and Emerging Technology (CSET) and DSE have also investigated AI R&D expenditures through these four mechanisms. Their results are summarized in Table 6. The focus of DSE's research was to demonstrate to European researchers that opportunities exist for them to apply for AI research funding from China; the funding estimates were not central to their thesis and thus were only roughly estimated. CSET (Acharya 2019) used expenditures made by the NSFC and the NKPs as proxies for total Chinese expenditures on basic and applied R&D, respectively. They multiply the fraction of AI expenditures within each funding mechanism by the basic, applied, and experimental development budgets published by the Ministry of Finance to estimate China's total government expenditures on AI R&D.

We are in approximate agreement with CSET's estimation that AI R&D expenditures are likely about 1 percent of NSFC's total portfolio. We differ substantially, however, with respect to the NKPs. We find that expenditures supporting the AI PCA are likely only 0.7 percent of the total NKP R&D portfolio. This discrepancy is the result of our classification of individual projects as AI, rather than relying solely on a keyword search to determine the presence of AI. Further, we investigated a larger portion of the NKP budget, having analyzed about 60 percent more expenditures, thus providing greater coverage of NKP expenditures in the 2018 funding cycle. Despite this greater coverage, there are still more NKP expenditures that we did not analyze because our methodology was not designed to

capture every single NKP expenditure. Inclusion of these missing expenditures would likely affect CSET's estimated fraction of AI R&D within the NKP mechanism.

CSET estimated GGF investments between $2 and $8 billion in 2018. In contrast, we place an upper bound of $6 billion on GGF investment based on the total amount of reported venture capital investment into Chinese AI companies in 2018. These estimates were not included in Table 6, in part, to underscore that neither we nor CSET find investments made by GGFs to be comparable to U.S. Federal expenditures on R&D. Further, our estimate of $6 billion is an upper bound, while all of our other estimates are lower bounds.

Considering the data availability challenges associated with the funding mechanisms we have investigated, **we find that it is not possible to credibly estimate the amount of China's broader government expenditures on non-defense AI R&D**. We investigated funding mechanisms that publicly compete their awards; thus, they are among the most transparent of Chinese funding mechanisms. Only NSFC and the NKPs have sufficient publicly available data to analyze their entire R&D portfolio; data on expenditures for Megaprojects and GGFs are challenging to find and comprehensive data may not exist. The NSFC and the NKPs are responsible for only about 10 percent of the $60 billion that the Chinese central and local governments reportedly expended on R&D in 2018. Given the opacity of the publicly competed funding mechanisms, we find it unlikely that the remaining 90 percent of China's R&D portfolio can be analyzed at a similar fidelity as the 10 percent that we and CSET have investigated. Further, we have both investigated funding mechanisms where AI R&D was known to exist, which potentially biases any attempt at generalizing or extrapolating our results to the broader Chinese R&D portfolio. For the above reasons, we find that the uncertainties associated with a *national-level* estimate of Chinese government expenditures on non-defense AI R&D would be too great to allow for a credible comparison with the total U.S. Federal expenditures on non-defense AI R&D.

Appendix A. Heuristics for Classifying R&D

As discussed in the introduction, NITRD provides a broad definition for AI that is also dependent upon the other PCAs. Thus, to use their definition to classify R&D activities as AI or not, we must have a functional definition of *all* of the PCAs. Detailed below is the definition provided on the NITRD website for each PCA (NITRD n.d.), some clarifying examples also provided on the website, and any additional information that we used as a heuristic to classify Chinese projects according to the NITRD PCAs. To gain additional insight into NITRD's definitions, we closely read the NITRD budget supplement to develop our heuristics for each PCA.

AI - Artificial Intelligence

Definition: AI R&D advances the ability of computer systems to perform tasks that have traditionally required human intelligence; this includes R&D in machine learning, computer vision, natural language processing/understanding, intelligent decision support systems, and autonomous systems, as well as the novel application of these techniques to various domains, where not principally covered by other PCAs.

NITRD Clarifications:

- "Intelligent autonomous systems that exist only in cyberspace, with no physical embodiment, would be reported under AI";
- "R&D on algorithms for computational linguistics would fall under AI";
- "R&D on the cybersecurity challenges unique to AI, such as the ability to exploit flaws in an AI system's goals would fall under AI"
- "R&D on special neuromorphic computing architectures or chips optimized for neural nets would fall under AI"

Heuristic:

- R&D on algorithms associated with AI
- Not building physical hardware, with single exception of chips that are optimized for use with AI
- Robotics and healthcare are covered by other PCAs, thus application of AI to those topics are not included here

CHuman - Computing-Enabled Human Interaction, Communication, and Augmentation

Definition: CHuman R&D advances information technologies that enhance people's ability to interact with IT systems, other people, and the physical world; this includes R&D in social computing, human-human and human-machine interaction and collaboration, and human and social impacts of IT.

