CSET CENTER *for* SECURITY *and* EMERGING TECHNOLOGY

SEPTEMBER 2020

Tracking AI Investment

INITIAL FINDINGS FROM THE PRIVATE MARKETS

AUTHORS
Zachary Arnold
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Tina Huang

CENTER *for* SECURITY *and* EMERGING TECHNOLOGY

Established in January 2019, the Center for Security and Emerging Technology (CSET) at Georgetown's Walsh School of Foreign Service is a research organization focused on studying the security impacts of emerging technologies, supporting academic work in security and technology studies, and delivering nonpartisan analysis to the policy community. CSET aims to prepare a generation of policymakers, analysts, and diplomats to address the challenges and opportunities of emerging technologies. During its first two years, CSET will focus on the effects of progress in artificial intelligence and advanced computing.

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Executive Summary

The private sector drives progress in artificial intelligence. National governments were once the prime movers behind strategic technologies, from networked systems to nuclear energy, and supported foundational work on AI techniques. But today, governments mostly rely on private companies to build their AI software, furnish their AI talent, and produce the AI advances that underpin economic and military competitiveness.

This shift brings risks and opportunities for the United States. America could reap massive security benefits from private sector AI innovation in the coming decades. Policymakers may be able to extend these benefits even further by developing policies that boost American AI companies' economic prospects and guide them toward work supporting national security and public interests. Yet at the same time, other countries could harness their own companies to similar ends—or even exploit American private-sector strength by co-opting, subverting, or stealing from U.S. firms leading in AI innovation today.

Policymakers have many tools to mobilize American AI companies and protect their long-term edge in a competitive global marketplace, from R&D subsidies and public-private partnerships to defensive measures such as investment screening, sanctions, and export controls. To achieve the intended outcomes and avoid unwanted distortions and side effects in the market, **policymakers should understand where commercial AI activity takes place, who funds it and carries it out, which real-world problems AI companies are trying to solve, and how these facets are changing over time.**

This paper explores these issues by analyzing equity investment into privately held AI companies, defined here as for-profit businesses (including state-owned or affiliated enterprises) focused on AI and not traded on a stock exchange. (We sometimes use the term "private-market" to describe this investment.) Using general purpose investment data from leading sources along with our own analytic tools, we find:

1. **As of the end of 2019, the United States had the world's largest investment market in privately held AI companies. (*moderate to high confidence*)**

    - In 2019, privately held AI companies attracted nearly $40 billion in disclosed equity investment—defined as venture capital, private equity, and mergers and acquisitions—across more than 3,100 discrete transactions.
    - U.S. companies attracted most of this investment: $25.2 billion in disclosed value (64 percent of the global total) across 1,412 transactions.
    - Based on estimates of transactions without publicly disclosed values, the U.S. market and the overall global AI market could be twice as large as public data indicates.

2. **China's market faded in the last two years, while investment elsewhere grew. (*moderate to high confidence*)**

    - Consistent with broader market trends and data from other sources, we assess that China's AI market roughly quintupled between 2015 and 2017 (as measured by disclosed transaction value), then fell back to near-2015 levels.
    - U.S.-based AI companies account for a steadily shrinking percentage of global transactions, but remain ahead in transaction value.
    - AI investment in Western Europe, Israel, India, Japan, and Singapore is growing quickly by all metrics.

3. **While active in AI both at home and abroad, Chinese investors are minor players in markets outside China. (*moderate confidence*)**

    - Seven percent of the transactions in our dataset involved at least one disclosed Chinese investor (whether alone or together with additional Chinese or non-Chinese investors). These transactions typically involved Chinese targets.
    - In 2019, disclosed Chinese investors participated in only 2 percent of investments into U.S. AI companies, down from a peak of 5 percent in 2016.

4. **Mergers and acquisitions (M&A) activity accounts for a significant share of AI investment outside China. (*moderate confidence*)**

    - Outside China, total M&A value may have exceeded venture capital value from 2015 to 2019, based on estimates of M&A transactions with undisclosed values.
    - Including M&A transactions significantly reduces Chinese companies' share of the market. Chinese restrictions on foreign investment may play a role.

5. **Most privately held AI companies focus on transportation, business services, or general purpose applications. However, Chinese AI companies may be more likely to focus on certain applications. (*moderate confidence*)**

    - Compared to the United States and the rest of the world, investment into Chinese AI companies is concentrated in transportation, security and biometrics, and arts and leisure.
    - China's active industrial policy, and the United States' greater reliance on the private sector, may help explain these differences.

6. **National security applications attract little direct private-market investment. (*high confidence*)**

    - While many AI technologies might be adapted for government use, just a tiny percentage of all AI companies receiving investment make products designed specifically for government and military use.
    - However, security and biometrics applications such as facial recognition, which have obvious governmental uses, account for a larger share of private-market investment in China than elsewhere.

7. **In the aggregate, when they invest outside China, Chinese investors do not seem to disproportionately invest in different AI applications from non-Chinese investors. (*low to moderate confidence*)**

    - Our data do not indicate that Chinese equity investors disproportionately seek out defense-relevant AI companies when investing outside China.
    - Although some China-based investors clearly invest abroad to extract security-sensitive information or technology, our data suggest they are probably a relatively small piece of a larger and more diverse AI investment market.

For U.S. policymakers, these findings are cause for some optimism. America's AI startups and other privately held AI companies lead the world in attracting equity investment. Little evidence suggests that America's closest AI competitor, China, is narrowing the overall gap according to this metric, and Chinese investors don't seem to be co-opting privately held U.S. AI companies in large numbers through the equity investment marketplace.

At the same time, the findings point to significant challenges for the United States. America's technological leadership is often taken for granted, but the United States has no monopoly on commercial AI activity. Other countries collectively account for a large and, by some metrics, growing share of the investment measured in this paper. And although the U.S. AI sector is booming, few of the American AI companies examined focus on national security or other governmental priorities. In some priority areas, such as transportation and security, America's lead in investment over China, its closest competitor, shrinks or even disappears. Finally, with respect to technology transfer, the aggregate trends explored in this paper can mask troubling transactions and developments at the level of individual companies and technologies. Finding these needles in the haystack of the broader market, and addressing them without unduly disrupting that market, will present a regulatory problem in the years to come.

This report explains our findings in detail, presenting the methodological choices, the assumptions shaping them, and the numbers supporting them. Our findings are subject to two basic caveats. First, they are not comprehensive. We measure only one aspect of commercial AI activity: equity investment flows into AI companies that are not publicly traded. While our approach provides meaningful insight into AI innovation and growth in the commercial sector, the numbers in this paper are not meant to measure all such activity. In addition, our dataset ends in late 2019 and does not cover more recent shifts in AI investment—including shifts related to the COVID-19 pandemic, certain to reshape AI investment in coming years.

Second, our numerical calculations are estimates. Defining AI investments and AI companies is inherently subjective, and the "AI hype" phenomenon increases uncertainty. Moreover, implementing these definitions always entails some error, and even the best available investment datasets have gaps. Our analysis of Chinese investment patterns also involves simplifying assumptions. Most importantly, we only count publicly disclosed Chinese investors and generally assume organizational investors have the nationality of the countries where they are headquartered, which could lead us to underestimate Chinese investors' activity to some degree. Despite these unavoidable uncertainties, our basic findings (particularly those described as "high confidence") would be unlikely to change under a range of alternative approaches or assumptions.

Introduction

AI is a rapidly evolving technology with profound implications for national security.[1] Today, for-profit businesses around the world drive progress in AI and other emerging technologies. Former Secretary of Defense Ashton Carter recently reflected that in the mid-20th century, "all technology of consequence for protecting our people, and all technology of any consequence at all, came from the United States and came from within the walls of government. Those days are irrevocably lost. . . . [now] I've got to go outside the Pentagon no matter what."[2] Although Carter may have overstated the case somewhat, few dispute that business leads in many aspects of AI innovation today.

Defining AI

Artificial intelligence is a broad term with no single authoritative definition. This paper defines AI as:

1. The capability of a non-human system to perform functions typically thought of as requiring human intelligence, such as reasoning, recognizing patterns or understanding natural language.
2. A field of study dedicated to developing these systems.

AI is sometimes used interchangeably with machine learning, a set of techniques by which a computer system learns how to perform a task through recognizing patterns in data and inferring decision rules, rather than through explicit instructions. However, AI and machine learning are not identical. Machine learning is one prominent set of techniques used to develop AI, but others exist.

COMMERCIAL AI ACTIVITY AND NATIONAL SECURITY

Commercial AI activity supports America's national security directly and indirectly. Most directly, the Department of Defense (DOD) and other federal agencies buy tailor-made AI products and services from the private sector. Many smaller AI companies and AI consultancies within traditional government contractors target the government as their niche, and large multinationals such as Google, Amazon, and Microsoft sell AI to federal customers.[3] More significantly, governments and those that cater to them rely on basic AI tools and techniques produced by for-profit companies. These include software like Google's TensorFlow and Facebook's PyTorch; commercially developed algorithms for image recognition, language processing, and other AI applications; and essential hardware components, such as computer chips tailored for machine learning and sensors for autonomous navigation.[4] America's private sector also supports the world's broadest and deepest AI talent pool—an essential national security resource that the DOD and other federal agencies increasingly seek to mobilize.[5] Finally, commercial AI innovation contributes to economic prosperity both at home and abroad, indirectly but pervasively sustaining U.S. national security.[6]

However, non-state actors' leading role in AI innovation also poses critical national security challenges. America's competitors and adversaries have their own AI companies to draw on, and can also access U.S. companies' innovations in licit and illicit ways.[7] As the 2018 National Defense Strategy warns, "[t]he fact that many technological developments will come from the commercial sector means that state competitors and non-state actors will also have access to them, a fact that risks eroding the conventional overmatch to which our nation has grown accustomed."[8] In a world where cutting-edge software is shared openly and globally, leading tech companies conduct research and sell products on multiple continents, and startups proliferate across the world, commercial AI innovation may not always benefit the United States.

The federal government may not be in the driver's seat for AI, but it has tools to help align AI innovation with America's national security needs. Policymakers can use acquisition, fiscal support, and federal research to fill strategically important gaps in private-sector AI activity.[9] They can pursue broader, structural policies—from AI standards development to immigration reform—to keep America's private sector vibrant and innovative.[10] And they can restrict foreign access to and interference with security-sensitive AI companies using a variety of tools, including foreign investment review, export controls, and counterintelligence operations.[11]

EXISTING ANALYSES OF COMMERCIAL AI ACTIVITY

For these tools to work and to avoid unwanted side effects in the market, policymakers should understand where commercial AI activity occurs, who funds it and carries it out, which real-world problems AI companies are trying to solve, and how all of these facets are changing over time. A number of recently published analyses, summarized in Appendix 4, shed light on these questions by estimating financial investment flows into AI-related companies. As discussed in Section 2, this is an imperfect but generally reasonable way to assess commercial AI activity. However, existing analyses vary widely in their specific methodologies, and often fail to adequately describe those methodologies and the underlying data sources.[12] We hope to provide a clearer, more thoroughly documented analysis in this paper.