NITRD Clarifications:

- R&D on the broad problem of human-machine interaction, even if it contains an element of natural language processing, would fall under CHuman.

Heuristic:

- Brain machine interfaces

CNPS - Computing-Enabled Networked Physical Systems

Definition: CNPS R&D advances information technology-enabled systems that integrate the cyber/information, physical, and human worlds; this includes R&D of cyber-physical systems, Internet of Things (IoT), and related complex, high-reliability, networked, distributed computing systems.

NITRD Clarifications: None

Heuristic:

- R&D on robots whose functionality derives from being part of a network (e.g. autonomous cars operating in a smart city that has networked cars and infrastructure together; swarms of unmanned aerial vehicles)
- Smart cities
- IoT
- Distributed surveillance systems

CSP - Cyber Security and Privacy

Definition: CSP R&D advances protection of information and information systems from cyber threats and prevention of adverse privacy effects arising from information processing; this includes R&D to deter, detect, prevent, resist, respond to, recover from, and adapt to threats to the availability, integrity, and confidentiality of information and information systems, as well as R&D of privacy-protecting information systems and standards.

NITRD Clarifications:

- AI supporting cybersecurity research would fall under CSP

Heuristic:

- The above are sufficient

EdW - Education and Workforce

Definition: EdW R&D advances use of information technology to improve education and training; this includes IT to enhance learning, teaching, assessment, and standards, as well as preparation of next-generation cyber-capable citizens and professionals.

NITRD Clarifications: None

Heuristic:

- Main focus is on education or workforce training

EHCS - Enabling-R&D for High-Capability Computing Systems

Definition: EHCS R&D advances high-capability computing and development of fundamentally new approaches in high-capability computing; this includes R&D in hardware and hardware subsystems, software, architectures, system performance, computational algorithms, data analytics, development tools, and software methods for extreme data- and compute-intensive workloads.

NITRD Clarifications:

- General research in neuromorphic computing would fall under EHCS

Heuristic:

- Developing computation-intensive software or tools that would use elements of machine learning or upon which machine learning could be run
- Anything that could be tagged as the HCIA PCA

HCIA - High-Capability Computing Infrastructure and Applications

Definition: HCIA investments advance operation and utilization of systems and infrastructure for high-capability computing, including computation- and data-intensive systems and applications; directly associated software, communications, storage, and data management infrastructure; and other resources supporting high-capability computing.

NITRD Clarifications: None

Heuristic:

- We are unclear how this differs from EHCS. Nothing will be tagged as HCIA.

IRAS - Intelligent Robotics and Autonomous Systems

Definition: IRAS R&D advances intelligent robotic systems; this includes R&D in robotics hardware and software design and application, machine perception, cognition and adaptation, mobility and manipulation, human-robot interaction, distributed and networked robotics, and increasingly autonomous systems.

NITRD Clarifications:

- R&D on robots, even if the robots employ machine vision, would fall under IRAS

Heuristic:

- Any project that appears to be building a robot that can function without being part of a network (e.g., a single autonomous car that carries its sensors and compute capability onboard)
- Robotic control
- Robotic testbeds

LSDMA - Large-Scale Data Management and Analysis

Definition: LSDMA R&D advances extraction of knowledge and insight from data; this includes R&D in the capture, curation, management, access, analysis, and presentation of large, diverse, often multisource, data.

NITRD Clarifications:

- R&D on the larger data management and analysis ecosystem, even if it contains an element of machine learning, would fall under LSDMA

Heuristic:

- Focus on building a data management tool
- Development and use of Big Data techniques
- Data standards

LSN - Large-Scale Networking

Definition: LSN R&D advances networking technologies and services; this includes R&D in networking architectures, wireless networks, software-defined networks, heterogeneous multimedia networks, testbeds, grid and cloud research and infrastructure, network service and cloud computing middleware, identity management, and end-to-end performance enhancement and performance measurement.