1 Methodology and assumptions

This section explains our research methodology, data sources, and key uncertainties and assumptions, with further detail provided in Appendix 1. The code and aggregate data supporting our results are available online.[13]

OVERVIEW AND CONFIDENCE

In brief, we measured AI investment by measuring **equity investment** into **privately held AI companies**—that is, AI-focused companies not traded on a stock exchange. We relied on financial data from Crunchbase and Refinitiv, two leading data vendors. To identify AI companies, we searched across company descriptions in both of these sources for keywords and keyword combinations indicating activity consistent with our definition of "AI companies."[14] Then, we used Crunchbase data to count investments in these companies, add up their aggregate disclosed value, and estimate the total value of all the investments, including investments for which actual values were not disclosed.[15] Finally, we calculated subtotals based on the location of the investment target, the nationality of the investors participating in the investment (when disclosed), whether the investment was M&A-related, and the primary application area of the investment target.

Our analysis is subject to two basic caveats. First, our measurements do not cover *all* AI-related investments or commercial AI activity. We measured only one aspect of that activity: financial investment flows into privately held AI companies. This approach provides meaningful insight into AI innovation and growth among for-profit businesses, but it cannot comprehensively measure those dynamics. And because our analysis ends in 2019, it does not capture more recent shifts in AI investment, including those caused by the COVID-19 pandemic.[16]

Second, our measurements are only estimates. We use leading databases in our analysis, but no database perfectly covers the entire market. Crunchbase and Refinitiv are English-language, Western-based services and may undercount China-bound investments to some extent. Also, like any other method of measuring AI activity, ours involves human judgment calls. For example, there is no single, objective definition of an "AI company." While we believe our definition provides a reasonable starting point, it leaves out some companies and transactions other analysts might describe as AI-related and includes some companies and transactions other analysts might exclude.[17] And because we rely in part on relatively superficial public data when analyzing Chinese investment activity, we likely miss some transactions other analysts might link to Chinese actors.

COVID-19 and the future of AI investment

Our analysis ends in late 2019, before the COVID-19 pandemic developed. The pandemic and related economic disruptions are expected to have massive effects on global equity investment markets in the coming months and years. It's too early to predict how COVID-19 will affect countries' relative standing in terms of AI investment, but absolute investment will probably decline in 2020 across all markets.[18] The 2015–2019 trends described in this paper are unlikely to extrapolate neatly into 2020 and beyond.

To account for these uncertainties, we provide a confidence level for each of our findings. Our higher-confidence results are replicable using a wide range of plausible alternative definitions and data sources; these findings are also consistent with evidence and analyses from other sources. Findings with lower confidence levels are more sensitive to the assumptions we draw and the quality of our data.

WHY EQUITY INVESTMENT?

We assess AI activity in the commercial sector by measuring equity investment—that is, investments involving a transfer of equity in the investment target to the investor(s), including venture capital rounds, private equity transactions, and corporate mergers and acquisitions. Although this approach has important limitations, we believe it is a reasonable starting point.

Measuring equity investment provides useful insight into private-sector AI activity. For example, compared to lenders and other types of funders, such as grantors and crowdfunders, equity investors tend to exercise more control over the companies in which they invest.[19] In that sense, equity investment trends are especially important for national security policymakers, because assessing these investment flows

can indicate who may be in a position to influence or extract value from private AI companies.[20]

Equity investment flows also correlate with the size and prospects of their targets, that is, the AI companies receiving investment. Because of this, measuring equity investment into AI companies helps understand the health of these companies and the broader AI sector. Companies with good access to equity investment tend to be more innovative, productive, and financially successful,[21] and countries with active equity investment markets have higher growth and attract more businesses, especially early-stage businesses.[22]

Key terms

In this paper, **mergers and acquisitions** (M&A) refer to investment transactions in which 100 percent of the equity (ownership interest) of the target company is sold. Mergers create new corporate entities with new ownership and business structures; in acquisitions, an investor takes over a target, but the investor's business structure remains intact. Our analysis groups mergers and acquisitions together.

Other equity investments are grouped together under the label of **venture capital and private equity** ("VC/PE"). The term **private equity** usually refers to the purchase and sale of equity interests that are not available to the general public—typically, because the interests are not listed on a stock exchange. While many M&A transactions can also be considered private equity transactions, this paper reserves "private equity" for transactions in which less than 100 percent of the target company's equity is sold.

Venture capital (VC) can be considered a subset of private equity. Although some VC deals are quite large, venture capital transactions most often involve smaller, earlier-stage target companies and smaller investment amounts.[23]

At the same time, equity investment flows have important limitations as an indicator of commercial AI activity. Most importantly, these flows only *indirectly* reflect companies' AI activity. Companies with more funding may tend to produce more and better products, but this relationship is far from straightforward given the many steps between investment and business success and the relatively open nature of AI technology.[24] Causation flows both ways: investment helps companies succeed, and successful companies attract investment. Finally, some equity investors have goals other than innovation and long-term success in mind when buying stakes in compa-

nies—for instance, eliminating their competitors or extracting short-term profit (at the cost of longer-term returns) through strategies such as "asset stripping."[25] These sorts of investments may be less likely to drive AI growth and innovation, further attenuating the link between aggregate investment flows and meaningful AI activity in the commercial sector.

Studying other inputs to AI development could shed more light on this activity. For example, metrics related to hiring or R&D spending by private companies are slightly "closer" to AI companies' finished products and services than the equity investment that funds these activities. We could also try to measure outputs—for instance, AI companies' sales volume, their patenting and publication activity, or their products' performance against technical benchmarks. Those would more directly show whether and to what extent AI companies produce useful products and services.

CSET plans to measure many of these inputs and outputs in future work, in hopes of producing a well-rounded picture of AI innovation among for-profit companies. In the meantime, equity investment flows offer a starting point. Public data on these flows, while patchy, is much richer than available data on other inputs and outputs, such as sales volume and technical performance.[26] Assessing each of those inputs and outputs also entails its own conceptual problems; for example, patenting activity may not reflect true innovation in many cases.[27] Finally, as discussed above, because funding is a basic and essential resource in business, tracking the ebb and flow of one of the dominant sources of this funding—equity investment—can provide an incomplete but informative picture of activity in the commercial sector.

COMPANIES INCLUDED AND EXCLUDED

In addition to focusing on equity investment, this analysis is limited to investments in privately held AI companies.

"AI companies" include all companies whose core products and services rely on artificial intelligence, or who produce hardware designed specifically to develop or implement artificial intelligence. Examples in the first group include AI software publishers and startups applying AI techniques to real-world problems, such as autonomous navigation, industrial process control, customer service, and marketing. Examples in the second group include AI chip designers and manufacturers. To identify these companies, we ran a keyword-based search query against business descriptions in commercial datasets. As discussed in Appendix 1, we believe this method is reasonable, but we acknowledge its imperfections. Notably, because it relies on companies' self-descriptions, it may count companies (and, in turn, investments) with a less strong connection to AI—for example, companies that apply relatively less advanced AI technologies or simply engage in "AI hype." This could make our investment estimates higher than they would be with a more restrictive definition.

"Privately held" AI companies include for-profit enterprises whose shares were not traded on a stock exchange at the time of investment. "Privately held" does *not* necessarily mean independent from the state; a state-owned or state-supported company could be "privately held" by this definition and included in our calculations as long as its shares are not publicly traded on a stock exchange. This distinction is most relevant for companies in China and other countries with heavy state involvement in commerce.[28]

By excluding publicly traded companies, our analysis omits many of the most important companies in AI—from Alphabet, Microsoft, Amazon, and Facebook in the United States to Tencent, Baidu, and Alibaba overseas. Concentrating on "AI companies" also excludes diversified companies that are not AI-focused but have significant AI activities.[29]

Ultimately, determining whether and to what extent investments into diversified companies, including the publicly traded "tech giants," are AI investments proves difficult. For example, Alibaba is a major global player in AI research, development, and commercialization, but also operates e-commerce platforms, mobile payment systems, retail shops, and logistics and warehousing facilities, among others.[30] While Alibaba raised $25 billion in a 2014 IPO, it's not clear how much of this investment went toward Alibaba's AI activities versus activities in which AI played a tangential role or none at all.[31] Our analysis therefore ignores this $25 billion equity investment in Alibaba,[32] and a great deal of AI-related equity investment into other diversified and/or publicly traded companies, in exchange for greater certainty that the investment we *do* capture is consistently AI-related.

Although these exclusions make our analysis less comprehensive,[33] focusing on privately held, AI-focused companies still provides insight into a critical segment of commercial AI activity. The startups and other, early- and mid-stage, privately held AI companies we focus on are not the only companies driving AI forward. Yet they play an important role in AI innovation, growth, and talent development,[34] and almost certainly comprise a large majority of all companies focused on AI.[35]

DEFINING COMPANY AND INVESTOR NATIONALITY

Many of our findings address the activity of companies and investors of different nationalities, such as "American companies" and "Chinese investors." These findings are subject to two important caveats.

First, many investors in AI-related equity transactions are undisclosed. Some of these undisclosed investors may be Chinese (for example), and to the extent they are in fact Chinese, our analysis doesn't count them as such.

Second, and more significantly, our method for identifying nationality may undercount Chinese investors relative to other methods. We assume each company has the nationality of the country where it is headquartered. Similarly, we assume

each organizational investor has the nationality of the country where it (in the case of corporate investors) or its managing entity (in the case of VC and PE funds) is headquartered, according to the Crunchbase dataset. Given increasing concern among policymakers about the influence of Chinese entities over non-Chinese companies, this assumption is especially salient to our analysis of Chinese investors.[36] We count an investor as Chinese only if it is headquartered in China according to our data sources. For example, an investment firm or M&A acquirer based in New York generally would be classified as American in our analysis, even if (for example) it had significant Chinese investors or engaged in a major joint venture with a Chinese company.

We explain these issues in greater detail in Appendix 1. Overall, our method probably somewhat undercounts investors others might reasonably describe as "Chinese," but we remain moderately confident in our related higher-level findings. Nonetheless, this probable undercounting is an important source of uncertainty in our analysis.[37]

DEFINING COMPANIES' PRIMARY APPLICATIONS OF AI

Finally, to better understand the markets and needs met by today's AI companies, we developed a set of 17 different AI applications—that is, 17 different real-world uses of AI technology AI companies might focus on. We describe this taxonomy in greater detail in Appendices 1 and 3. To be clear, our approach doesn't draw distinctions in terms of business maturity, technological maturity, sales strategy, or other ways analysts might classify AI companies. Under this approach, an early-stage startup developing novel machine learning techniques and a larger, well-established company applying proven AI methods would be placed in the same application category—medicine and life sciences—if both specialized in AI-assisted drug discovery (for example).

CSET analysts assigned each AI company in our dataset the application that best described the company's activity, taken as a whole. This method allowed us to measure aggregate investment flows by primary application. Again, these measurements are estimates. As discussed in greater detail in Appendix 1, in some cases, different annotators might reasonably classify the same company in different application categories, so the precise numbers we present matter less than the rough magnitude of activity they indicate across different applications.[38]

2 Findings

THE UNITED STATES HAS THE WORLD'S LARGEST INVESTMENT MARKET IN PRIVATELY HELD AI COMPANIES (*MODERATE TO HIGH CONFIDENCE*)

The AI market is quickly expanding, and most observers expect it will grow even faster in the future.[39] Nations with vibrant commercial AI sectors stand to benefit both economically and militarily.[40] Equity investment is fuel for these national AI sectors, so the distribution of AI-related equity investment today helps show which countries are best positioned to reap these benefits over the coming decades.

Globally, investment in AI companies has increased tremendously over the past five years. In 2019 alone, we estimate that privately held AI companies attracted nearly $40 billion in disclosed equity investment across more than 3,100 discrete transactions. Because some transactions do not have publicly disclosed values, total transaction value could have been significantly higher—as much as $74 billion, by our estimate.

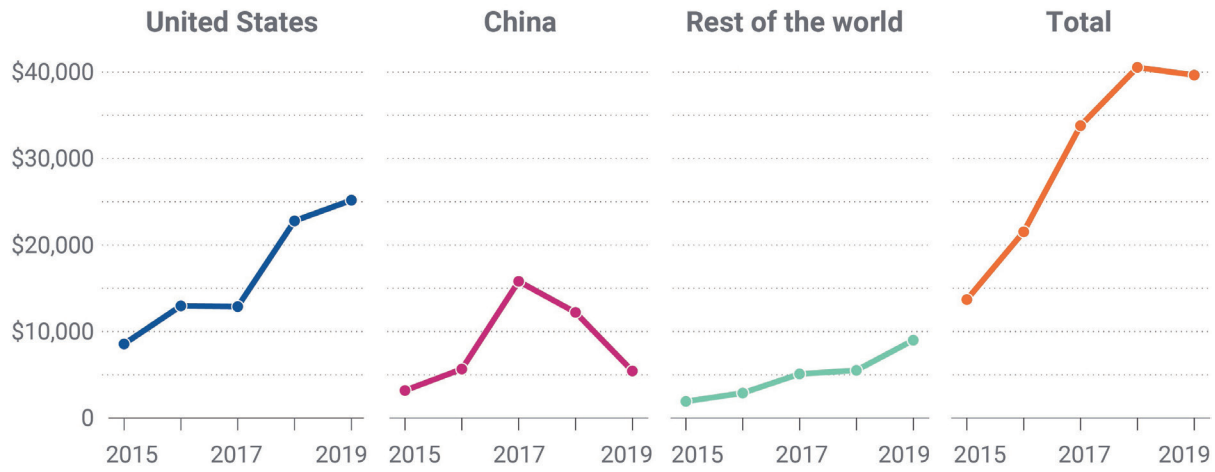
In many cases, CSET's topline investment estimates diverge from estimates by other analysts. Appendix 4 compiles some of these estimates and explains why our calculations may differ. For example, other analyses may omit M&A transactions, use different investment data sources, or define "AI companies" and "AI transactions" more narrowly or broadly than CSET.

In 2019, U.S.-based companies accounted for the majority of disclosed investment value: $25.2 billion, or 64 percent of the global total, across 1,412 discrete transactions.[41] China is the world's second biggest market by disclosed value, and rivaled the United States in scale by 2017. But since then, investment into China-based AI companies appears to have shrunk dramatically, consistent with broader trends in China's tech sector.[42] China's contraction, along with slower growth in the U.S. market, contributed to a leveling off in global disclosed investment value from 2018 to 2019.

FIGURE 1

Total disclosed value of equity investments in privately held AI companies, by region of investment target

IN MILLIONS OF U.S. DOLLARS



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

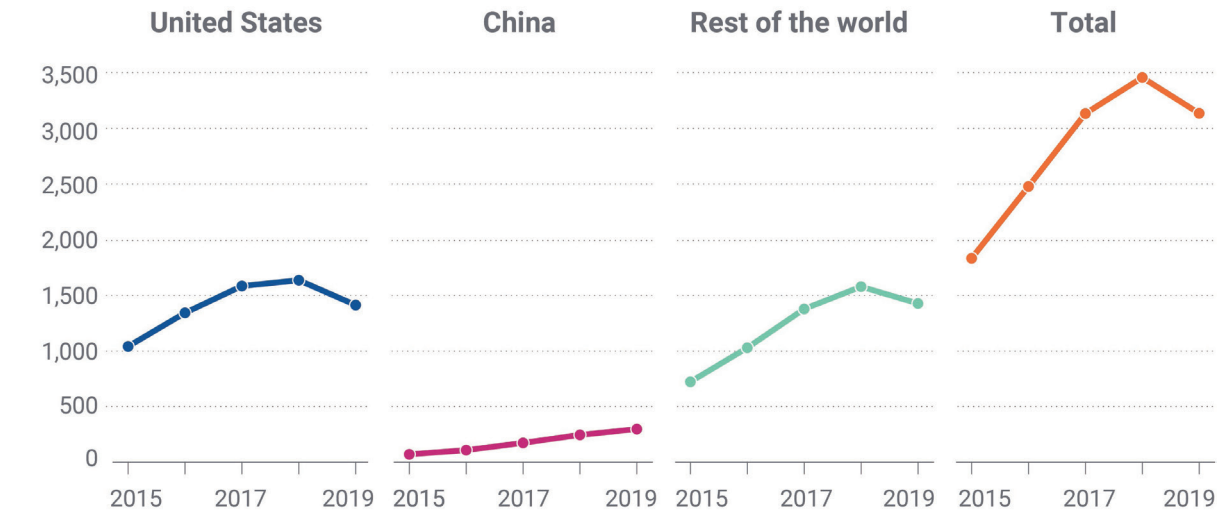
In many AI investment transactions, the investment amount is never revealed publicly. As a result, Figure 1—based on disclosed investment values—gives an incomplete picture of AI-related investment flows. We use two other metrics, investment count and estimated total value, to develop a clearer view of the market as a whole.

Figure 2 shows the number of AI investment transactions ("investment count") in our dataset in each region. Chinese AI companies account for a smaller proportion of investment count than disclosed investment value, while countries other than the United States and China account for a much larger share of investment count than disclosed value.[43] In fact, counting individual investment transactions shows that in 2019 those countries collectively overtook the United States in terms of transaction

count.[44] China lags behind the United States, but leads any other country. However, English-language datasets likely undercount investments in Chinese companies, especially smaller and earlier-stage transactions.[45] While this affects our analysis,[46] the data disparity is large enough to persist even if China-bound investments were several times more numerous than our counts indicate. (We plan to incorporate Chinese-language investment datasets into our analysis in future work.)

FIGURE 2

Total count of equity investments in privately held AI companies, by region of investment target



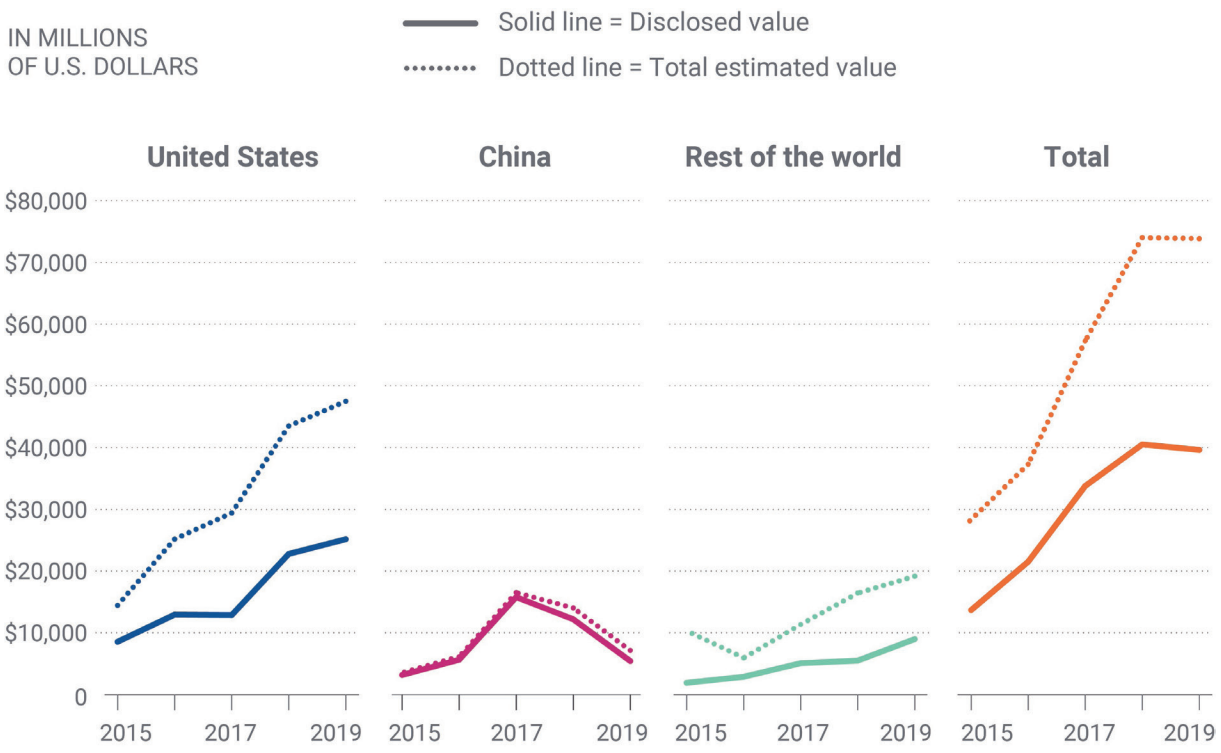
SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

Finally, Figure 3 presents our estimates of total investment value, which includes estimated values for investments with undisclosed actual values. Based on these estimates, we find that AI investment volume is significantly higher than disclosed values would imply—especially for investments into companies outside the United States and China. Figure 3 presents revised dollar totals that include these estimated values, which we calculated using median values from disclosed-value investments with comparable features (e.g., funding series, target country, etc.).[47] Including the estimated values roughly doubles the global value total, increases the share of value attributable to countries other than China and the United States (in 2019, 23 percent without estimated values, 26 percent with estimated values), and decreases China's share (14 percent and 10 percent, respectively).

These estimated values are rough. We include them to illustrate the potential significance of undisclosed-value transactions; the exact estimated totals are less meaningful. Notably, the incremental estimated value of investments into Chinese companies is relatively small in all years, because the comparable China-bound investments on which our estimates are based tended to have lower disclosed values.[48] It's not clear whether China-bound investments with undisclosed values trend smaller, or whether this reflects limitations in our dataset.