NITRD Clarifications: None

Heuristic:

- Cloud design and services

- Design of large scale networks
- Network optimization

SPSQ - Software Productivity, Sustainability, and Quality

Definition: SPSQ R&D advances timely and affordable development and sustainment of low-defect, low-vulnerability software; this includes R&D to significantly improve software production processes, productivity, quality, economics, sustainability, measurement, assurance, and adaptability, and to achieve guarantees of essential requirements such as security, privacy, usability, reliability, and autonomy.
NITRD Clarifications: None
Heuristic:

- Software development methods and models
- Software development environments

HIT – Health Information Technology R&D

Definition: This is not a NITRD PCA, but rather an interagency working group (similar to NITRD) that focuses on health information technologies. It focuses on "R&D efforts that will lead to more efficient and effective healthcare and improve the quality of American lives through technologies that support effective health monitoring; individualized screening, diagnosis, and treatment; disease prevention; disaster and emergency response; and broad access to health and healthcare information and resources. Federal agencies funding work in this group do not presently report budgets under one specific NITRD PCA but rather report under several PCAs, depending on the principal focus areas of their work."
NITRD Clarifications: None
Heuristic:

- Development of sensors that gather health data to be used in a machine learning tool
- Developing diagnostic software tools that have machine learning as one among many techniques

Appendix B. NSFC Supporting Information

What is the source, volume, and depth of the data available on expenditures?

The NSFC website lists all the awards granted each year, including titles, direct funding amounts, grantees of the award, and a funding code corresponding to the department, office, and research topic area of the funds. We were not able to gather the abstracts corresponding to each award; however, we know that such information exists and is available through Dimensions—a subscription-based R&D analytics database. At the time we contacted Dimensions in October 2019, its abstract-level data appeared to be a year behind the most recent awards. Alternatively, many research analytics tools (including Dimensions) could be used to identify publications funded by NSFC and the identified papers could be linked to expenditure data through the grant numbers.

NSFC publishes a *Guide to Programs* every year in December that describes the research programs to which applicants may apply in the coming calendar year as well as eligibility and application requirements. It also provides a summary of direct funding awarded in the current and previous calendar year for each research program and department within NSFC. For instance, the 2019 Guide to Programs was published in December 2018, and it reports that the Third Division of the Department of Information Sciences provided nearly 140 million yuan in direct funding to 231 projects for "artificial intelligence and intelligent systems" within the General Program.[10]

NSFC also publishes an *Annual Report* to publicize the accomplishments of its grantees and more detailed summary statistics of its expenditures from the previous year. Expenditures for each department and program can be extracted from the *Annual Report*. The most recent *Annual Report* was released in 2019 and contains information for calendar year 2018 (NSFC 2019a).

What entities would provide the money?

The NSFC, a central government entity, appears to be the sole contributor for the majority of its expenditures; however, there are some NSFC programs that require joint financial support from Chinese SOEs, such as the Joint Fund for Aerospace Advanced Manufacturing Technology—or foreign partners, such as Key International (Regional)

[10] We note that the Guide to Programs contains a substantial typographical error. It incorrectly attributes the 231 projects to "Systems science and system engineering" (code: F07)—an error that is partially revealed by a comparison with the 2018 Guide to Programs and further confirmed through the use of project-level data taken from the NSFC's online database.

Joint Research Programs (NSFC 2019b). NSFC funding is predominantly grant-based and, while there are overarching guidelines that constrain how many collaborating entities may be associated with a particular grant and establish the minimum qualifications of applicants, there does not appear to be co-funding in a majority of its funding programs.

Who would be the ultimate recipients of the money?

NSFC funding is predominantly awarded to principal investigators and researchers at universities or research institutions. An examination of project-level awards gathered from the NSFC's public awards database[11] generally lists the awarded institution for the project. Summary statistics that show which organizations were recipients of NSFC awards are also presented annually in the Annual Report (NSFC 2019a).

How does money flow from the source to the final recipient?

It appears that all NSFC grants are competitively awarded. Applicants must submit research proposals to a specific type of program (e.g., General Program, Key Program, Young Scientists Fund, Fund for Less Developed Regions). The NSFC reviews all proposals based on the selection criteria listed in *National Natural Science Foundation Regulations* and *Guide to Programs*. Funding is then distributed to the host institutions of the grantees. NSFC publishes the acceptance rates for all of the grants, which usually range between 20–25 percent (NSFC 2019b).

What is the timeframe of the expenditure?

The NSFC award lengths in our database vary between 1 to 4 years. The Guide to Programs seems to indicate that 600,000 RMB is the total award amount, as opposed to an annual funding amount, for projects in the General Program (NSFC 2019b). Total award amounts are reported by department, and by division for some programs, within the annual reports.

Does the expenditure support activities other than R&D?

NSFC programs are meant to support basic science and strengthen research and development. We have found no indication that they provide support for non-R&D related activities.

Does the expenditure support activities other than AI?

Yes; however, sufficient information exists to approximately determine the amount of expenditures that NSFC self-identifies as basic research in AI. The NSFC accepts proposals for basic and applied research in AI primarily within the Third Office of the Department of Information Sciences under the following two category codes: F06 -

[11] NSFC's public awards database can be accessed at https://isisn.nsfc.gov.cn/egrantindex/funcindex/prjsearch-list

artificial intelligence; and F07 - cross-disciplinary information sciences (NSFC 2019b). Areas of AI funding under these codes include AI fundamentals, machine learning, machine sensing and pattern recognition, natural language processing, knowledge representation and processing, fundamental theories and methodologies for AI-driven education, and AI and mathematics cross-disciplinary studies.

It is possible to use these funding categories to identify the total amount of funding associated with them. This can be done at the aggregate level by using the Guide to Programs or at the individual award level by scraping the NSFC website. Thus, information exists to identify many AI-related projects. It is possible that a substantial amount of AI-related research may be funded through other category areas; however, we think it is reasonable to assume that such research would not constitute fundamental AI research, as defined by NITRD. Regardless, a potentially finer-grained analysis may be possible by performing a keyword search through grant-level abstracts; however, we did not purchase access to these data and thus did not pursue this method.

Is there evidence to suggest that the previously mentioned ways the mechanism should work are not the way it actually works?

We have seen no evidence that calls into question NSFC operations; it probably works as advertised. However, we have found suggestions that the NSFC may operate substantially differently from the U.S. National Science Foundation in one important regard. “All of NSFC’s funding instruments cover the costs for equipment, apparatus, travel costs, etc. But NSFC grants, as most other research grants in China, do not cover the salaries of the applicants or the members of their research team. Researchers’ salaries are financed by the universities or research institutes themselves (i.e. indirectly by the Ministry of Education or the Chinese Academy of Science)” (Embassy of Switzerland in China 2014).

Appendix C. National Key R&D Programs

What is the source, volume, and depth of the data available on expenditures?

STPI collected publicly available program guides and announcements of proposed awards from the MOST website.[12] STPI searched for the relevant documents based on a list of active NKPs compiled by DSE (DSE n.d.). Of the 65 NKPs that were initiated between 2015 and 2018, we were able to locate the program guides for 64 in the 2018 cycle of solicitations. We were able to collect the corresponding award announcements for 62 of those 64 NKPs. We may have missed many "key special projects" (**重点**专项), where their program guide does not contain the phrase "national key R&D program" (**国家重点研**发计**划**) or reference the name of the NKPs found by DSE website. It is unclear whether these key special projects should be counted as part of the NKP mechanism or not. For this analysis, we omitted them.

The proposed award announcements contain the intended awardee and the amount of research funding, which we assume will be provided by MOST, for each project within the NKP. The award announcements provide a short period of time for dissenting opinions to contest the proposed award; however, we were not able to determine whether awards were adjusted in response to public opinion. The award announcements list the allocated state funding, but do not list the total amount of additional funding for those projects that require matching funds; it is possible that the agreed upon matching funds do not exactly reflect what was prescribed in the program guide.

Public solicitations for competitive awards are released annually on the MOST website, and awards for the 2018 cycle of NKPs were announced within one year of project solicitations. While NKP solicitations and awards are labeled for a given year, this does not guarantee that they will be released within that calendar year. Some solicitations for the 2018 cycle of NKPs were released as early as October of 2017, and some awards for the 2018 cycle were announced as late as July of 2019. Examples of the 17 new NKPs announced in 2018 include: S&T innovation in increasing the quality, yield, and industrial quality and efficiency of China's main cash crops; broadband communication and new networks; and solid waste recycling.

Project descriptions are sufficiently detailed to understand the intended research content for each project. However, we were unable to find information that describes what

[12] MOST documents can be searched for at https://service.most.gov.cn/2015tztg_all/.

the potential awardees proposed to win the award; thus, it is possible that the awarded research is not fully aligned with the program description.

What entities would provide the money?

For each funded project within an NKP, the central government and the project awardees both contribute money. Awardees tend to be universities, private companies, and government research institutes. The program guides published on the MOST website for each NKP specify the matching ratio that each applicant must accommodate to be competitive for the award.

Who would be the ultimate recipients of the money?