FIGURE 3

Aggregate investment value with and without median-based estimation of undisclosed values, by region of investment target



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

CHINA'S MARKET FADED IN THE LAST TWO YEARS, WHILE INVESTMENT ELSEWHERE GREW (*MODERATE TO HIGH CONFIDENCE*)

Analysts and policymakers often use AI investment statistics in arguments about competition between nations. For example, many have cited Chinese investment totals from various points in time to claim that China is challenging the United States for AI leadership.[49] But trends over time, rather than single data points,

suggest that these claims are often overstated. Meanwhile, our trend analysis indicates that nations other than the U.S. and China appear to be gaining ground quickly in AI investment.

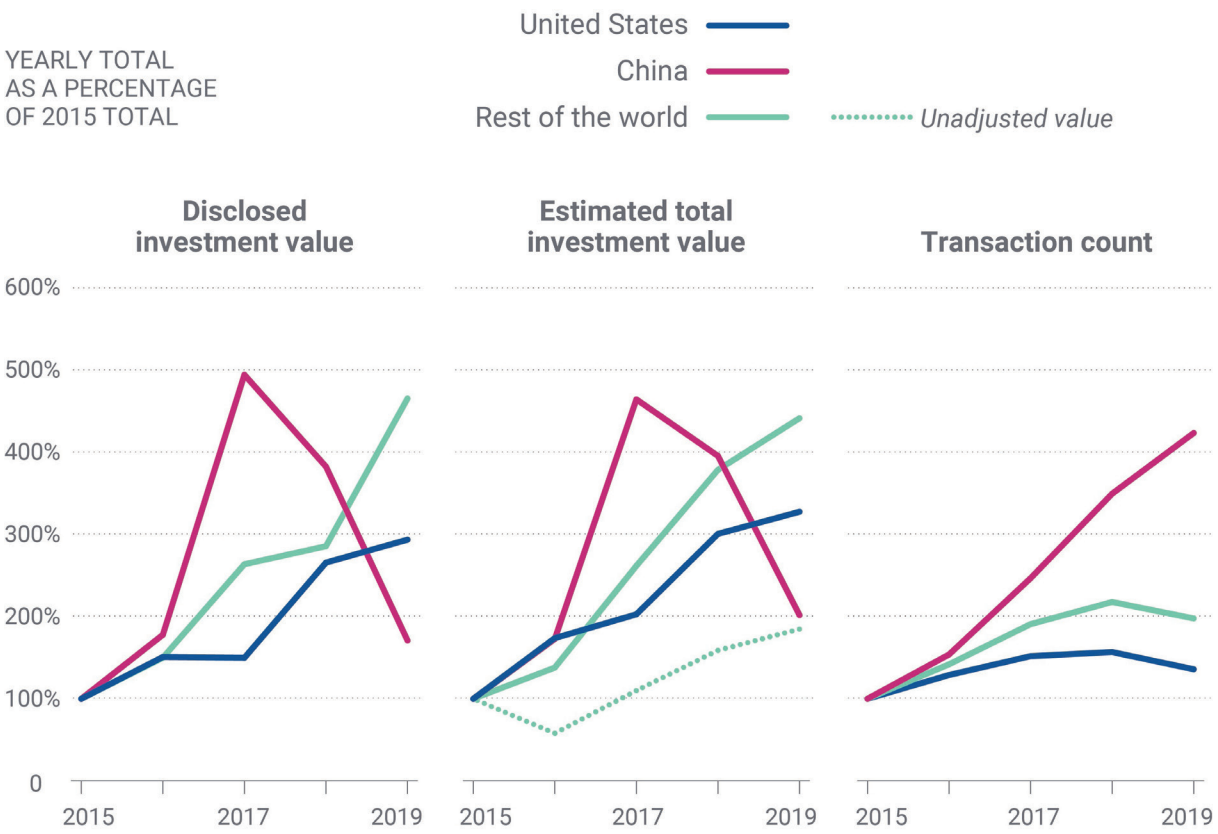
Although global AI investment generally rose from 2015 to 2019, different regions saw different trends unfold:

- China's disclosed investment value—that is, total disclosed value for investment transactions involving China-based targets—roughly quintupled between 2015 and 2017, then fell back to near-2015 levels, consistent with broader financing trends and data from other sources.[50] "Mega-rounds"—venture capital investments into Chinese startups measured in the hundreds of millions or even billions of dollars—were common in China for most of the period studied, but average disclosed transaction value declined dramatically after 2017.[51] Given these findings, arguments based on investment totals from more than a couple years ago may overstate China's presence in global AI investment.
- Measured by value, U.S.-bound AI investment roughly tripled from 2015 to 2019, but growth slowed in 2019; whether this is a momentary pause or the beginning of a broader trend remains to be seen.
- Total investment value into AI companies outside the United States and China grew consistently and rapidly—more than 400 percent (albeit from a small baseline).

Figure 4 tracks investment growth in each of the regions using 2015 numbers as a baseline.

FIGURE 4

Normalized growth in AI investments relative to 2015 baseline, by region of investment target

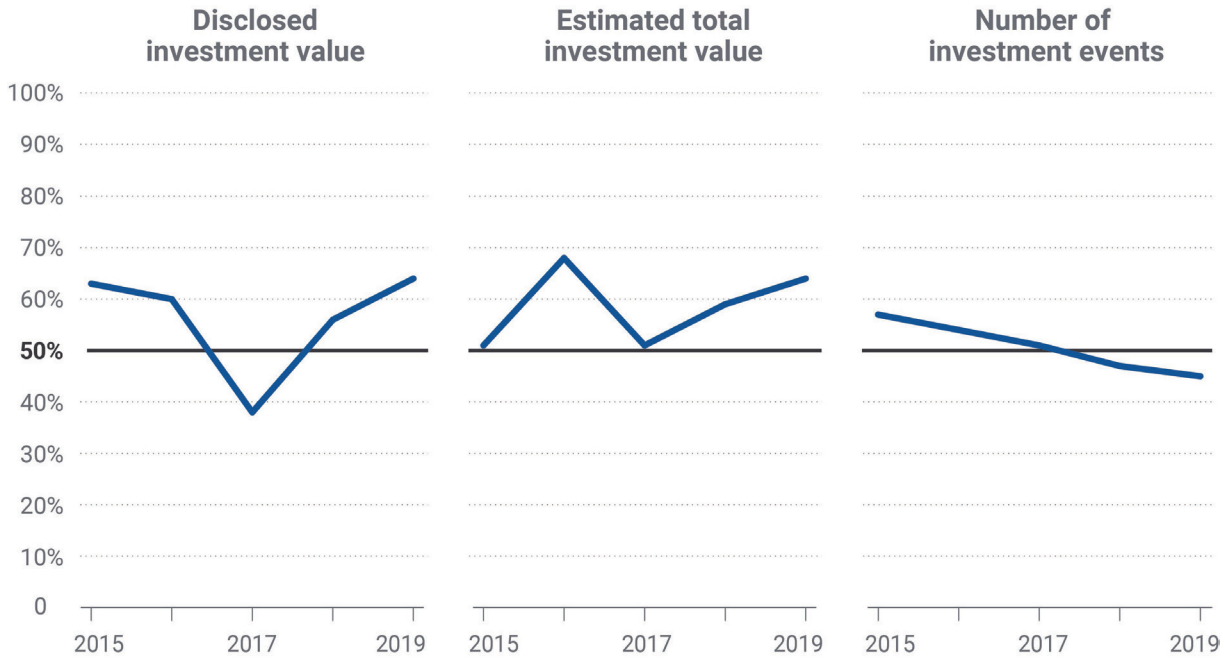


SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA. "ADJUSTED" DATA IN THE SECOND CHART OMITS AN OUTLIER ESTIMATED VALUE FROM 2015.[52]

Between 2015 and 2017, American targets' share of global AI transaction value fell as China's AI market expanded; then, when China's market later contracted, American targets' share recovered. However, American targets' share of global transaction count fell steadily during the period analyzed. In 2019, American firms accounted for fewer than half of AI investment transactions worldwide, but nearly two-thirds of transaction value.

FIGURE 5

U.S. AI companies' share of global investment



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

Meanwhile, AI companies in countries other than the United States and China saw impressive growth in inbound investment over the past five years—boosted, in some cases, by large M&A transactions like Intel's 2019 acquisition of Habana Labs, an Israel-based AI hardware firm.[53] As of 2019, other countries remained behind the United States and China by all metrics, but most were growing rapidly—significantly faster than the two leaders in many cases.

TABLE 1

Investment activity and growth in the top 10 target countries (ranked by disclosed value)

COUNTRY OF INVESTMENT TARGET	DISCLOSED INVESTMENT VALUE, 2019	GROWTH 2015–2019	ESTIMATED TOTAL INVESTMENT VALUE, 2019	GROWTH 2015–2019	DISCRETE INVESTMENT EVENTS, 2019	GROWTH 2015–2019
United States	$25,170	194%	$47,486	228%	1412	36%
China	5,446	71%	7,165	102%	297	324%
Israel	3,056	1109%	5,584	1765%	141	110%
United Kingdom	1,655	189%	2,575	130%	259	82%
Canada	885	307%	1,629	392%	129	55%
India	486	275%	1,072	361%	153	178%
Japan	510	1031%	1,574	3133%	67	347%
Germany	356	164%	802	95%	82	148%
Singapore	314	248%	352	160%	64	88%
France	312	245%	505	94%	54	32%

SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA. TARGET COUNTRIES ARE ORDERED BY DISCLOSED INVESTMENT VALUE IN 2019; DOLLAR AMOUNTS ARE IN MILLIONS. READ AS: "IN 2019, U.S.-BASED AI COMPANIES ATTRACTED ABOUT $25.2 BILLION DOLLARS IN DISCLOSED INVESTMENT, REPRESENTING 194 PERCENT GROWTH SINCE 2015."

WHILE ACTIVE IN AI BOTH AT HOME AND ABROAD, CHINESE INVESTORS ARE MINOR PLAYERS IN MARKETS OUTSIDE CHINA (*MODERATE CONFIDENCE*)

China-based investors—including private venture capital firms, large AI corporations, and state-owned entities—are significant players in AI investment and often invest outside China. Many analysts and policymakers worry these investments could boost the Chinese party-state's AI capacity at the expense of the target nations.[54] However, this risk may be limited because Chinese AI investment outside China in the aggregate appears to be modest.

To track Chinese AI investors' activity, we calculated the number and value of AI company investments with at least one publicly disclosed Chinese investor

participating, whether alone or with additional Chinese or non-Chinese investors. (For example, a venture capital transaction involving a Chinese investor and two non-Chinese investors would be included in these calculations.)