NKP funding is awarded to universities, private companies, and government research institutes. Applicants can apply individually or as a consortium of entities with a designated project lead unit. For the 2018 cycle of NKP-funded projects that STPI was able to collect, 43 percent of projects were led by universities, totaling 9.58 billion RMB in central government expenditures. Central government research institutions won a substantial portion of the awards; for instance, institutes within CAS led 11 percent of awarded projects, receiving 2.78B RMB in central government expenditures. These expenditure amounts do not include matching funds provided by the awardees.

How does money flow from the source to the final recipient?

NKPs are awarded competitively. MOST releases a program guide for each NKP annually to solicit applications.

What is the timeframe of the expenditure?

The length of each awarded project is detailed in the annual award announcement, and varies from 1 to 5 years. We assume, but cannot conclusively determine, that the amount of funds listed is for the entire duration of the project, and not an annual award amount.

Assuming that the allocated funds are for the entire length of the project, it is still unclear how the allocated funds will be dispensed over this time period. In cases where the central government only provides a portion of the total funding for each project, it may be possible that MOST distributes its portion of the funds entirely up front, evenly across the years, or at the end of the project upon achievement of the performance indicators. To be clear, we found no evidence to support an assumption for one of these options over another. This uncertainty is crucial to consider when trying to connect expenditures made through NKPs—and potentially other funding mechanisms—with central-level R&D statistics compiled by the National Bureau of Statistics or the Ministry of Finance.

Does the expenditure support activities other than R&D?

NKPs are meant to fund research in areas of social welfare and people's livelihood, and the project goals integrate basic research, application, and commercialization (DSE 2017a). The degree to which a project consists of R&D compared to product development varies by project, but can be understood through the descriptions within the program guides. In general, the projects appear to skew toward applied research and are judged based on performance parameters of the technological systems to be developed.

Some awards go to enterprises, who may already sell services or systems with similar capabilities. In this case, the awards might not be considered R&D, per NCSES's definition, but instead be classified as product development.[13] While we have the list of awardees for each project, we have made no attempt to investigate or assess this possibility. This is due to the time and resources required to determine if the awarded enterprise already sells a substantially similar capability.

Does the expenditure support activities other than AI?

Yes. There are no active NKPs that are dedicated directly to AI; however, there are projects within some NKPs that focus on or involve AI. Sufficient information exists to determine projects that are credibly, though perhaps not exclusively, focused on NITRD topic areas including AI.

Is there evidence to suggest that the previously mentioned ways the mechanism should work are not the way it actually works?

While some uncertainties do exist in the interpretation of our data, we did not encounter any information to challenge the data's veracity. This funding mechanism appears to be relatively straightforward.

AI Keywords

The keywords used to identify AI-related projects within the NKPs were primarily drawn from China's *New Generation Artificial Intelligence Development Plan* (2017). A few of the keywords do not appear in China's AI development plan, but were added on the advice of experts. The keyword search through NKP project descriptions was performed using the Chinese characters.

[13] "Adaptation of an existing capability to a particular requirement or customer's need as part of a continuing commercial activity" is excluded from business R&D statistics.

Table C-1. Keywords Used to Identify Potentially AI-Focused Research Tasks within the NKPs

Adaptive autonomous learning	自适应自主学习	**Intelligent assistant**	智慧型個人助理
AI hardware	人工智能硬件	**Intuitive machine reasoning**	机器直觉推理
AI software	人工智能软件	**Intuitive sensing**	直觉感知
Artificial intelligence	人工 智能	**Knowledge reasoning**	知识表示
Augmented reality	擴增實境	**Knowledge representation**	自动推理
Autonomous cooperation and decision-making	自主协同与决策	**Language sensing**	言语感知
Autonomous coordination	自主协同控制	**Machine learning**	机器学习
Autonomous intelligent systems	自主智能系统	**Multi-agent system**	多智能体系统
Autonomous multimedia learning	多媒体自主学习	**Natural language processing**	自然语言处理
Biometric	生物辨識技術	**Natural language understanding**	自然语言理解
Brain-inspired intelligence	类脑智能	**Neural network**	神经网络
Cognitive system	认知	**Optimized decision-making**	优化 决策
Collective intelligence	群体智能	**Self-adaptive learning**	自适应学习
Comprehensive deep reasoning	综合深度推理	**Swarm integrated intelligence**	群体 集成智能
Comprehensive reasoning	综合推理	**Swarm intelligence**	群体 智能
Computer vision	(计算机视觉)	**Unsupervised learning**	无监督学习
Deep learning	深度学习	**Virtual reality**	虚拟现实
Face recognition	臉部辨識	**Visual recognition**	视觉识别
General AI	用人工智慧	**Voice recognition**	语音识别

Appendix D. Megaprojects

What is the source, volume, and depth of the data available on expenditures?