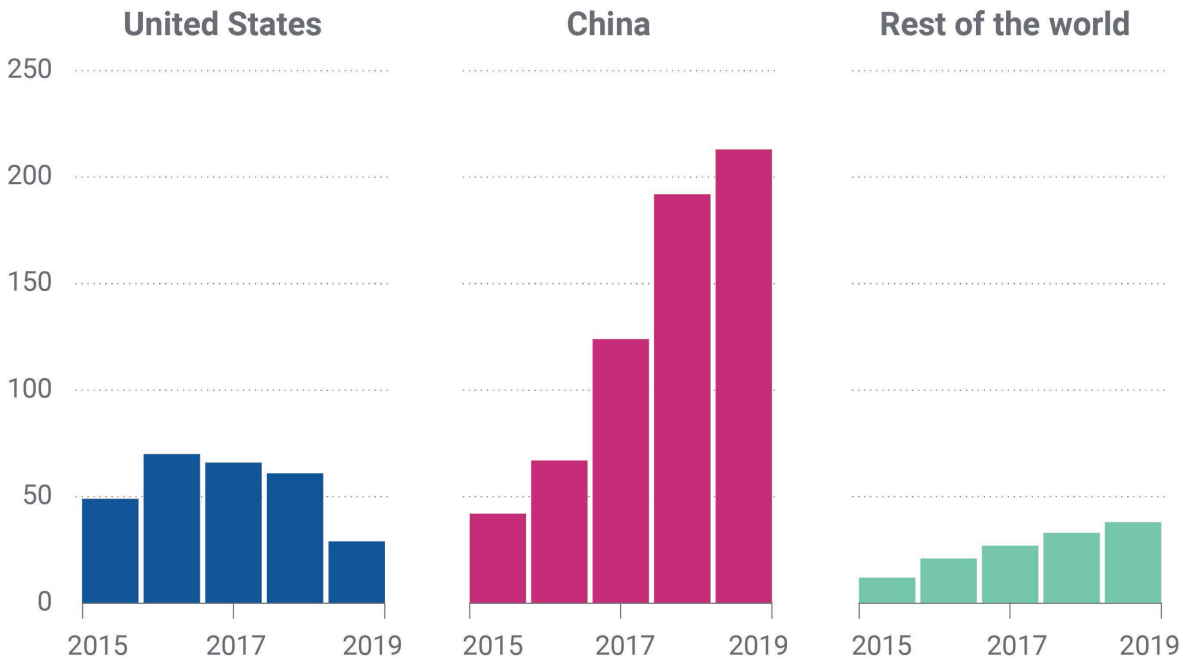
Appendix 1 includes a more detailed explanation of this method and its limitations. Among other caveats, we count only *disclosed* Chinese investors, and as discussed above, generally consider investors "Chinese" only if headquartered in China. For example, a U.S.- or Europe-based investment firm with Chinese indirect or beneficial owners would not ordinarily be counted as Chinese by our methodology. While this method may undercount Chinese investors' activity abroad, our assessment probably would not change even if Chinese investors' activity in the United States was double or triple what we calculate (for example), so we remain moderately confident in our conclusions.[55]

According to our method, from 2015 to 2019, 1,044 of the private-market transactions in our dataset—7 percent of the global total—involved disclosed Chinese investors. These investment events represented about $38 billion in disclosed transaction value (about a quarter of the global total) and about $42 billion in estimat-

FIGURE 6

Regional distribution of targets in investment transactions involving Chinese investors, by region of investment target

COUNT OF INVESTMENT EVENTS WITH AT LEAST ONE CHINESE INVESTOR PARTICIPANT



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

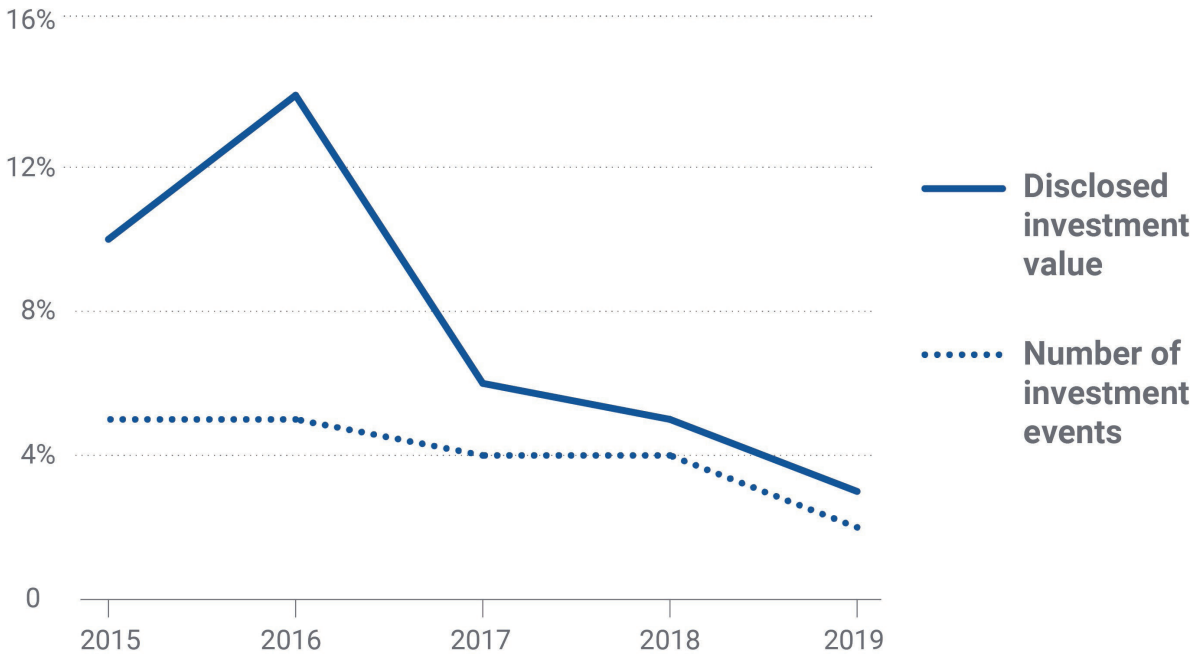
ed total transaction value.[56] However, most of these investments involved Chinese targets. Simply put, the Chinese investors in our dataset generally seem to invest in Chinese AI companies.

U.S. numbers reflect these global trends. As shown in Figure 7, in 2019, about 2 percent of all investments into U.S. AI companies—about 3 percent of disclosed transaction value—involved disclosed Chinese investors. These numbers are down from their 2016 highs (5 and 14 percent, respectively). Heightened regulatory review enacted pursuant to the Foreign Investment Risk Review Modernization Act of 2018 and changing priorities at the Committee on Foreign Investment in the United States almost certainly play a role in these numbers.[57] However, these policy changes can't entirely explain the trends: even before they occurred, Chinese investors were scarce in the U.S. AI market, and becoming scarcer. More fundamentally, Chinese venture capital investment into the United States was minimal as recently as 2013; despite significant growth since then, it still comprises a small share of the overall U.S. market.[58] Domestic regulatory developments in China, including 2016 and 2017 restrictions on outbound investment, may have also slowed AI-related investment in the past three years.[59]

FIGURE 7

Share of U.S.-bound investments with Chinese investors

PERCENTAGE OF ALL INVESTMENT INTO U.S.-BASED AI COMPANIES



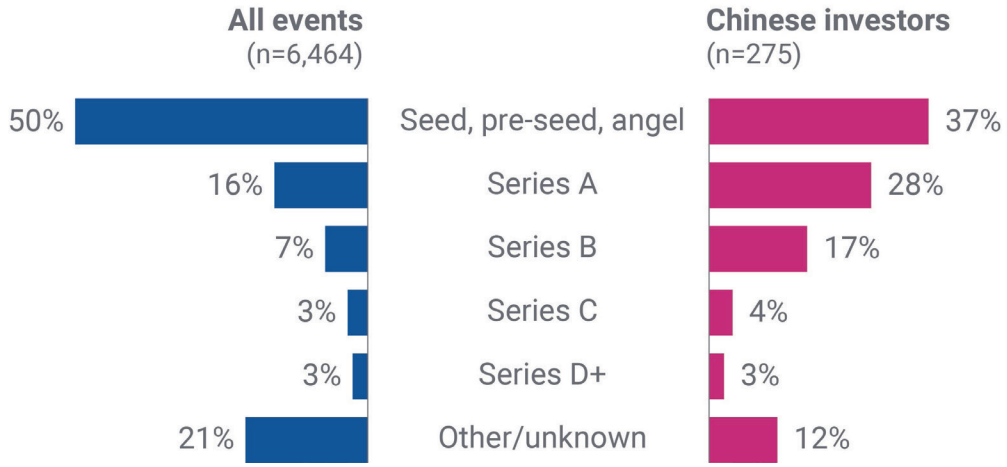
SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

Finally, over the period studied, Chinese investors were more likely to participate in early- to intermediate-stage venture financings of U.S.-based companies (Series A, Series B), and less likely to participate in very early-stage financings, such as pre-seed and seed rounds.[60] This is not especially surprising, since seed investors tend to invest locally—although that may be changing.[61]

FIGURE 8

Count of U.S.-bound investments with Chinese investors, 2015–2019, by investment stage (excluding M&A)