Data on Megaprojects were collected primarily from project declaration guides, available on the MOST website. Project declaration guides describe the goals of the project and the specific research tasks that will be supported by the Megaproject in that funding cycle. STPI was only able to find four project declaration guides: New Generation of Artificial Intelligence (2018); Clean and Efficient Use of Coal (2018); Advanced CNC Machines (2016); and Water Pollution Control and Treatment Science and Technology (2018). Other researchers have noted similar difficulties gathering information about Megaprojects; the program guides are inconsistently available (DSE 2017a). Some of these declaration guides, including the New Generation of AI Megaproject, also provide an estimated budget for the entire Megaproject. The award announcements provide the awardees for each task within the Megaproject, but they do not provide the award amount.

What entities would provide the money?

The National Science and Technology Megaprojects are initiated by the central government through MOST. The central government determines the relevant research tasks and allocates funds to support projects; in many cases the state allocated funds will also need to be supplemented by outside funding at a ratio of 1:1 or higher.

Who would be the ultimate recipients of the money?

Award recipients include universities, enterprises, and research institutes. Funds can also be awarded to a consortium of recipients, coordinated by a project lead. Project units can apply independently, in which case the evaluation committee will group them into consortia. Previously formed consortia must have detailed technical and financial proposals when applying (DSE 2017a).

How does money flow from the source to the final recipient?

Funding for Megaprojects is publicly competed and new tasks under each Megaproject are supposed to be announced annually; however, we were unable to find a program guide for the 2019 New Generation of AI Megaproject. Eligibility requirements for applicants are specified in individual solicitations. Requirements generally include matching funds provided by local government departments and possession of good financial standing (e.g., the applicant's capacity to provide additional funding) and, while not required, "industry-university-research cooperation" is encouraged (DSE 2017a).

The project declaration guides provide detailed descriptions of the project content and goals for each relevant research task contained within a Megaproject. These guides also specify the required ratio of external funds to state funds supporting a project. We have seen matching requirements of 1:1 and higher in the New Generation of AI Megaproject.

What is the timeframe of the expenditure?

Projects supported by Megaprojects are intended to last 3–5 years. We assume, but are unable to verify, that the publicized budget for each megaproject is intended to cover the entire period of performance. It is unclear how allocated funds will be dispensed throughout this period, especially in cases where the central government is only providing a portion of the total funding for the project.

Does the expenditure support activities other than R&D?

The National S&T Megaprojects are meant to tackle major bottlenecks in technology. For the Megaproject dedicated to AI, the bottleneck identified is basic research on AI, as shown by the major technical directions and research tasks outlined in the project guide, which relate to AI basic theory and technology. Of the projects supported in 2018 by the AI Megaprojects, all but two were led by either universities or government research institutes, which leads us to believe that the expenditure is heavily focused on R&D activities, rather than product development.

Does the expenditure support activities other than AI?

There are several megaprojects that tackle different technological bottlenecks, but there is a megaproject that is dedicated to AI, known as the New Generation of Artificial Intelligence megaproject. The project is broken down into three "technical directions" which are further broken down into 16 total research tasks, each of which can fund multiple projects relating to the same research content. The total estimated expenditure is 870 million RMB, and projects are intended to last 3 to 5 years. The three technical directions relate to Artificial Intelligence Basic Theory, Technology Development for Major Needs, and New Sensors and Smart Chips. The 16 research tasks are listed in Table 4.

Is there evidence to suggest that the previously mentioned ways the mechanism should work are not the way it actually works?

No. We did not find any evidence to suggest that Megaprojects are administered differently from their description in policy and program documents.

Appendix E. Guiding Funds Critical Aspects

What is the source, volume, and depth of the data available on expenditures?

Nearly all of the data and information we use is sourced from policy reports, journal papers, and various news articles. While these sources provide information on the structures, goals, and challenges of GGFs in general, they mostly do not provide data on any specific central and local GGFs nor their expenditures. For example, China Money Network publishes a list and ranks GGFs, but it does not provide information on whether any GGFs have reached their capitalization goals, nor does it provide information on how much the associated central or local government entity has contributed to the GGF (China Money Network n.d.). Zero2IPO Group also provides information and research on the investment and VC industry, but it does not provide publicly available data on specific GGFs and their expenditures. We were not able to identify or create a comprehensive dataset on GGF expenditures from publicly available data.