COUNT OF INVESTMENT EVENTS WITH U.S.-BASED AI COMPANY TARGETS



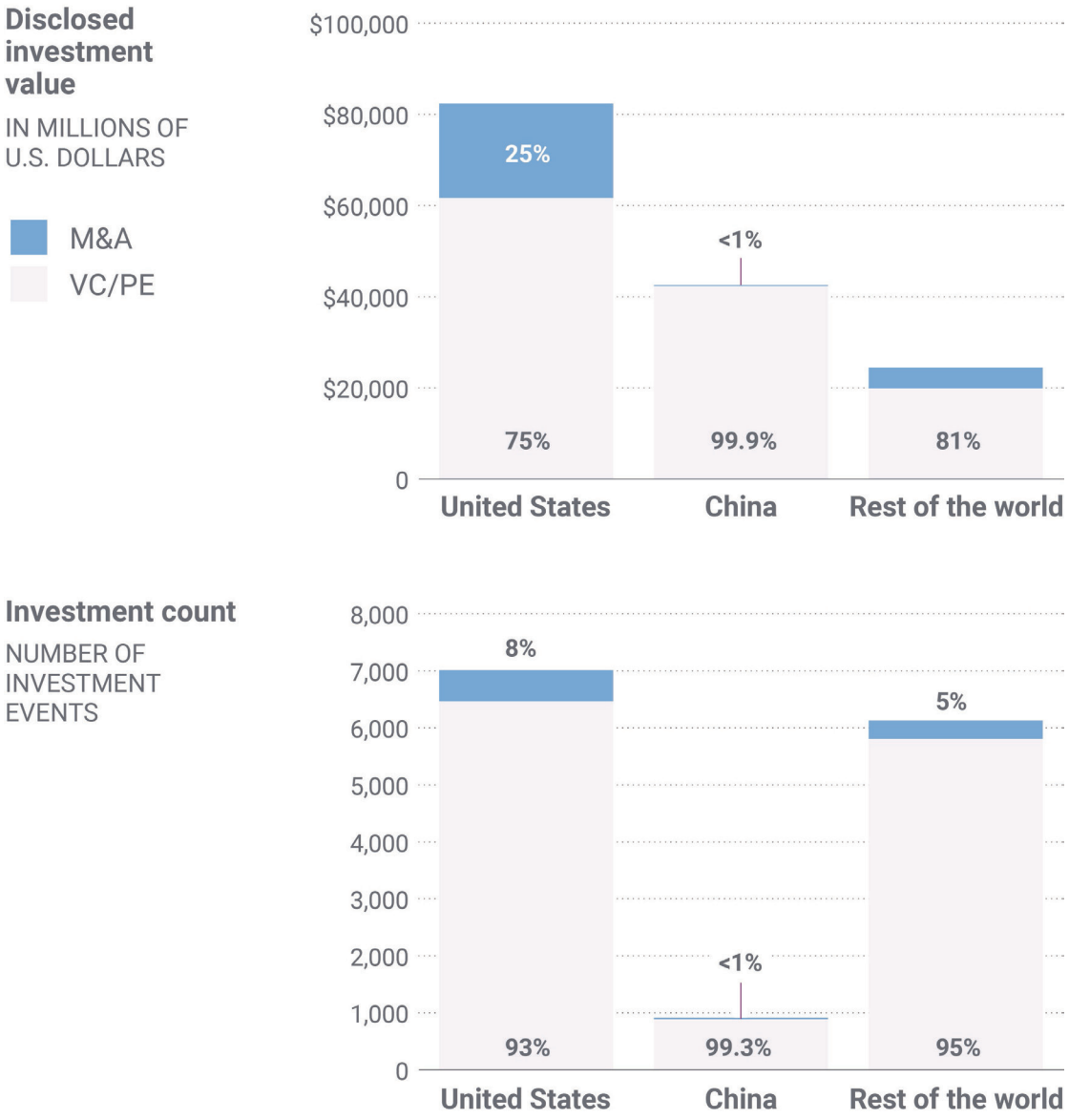
SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

M&A ACTIVITY ACCOUNTS FOR A SIGNIFICANT SHARE OF AI INVESTMENT OUTSIDE CHINA (*MODERATE CONFIDENCE*)

Analyses of national strength in AI often focus on venture capital, but according to our data, corporate mergers and acquisitions are a comparable or even larger source of investment capital for privately held AI companies. While venture capital transactions outweigh M&A transactions in our dataset, M&A accounts for a large share of disclosed value, especially among transactions with non-Chinese targets (as discussed below). We include M&A transactions in which large, publicly traded companies are buyers, despite excluding investment transactions in which they are targets.[62]

FIGURE 9

Nature of investments by target region, 2015–2019

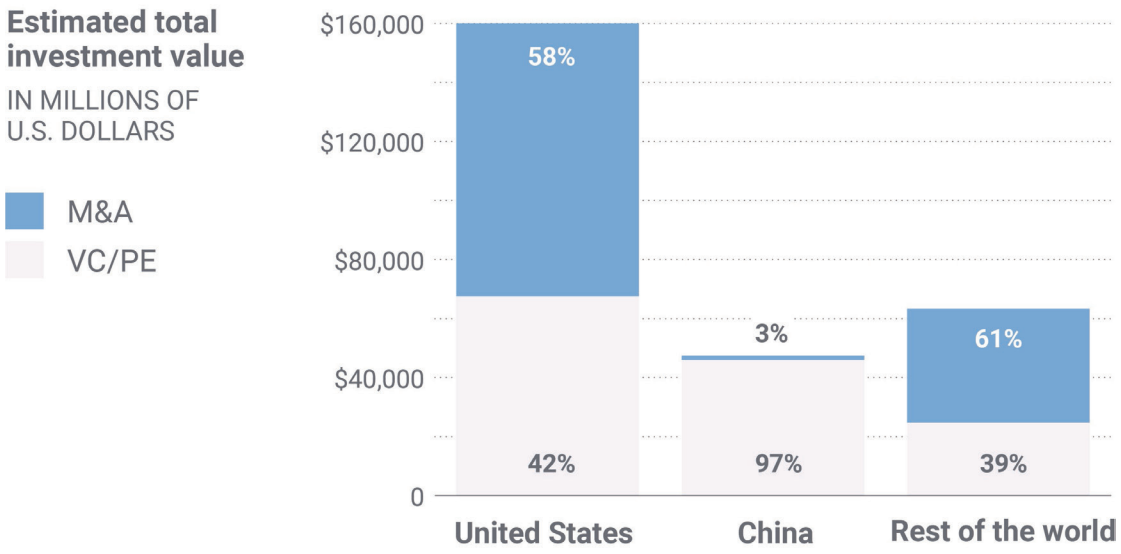


SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

Disclosed-value totals probably significantly understate M&A's share of the market, because many AI companies sell for undisclosed amounts. In fact, nearly 90 percent of the M&A transactions in our dataset lack disclosed values.[63] When we estimate amounts for M&A transactions with undisclosed amounts using medians from comparable transactions,[64] we find that M&A value may have even exceeded venture capital value outside China over the period analyzed. While imprecise, these estimates suggest M&A activity is a critical element of the AI funding ecosystem.

FIGURE 10

Estimated total investment value by nature of investment and target region, 2015–2019



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

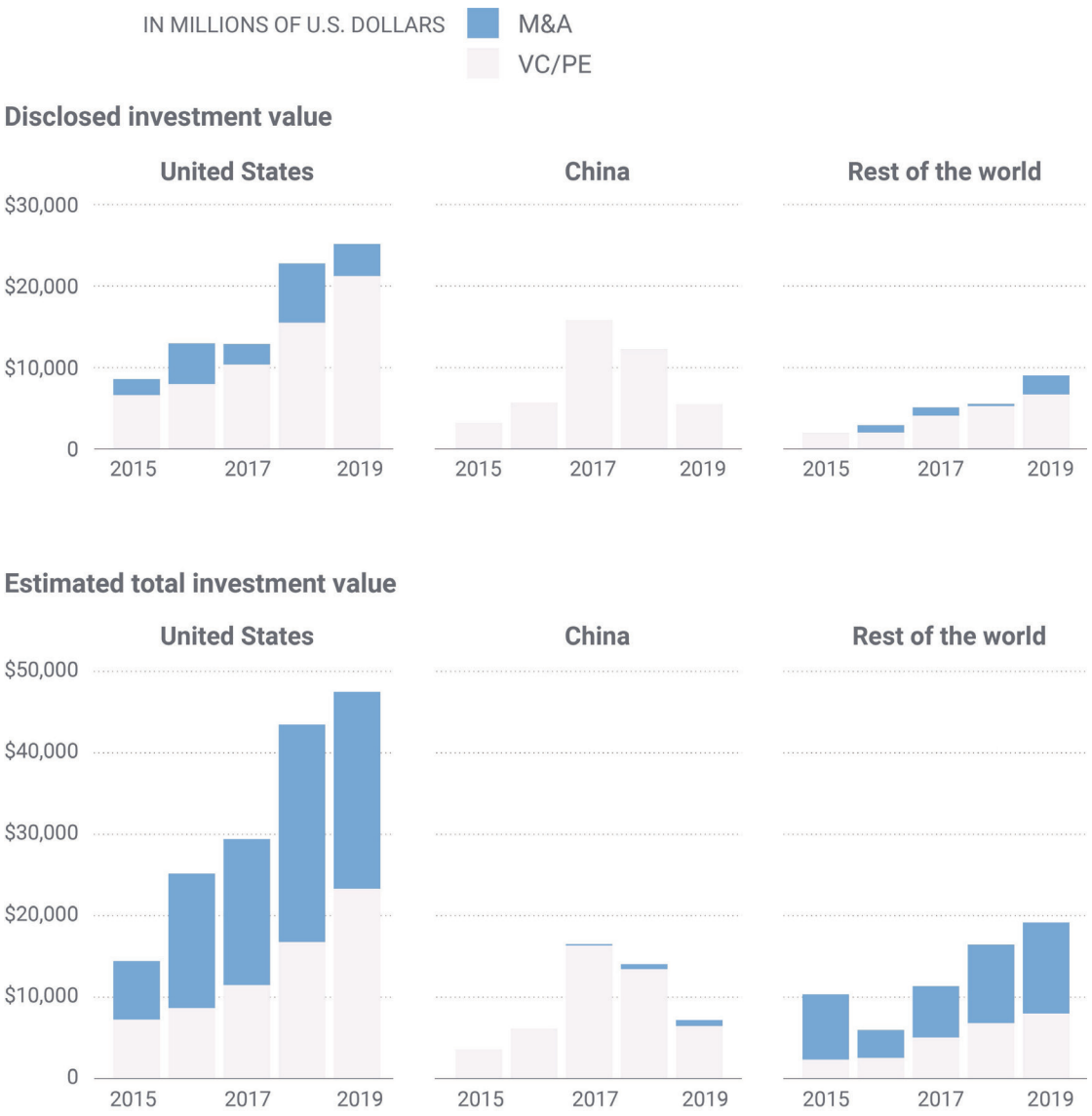
According to our data, Chinese AI companies are less likely to be M&A targets, and M&A accounts for a smaller share of aggregate investment into these companies. That does not necessarily mean Chinese AI companies are less innovative or promising. Rather, several factors could discourage China-bound AI M&A. Foreign buyers may face regulatory or political obstacles to acquiring Chinese AI startups: over most of the period studied, Chinese investment controls prevented many would-be M&A buyers from accessing the Chinese market.[65] Older, cash-rich U.S. tech incumbents may be more interested in acquisitions as a means of eliminating smaller competitors, and for reasons of proximity or familiarity, may be more likely to pursue U.S. startups.[66] China also has a much smaller M&A market than the United States, especially recently,[67] and there may be fewer small-scale Chinese AI startups suitable for larger firms to acquire.[68] Finally, English-language data sources may undercount China-bound M&A, but from preliminary review of Chinese-language sources, we do not think this has a major impact on our measurements.[69]

For now, the apparently low level of M&A activity involving Chinese targets complicates claims that Chinese AI companies attract as much private-market equity investment as American companies, or even more.[70] These claims most often cite venture capital statistics from the peak of China's AI investment boom around 2017, and our data indicates that China's venture capital market may in fact have led the

world in disclosed investment value that year.[71] But China had dramatically less M&A activity; when M&A is considered together with other forms of equity investment (venture capital and private equity), the gap between China and the United States narrows or even flips, depending on whether estimated values are included for transactions with undisclosed amounts. According to this broader perspective, China's AI investment boom was less dramatic than initially thought.

FIGURE 11

Disclosed and estimated total investment value by target region and nature of investment



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

MOST PRIVATELY HELD AI COMPANIES FOCUS ON TRANSPORTATION, BUSINESS SERVICES, OR GENERAL PURPOSE APPLICATIONS. HOWEVER, IN THE AGGREGATE, U.S. AND CHINESE AI COMPANIES FOCUS ON DIFFERENT AI APPLICATIONS (*MODERATE CONFIDENCE*)

AI is a general purpose technology, but some of its applications seem more directly relevant to national security than others. Countries that attract more investment in these particular AI applications could enjoy greater "bang for the buck" in terms of national security, so it's important to understand how investment flows are distributed across application areas.

Table 2 and Table 3 divide equity investment in our dataset according to targets' primary application areas, as determined by CSET researchers after examining targets' Crunchbase profiles and websites. (The full methodology behind these tables is discussed in Appendix 1.) By disclosed value, companies active in transportation, business uses (including sales and business analytics), and general purpose tools account for most investment globally. Transaction count is somewhat more evenly distributed, but business uses and general purpose tools still lead the pack. Transportation's share of transaction count is sharply lower than its share of transaction value, possibly reflecting the sector's high capital intensity.

Chinese companies are especially active in areas including security and biometrics (including facial recognition), arts and leisure (including personal social media platforms), and transportation. These application areas attracted a larger share of disclosed China-bound investment than of investment generally. From 2015 to 2019, Chinese AI companies focused on transportation outraised their American peers in absolute terms, and accounted for nearly half of all disclosed private-market investment into Chinese AI companies.[72]

In contrast, business uses, general purpose applications, and medicine and life sciences attracted more investment in the United States and elsewhere. Transaction count was more evenly distributed across regions, although China's market retained a relatively higher concentration of investments in the transportation category.

TABLE 2

Distribution of disclosed investment value, 2015–2019

	REGION OF INVESTMENT TARGET ROW = "Rest of the World."			
APPLICATION AREA	**U.S. (TOTAL $82 BN)**	**CHINA (TOTAL $42 BN)**	**ROW (TOTAL $24 BN)**	**GLOBAL (TOTAL $149 BN)**
Medicine and life sciences	6.8%	1.7%	6.3%	5.3%
Agriculture	2.0%	4.1%	2.0%	2.6%
Transportation	17.3%	46.5%	8.8%	24.2%
Process automation	2.8%	1.2%	1.7%	2.1%
Consumer goods	0.4%	3.5%	0.7%	1.4%
Utilities	1.0%	0.2%	1.3%	0.8%
Construction and field services	0.3%	0.0%	0.4%	0.2%
Security and biometrics	7.4%	13.1%	4.4%	8.5%
Finance	4.9%	1.5%	12.5%	5.2%
Sales, retail, and customer relations	12.6%	1.9%	11.3%	9.3%
Business services and analytics	15.5%	3.5%	15.6%	12.1%
Broadcasting and media production	0.2%	0.0%	0.9%	0.3%
Arts, sports, leisure, travel, and lifestyle	3.2%	14.3%	3.9%	6.5%
Education	0.6%	0.9%	0.8%	0.7%
Military, public safety, and government	0.8%	0.1%	0.4%	0.5%
General purpose	20.0%	6.7%	27.8%	17.5%
Diversified/NOS/Unclear	4.3%	1.0%	1.2%	2.8%

SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA; TARGET APPLICATION AREAS WERE ASSIGNED BY CSET (SEE APPENDIX 1). READ AS: "FROM 2015 TO 2019, AI COMPANIES FOCUSED ON MEDICINE AND LIFE SCIENCES RECEIVED 6.8 PERCENT OF ALL INVESTMENT INTO U.S.-BASED AI COMPANIES, MEASURED BY DISCLOSED INVESTMENT VALUE."

TABLE 3

Distribution of investments, 2015–2019

	REGION OF INVESTMENT TARGET ROW = "Rest of the World."			
APPLICATION AREA	**U.S. (7,012 TARGETS)**	**CHINA (893 TARGETS)**	**ROW (6,130 TARGETS)**	**GLOBAL (14,035 TARGETS)**
Medicine and life sciences	10.2%	9.5%	9.8%	10.0%
Agriculture	1.5%	1.3%	2.5%	1.9%
Transportation	5.7%	14.1%	6.0%	6.3%
Process automation	2.7%	4.5%	3.0%	2.9%
Consumer goods	1.2%	4.4%	1.1%	1.3%
Utilities	1.7%	1.2%	1.9%	1.8%
Construction and field services	1.1%	0.0%	0.5%	0.8%
Security and biometrics	5.7%	5.6%	4.1%	5.0%
Finance	5.7%	6.0%	8.4%	6.9%
Sales, retail, and customer relations	16.4%	9.7%	17.1%	16.3%
Business services and analytics	20.0%	7.8%	17.7%	18.3%
Broadcasting and media production	1.6%	1.1%	1.7%	1.6%
Arts, sports, leisure, travel, and lifestyle	4.4%	2.9%	4.7%	4.4%
Education	2.1%	4.8%	1.7%	2.1%
Military, public safety, and government	0.6%	0.4%	0.5%	0.6%
General purpose	18.0%	22.4%	17.2%	17.9%
Diversified/NOS/Unclear	1.5%	4.0%	2.0%	1.9%

SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA; TARGET APPLICATION AREAS WERE ASSIGNED BY CSET (SEE APPENDIX 1). READ AS: "FROM 2015 TO 2019, AI COMPANIES FOCUSED ON MEDICINE AND LIFE SCIENCES ACCOUNTED FOR 10.2 PERCENT OF ALL INVESTMENT INTO U.S.-BASED AI COMPANIES, MEASURED BY INVESTMENT COUNT."

Fully understanding the roots of these differences is beyond the scope of this analysis, but a few possible causes bear mentioning. To some extent, Chinese public policy drives Chinese companies' emphasis on transportation and security applications of AI. As China deploys surveillance technology throughout the country, the Chinese computer vision sector has come to rely heavily on government procurement.[73] China's government has also subsidized electric vehicles for decades in an effort to "leapfrog" the Western and Japanese automotive industries.[74] These investments in technologically advanced transportation may indirectly benefit AI-focused firms; for example, NIO and Xpeng, two of China's leading EV producers, are also working hard on autonomous driving.[75]

In contrast to China, private firms and investors dominate American AI. The U.S. venture capital and private equity sectors are better developed than China's, and the U.S. government generally takes a less active role in America's economy and financing ecosystem than the Chinese party-state does in China's.[76] Because U.S. AI companies rely more on private venture capitalists and equity investors, their application areas may reflect those investors' particular needs and incentives. And most of these investors face significant pressure to generate double-digit returns on relatively short timeframes.[77] This pressure may push them, and the U.S. AI companies that depend on them, into "low-hanging fruit" application areas, such as business software and advertising, that have clearer pathways to profit.[78] On the other hand, China's state-backed investment funds, banks, and corporate investors may be more willing to invest in strategic AI applications that have higher capital intensity, more risk, or lower expected returns, but are politically favored.[79]

NATIONAL SECURITY APPLICATIONS ATTRACT LITTLE DIRECT PRIVATE-MARKET INVESTMENT (*HIGH CONFIDENCE*)

Unlike many other defense-relevant innovations, AI is a thoroughly "dual-use" technology, and the profit motive is widely believed to be the primary driver of its development.[80] Our data corroborate this belief. Military, public safety, and government applications of AI account for a tiny share of investment in our private-market dataset, as shown in Table 4. Even the broader category of security and biometrics, which we define to include facial recognition, is relatively insignificant, although its share is materially higher in China. Our methods have limitations, and don't capture every company and investment relevant to these applications or any other applications of AI. But even doubling or tripling the national-security related investments in Table 4 would not change the basic conclusion: the vast majority of private-market investments identified went to AI companies not focused on government needs.

TABLE 4

Investments with targets in the "military, public safety, and government" and "security and biometrics" categories, 2015–2019, by target region

	REGION OF INVESTMENT TARGET: APPLICATION AREA ROW = "Rest of the World."					
	U.S.: MILITARY, PUBLIC SAFETY, AND GOVERNMENT	U.S.: SECURITY AND BIOMETRICS	CHINA: MILITARY, PUBLIC SAFETY, AND GOVERNMENT	CHINA: SECURITY AND BIOMETRICS	ROW: MILITARY, PUBLIC SAFETY, AND GOVERNMENT	ROW: SECURITY AND BIOMETRICS
Disclosed investment value	$623	$6,091	$26	$5,553	$96	$1,070
Percentage of overall disclosed investment value	1%	7%	0%	13%	0%	4%
Estimated total investment value	$772	$11,790	$326	$5,843	$106	$3,503
Percentage of overall estimated total investment value	0%	7%	1%	12%	0%	6%
Investment count	44	399	4	50	33	252
Percentage of overall investment count	1%	6%	0%	6%	1%	4%

SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA. DOLLAR AMOUNTS ARE IN MILLIONS. READ AS: "FROM 2015 TO 2019, U.S.-BASED AI COMPANIES FOCUSED ON MILITARY, PUBLIC SAFETY, AND GOVERNMENT APPLICATIONS ATTRACTED $622.9 MILLION IN DISCLOSED INVESTMENT, WHICH WAS 1 PERCENT OF ALL DISCLOSED INVESTMENT INTO U.S.-BASED AI COMPANIES."

That said, given the dual-use nature of AI, government and military users can sometimes adapt AI commercial products to their needs.[81] The potential for adaptation varies among companies. Advances in autonomous vehicles, cybersecurity, and predictive maintenance have obvious defense applications, despite being developed for other markets. On the other hand, defense agencies might have less immediate use for AI tools designed solely to predict consumers' tastes in fashion (for example).

To roughly gauge the amount of investment activity involving companies and products relevant to government and military users, we divided the 17 primary applications of AI into higher- and lower-relevance groups, listed in alphabetical order in Table 5.