What entities would provide the money?

Central and local governments set up GGFs to boost national and regional economic growth (Lee 2018). The government entity announces the creation of a GGF with the intended size and goals of the GGF and the money is siphoned into a sub-fund. Other limited partners who contribute to the sub-fund include private investors, state-owned enterprises, and other government institutions.

The central government usually provides no more than 30 percent of the sub-fund's total capitalization, with the remaining 70–80 percent coming from other limited partners (Noble 2018; DSE 2017). The other limited partners could also be government institutions such as state-owned enterprises and banks. For example, the shareholders controlling 95 percent of The National Integrated Circuit Industry Investment Fund (Noble 2018) are all government entities: the Ministry of Finance, China Development Bank, China National Tobacco, and China Mobile (all of which are under the control of the central government), and local government corporations from Beijing, Wuhan, and Shanghai (Noble 2018). Thus, almost 100 percent of the money in a sub-fund could come from the government, albeit various entities in the government.

GGFs that are set up by local governments are unlikely to have central government funds. Indeed, local governments have become the leading actors in implementing GGFs starting in 2014 and 2015 (Lin 2017; Lance 2018; Lee 2018). Local governments have rushed to set up GGFs in order to boost regional economic growth, with directed

investment from local GGFs quadrupling from $7 billion in 2013 to $27 billion in 2015 (Lee 2018). According to data from Zero2IPO, in 2015, there were 417 local-level guiding funds with a capitalization target of 824 billion RMB ($124 billion) in investment, but only 9 central GGFs with a capitalization target of 275 billion RMB ($42 billion) (Lin 2017).

Who would be the ultimate recipients of the money?

The ultimate recipients of the money would be enterprises, most of which may be start-ups (Lee 2018) or small and medium enterprises (DSE 2017b). Companies that have received funds from GGFs include electric-vehicle makers BYD CO. and Nio, and outer-space launch service provider China Rocket Co., Ltd. (Li 2019; Ren 2018; China Daily 2016). We were unable to definitively list any AI companies that have received investments from GGFs, but such data may exist.

How does money flow from the source to the final recipient?

The government entity (sponsoring entity) announces the creation of a GGF with its intended total capitalization, the fraction of the total capitalization that the sponsoring entity will provide, and the goals of the fund. Fund management companies or sub-funds (generally VC firms) either competitively apply to the sponsoring entity to be designated as a GGF or they are appointed by the sponsoring entity. When a fund management company applies to become a GGF, they must raise sufficient capital from various limited partners before applying. Fund management companies that are designated as a GGF are entitled to the previously announced amount of money from the sponsoring entity. It is not clear when the sponsoring entity provides the money; it could be at the time GGF status is awarded or when the first investment in an enterprise has been made (Noble 2018).

Sub-funds may make direct equity investments in portfolio companies or may operate as a fund-of-funds, distributing money to more specialized VC firms that directly invest in companies. In principle, the general partner or manager of the sub-fund should be a well-established investment firm, who makes investment decisions on the basis of market principles like other VC firms (Noble 2018).

If the portfolio companies of the sub-fund ultimately fail, all the partners lose their investment, including the government (Lee 2018). If, however, portfolio companies succeed, the investments of all the partners will increase in value, but the sub-fund manager will cap the government's return from the fund at a predetermined percentage, and may use private money to buy the government's shares out at that rate (Lee 2018). In this way, the government is trying to attract capital from private entities and individuals to foster certain emerging industries.

What is the timeframe of the expenditure?

Unlike a research grant with a fixed period of performance, an equity investment has no natural timeframe. The proposed lifetime for most GGFs is usually 8 years, with some established to run 10 years. With most GGFs established between 2014 and 2018, one would expect a wave of exits from GGFs between the period of 2022 to 2028 (Ding 2018). Some GGFs were established earlier and should have already reached the end of their terms, yet as of March 2018, there has not been a single successful exit from a GGF (Ding 2018). It is unclear what the exit procedures will be and whether GGFs will follow the timeframe originally prescribed at the time of their announcements.

STPI finds that the funds are only credibly capitalized when the organizations who will function as sub-funds are announced; however, the target capitalization of the fund may not have been reached. For example, Premier Li Keqiang announced the creation of the National Emerging Industry Venture Capital Guiding Fund in January 2015;[14] however, the first solicitation for applications to be selected as a sub-fund appears to have been released a year and half later in June 2016.[15] It was not until January and February of 2017 that the selections had been made and the first three sub-funds were established: CICC Qiyuan LP, SDIC Chuanghe LP, and InfoTech LP (DSE 2017b). We make no claim that such an extended timeframe is representative of all national guiding funds, but provide this anecdote to underscore the point that announcement of a fund does not mean the money is real and that the true capitalization cannot be determined until the sub-funds who manage the money are created.

Does the expenditure support activities other than R&D?

Yes. Because GGFs provide equity investments to enterprises, the money from GGFs may be used for any part of the business's operations, which may or may not include R&D. Calculating how much money from GGFs are spent on R&D is made more difficult because such expenditures are up to an individual company's discretion and may not be publicly available.

Does the expenditure support activities other than AI?

STPI has not been able to positively identify any sub-funds or VC funds that are both specific to artificial intelligence and clearly the recipient of central GGFs, despite claims of there being some local GGFs that focus on AI. In a report on trends in GGFs, GYZ Holdings, a Chinese investment firm, claimed that the main investment areas of GGFs became healthcare and AI in 2016 (GYZ Holdings 2017). However, the entirety of such

[14] For more information, see: http://www.gov.cn/guowuyuan/2015-01/14/content_2804136.htm

[15] Additional information available at http://www.sdpc.gov.cn/gzdt/201607/t20160705_810449.html

investments in an AI-focused company would plausibly be spent on a mix of AI and non-AI related activities, supporting all parts of the company's operations.

Is there evidence to suggest that the previously mentioned ways the mechanism should work are not the way it actually works?

Despite being designed to emulate conventional VC funds, reports indicate that GGFs operate differently from conventional VC funds (Noble 2018). Local governments often intervene in fund management operations for their GGFs, appointing specific fund managers, mandating certain companies or locations to be funded (Noble 2018; Lin 2017). In addition, GGFs are established to achieve certain policy objectives (e.g., growing high-technology industries) rather than focus on high-return investments; this policy focus can lead GGFs to invest in companies that appear to support the policy objectives but are unable to provide financial profit (Noble 2018).

There is also an issue of the lack of demand for capital in China and whether sub-funds are actually able to successfully invest money in companies. Gavekal Dragonomics found that almost 40 percent of guiding funds have experienced issues raising or spending money (Noble 2018). For instance, the Government and Enterprise Cooperation Investment Fund, established in mid-2016 and worth 72 billion RMB, was only able to invest about one-tenth of its capital as planned; it placed 88.7 percent of its money into wealth management products by the end of 2017 (Ren 2018). China's top-down strategy for backing technological initiatives has demonstrated both success (Lee 2017) and notable under-performance (e.g., despite announcing a $150 billion semiconductor fund, only $12 billion has been invested since its establishment in 2014) (Zwetsloot at al. 2018).

The lack of promising start-ups may also be a reason for the oversupply of capital from the guiding funds (Ren 2018). For example, in a 2018 financial audit, the State Council questioned why the National Emerging Industry Venture Capital Fund and Advanced Manufacturing Industry Investment Fund both invested billions in the same company: electric-vehicle maker BYD CO.

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Abbreviations

AI	Artificial Intelligence
CAS	Chinese Academy of Sciences
CHuman	Computing-Enabled Human Interaction, Communication, and Augmentation
CNPS	Computing-Enabled Networked Physical Systems
CSP	Cyber Security and Privacy
DSE	Development Solutions Europe
EdW	Education and Workforce
EHCS	Enabling-R&D for High-Capability Computing Systems
GGF	Government Guiding Funds
HCIA	High-Capability Computing Infrastructure and Applications
IDA	Institute for Defense Analyses
IoT	Internet of Things
IRAS	Intelligent Robotics and Autonomous Systems
LSDMA	Large-Scale Data Management and Analysis
LSN	Large-Scale Networking
MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
NBS	Chinese National Bureau of Statistics
NCSES	National Center for Science and Engineering Statistics
NITRD	Networking and Information Technology Research and Development
NKP	National Key R&D Program
NSF	National Science Foundation
NSFC	National Natural Science Foundation of China
OECD	Organization for Economic Co-operation and Development
OMB	Office of Management and Budget
PCA	Program Component Area
R&D	Research and Development
S&T	Science and Technology
SOE	State-Owned Enterprise
SPSQ	Software Productivity, Sustainability, and Quality
STPI	Science and Technology Policy Institute
VC	Venture Capital