TABLE 5
Categories of application relevance

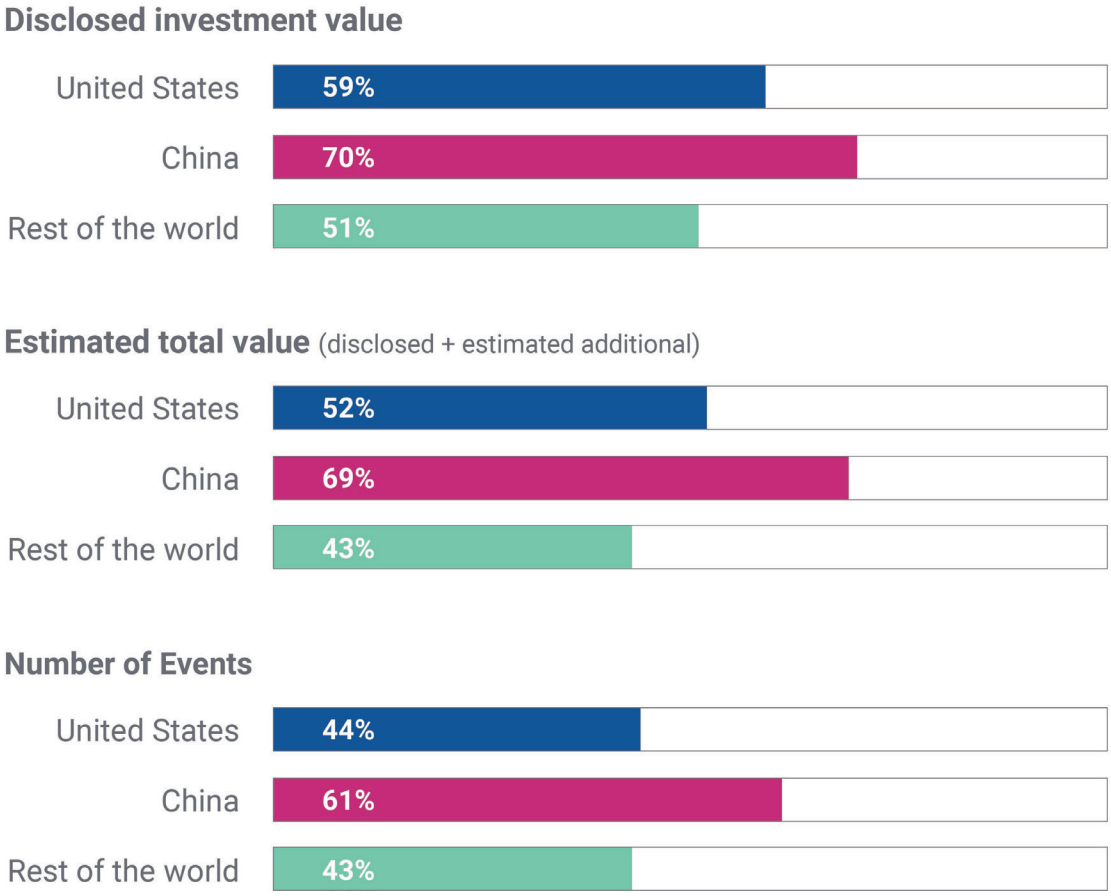
HIGHER RELEVANCE	LOWER RELEVANCE
Medicine and life sciences	Agriculture
Military, public safety, and government	Arts, sports, leisure, travel, and lifestyle
Transportation	Broadcasting and media production
Process automation	Business services and analytics
Security and biometrics	Consumer goods
General purpose	Construction and field services
Diversified/NOS/Unclear	Education
	Finance
	Sales, retail, and customer relations
	Utilities

These distinctions don't apply perfectly in practice: some products from medical and general purpose AI companies are unlikely to interest national security policymakers, while certain AI-based business analytics and education tools might be of interest. But as a first approximation, we find that half or more of all equity investment goes into applications with less direct relevance to national security. Figure 12 divides aggregate investment flows in our three regions among our higher- and lower-relevance categories. In the United States, for example, well under half of the investments in our dataset had higher-relevance targets—targets of which accounted for nearly 60 percent of disclosed investment value (and about half of estimated total value). China-bound investments performed somewhat better on this metric: higher-relevance targets accounted for roughly 60 percent of transaction count, 70 percent of disclosed value, and 70 percent of estimated total value.

FIGURE 12

Proportion of higher-relevance investment transactions, 2015–2019

PERCENTAGE OF ALL INVESTMENT INTO AI COMPANIES BASED IN THE SPECIFIED COUNTRY



SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA.

IN THE AGGREGATE, CHINESE INVESTORS DO NOT SEEM TO DISPROPORTIONATELY INVEST IN DIFFERENT AI APPLICATIONS WHEN THEY INVEST OUTSIDE CHINA (*LOW TO MODERATE CONFIDENCE*)

As previously discussed, Chinese investors are involved in relatively few AI investments into non-Chinese companies. If Chinese investors target sensitive companies and AI applications when they invest abroad, their investments could pose security risks. In several instances, Chinese organizations have acquired sensitive technologies by investing in U.S. and European high-tech companies.[83]

Many policymakers worry that Chinese investors are implementing a deliberate, security-focused technology transfer strategy when investing abroad.

However, in the aggregate, our data does not indicate that Chinese equity investors disproportionately seek out defense-relevant AI technologies and companies when investing outside China. To be clear, some Chinese investors have plainly invested abroad in order to extract sensitive information or technology. These efforts deserve scrutiny. Also, given the aforementioned limitations of our data on Chinese investors and on AI company application areas, our analysis of this issue has significant uncertainty.[84] Subject to these caveats, however, we assess that transactions meant to extract security-sensitive AI technology are probably a small piece of a larger and more diverse investment flow.

Specifically, we find that outside China, Chinese investors are active across the spectrum of AI application areas. Fifty-six percent of investments involving Chinese investors and non-Chinese targets fall within our higher-relevance category, as compared to 66 percent of investments with Chinese investors and Chinese targets. (Measured by disclosed value, the disparity remains: 57 and 68 percent, respectively.)

Within the higher- and lower-relevance categories, some variations in distribution exist, although the small number of transactions involving Chinese investors makes it less likely that the smaller variations are statistically meaningful. Table 6 and Table 7 compare transactions outside China with Chinese investors to transactions outside China without Chinese investors. Measured by aggregate value, transactions *with* Chinese investors were more concentrated in sales and retail, while transactions *without* Chinese investors were more concentrated in security and biometrics and business services. Measuring by transaction count saw more concentrated transactions with Chinese investors in medicine and life sciences and transportation; transactions without Chinese investors were more concentrated in sales and retail and business services.

TABLE 6

Distribution of aggregate disclosed investment value involving Chinese investors and non-Chinese targets, 2015–2019

APPLICATION AREA	NO DISCLOSED CHINESE INVESTORS (TOTAL $100 BILLION)	WITH DISCLOSED CHINESE INVESTORS (TOTAL $7 BILLION)
Medicine and life sciences	6.6%	8.9%
Agriculture	2.2%	0.0%
Transportation	15.1%	19.4%
Process automation	2.6%	1.3%
Consumer goods	0.5%	1.2%
Utilities	1.1%	0.1%
Construction and field services	0.3%	0.1%
Security and biometrics	7.0%	2.8%
Finance	6.4%	10.3%
Sales, retail, and customer relations	11.4%	25.0%
Business services and analytics	16.4%	3.6%
Broadcasting and media production	0.4%	0.4%
Arts, sports, leisure, travel, and lifestyle	3.5%	1.5%
Education	0.6%	1.2%
Military, public safety, and government	0.7%	0.1%
General purpose	21.8%	22.0%
Diversified/NOS/Unclear	3.7%	2.0%

SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA. READ AS: "FROM 2015 TO 2019, MEASURED BY DISCLOSED INVESTMENT VALUE, COMPANIES FOCUSED ON MEDICINE AND LIFE SCIENCES RECEIVED 6.6 PERCENT OF ALL INVESTMENT WITHOUT ANY DISCLOSED CHINESE INVESTOR PARTICIPANTS INTO AI COMPANIES BASED OUTSIDE CHINA. FOR INVESTMENT WITH DISCLOSED CHINESE INVESTOR PARTICIPANTS, THE CORRESPONDING PERCENTAGE WAS 8.9 PERCENT."

TABLE 7

Distribution of investments with Chinese investors and non-Chinese targets, 2015–2019

APPLICATION AREA	NO DISCLOSED CHINESE INVESTORS (12,736 INVESTORS)	WITH DISCLOSED CHINESE INVESTORS (406 INVESTORS)
Medicine and life sciences	9.9%	14.0%
Agriculture	2.0%	1.5%
Transportation	5.6%	11.3%
Process automation	2.8%	4.4%
Consumer goods	1.1%	3.0%
Utilities	1.8%	0.7%
Construction and field services	0.8%	1.0%
Security and biometrics	5.0%	4.7%
Finance	6.9%	6.9%
Sales, retail, and customer relations	16.9%	11.1%
Business services and analytics	19.2%	11.1%
Broadcasting and media production	1.7%	1.0%
Arts, sports, leisure, travel, and lifestyle	4.5%	4.9%
Education	1.9%	2.7%
Military, public safety, and government	0.6%	0.2%
General purpose	17.6%	19.7%
Diversified/NOS/Unclear	1.7%	1.7%

SOURCE: CSET ANALYSIS OF CRUNCHBASE AND REFINITIV DATA. READ AS: "FROM 2015 TO 2019, MEASURED BY INVESTMENT COUNT, COMPANIES FOCUSED ON MEDICINE AND LIFE SCIENCES RECEIVED 9.9 PERCENT OF ALL INVESTMENTS WITHOUT ANY DISCLOSED CHINESE INVESTOR PARTICIPANTS INTO AI COMPANIES BASED OUTSIDE CHINA. AMONG INVESTMENTS WITH AT LEAST ONE DISCLOSED CHINESE INVESTOR PARTICIPANT, THE CORRESPONDING PERCENTAGE WAS 14 PERCENT."

3 Next Steps

In the coming months, CSET plans to extend this preliminary analysis by:

- Refining our definition of AI companies. We will use data on AI patents, publications, and talent flows to develop new methods for identifying AI-related companies and investments into them.
- Adding additional data sources. We will supplement Crunchbase and Refinitiv with additional structured and unstructured investment data. In particular, we plan to incorporate Chinese-language structured data into our analysis.
- Estimating nonpublic investment information. We will use unstructured data and machine learning methods to fill relevant gaps in commercial investment databases.
- Assessing private-sector R&D spending. We intend to develop methodologies for inferring corporate spending on AI R&D.
- Exploring state-supported investment flows. The Chinese national and local governments have become significant players in the equity investment market through mechanisms known as "guidance funds." We will explore this mechanism and its implications in a forthcoming paper.

We welcome feedback on our research agenda. Please contact **zachary.arnold@georgetown.edu** with any suggestions.

Appendix 1. Underlying data and methodology

DEFINING AI COMPANIES

Our analysis is based on two private investment datasets.[85] The primary dataset, Crunchbase, is a commercial database widely used for research into tech-oriented and early-stage companies.[86] We supplement Crunchbase with data from Refinitiv, a leading market data provider recently formed from Thomson Reuters's financial data operations.[87]

Records of companies in Crunchbase and Refinitiv include short company descriptions derived from various sources, such as company websites, regulatory filings, and (in the case of Crunchbase) submissions from registered Crunchbase users.[88] We developed a regular expression-based search query, implemented in SQL, to identify AI-focused companies based on these descriptions. The query, reproduced in Appendix 2, returns companies whose descriptions include either:

a. terms associated with specific AI techniques or applications, from relatively general (e.g., "machine learning," "neural network," "computer vision," "autonomous vehicle") to specific (e.g., "generative adversarial network," "TensorFlow," "q-learning"), or

b. a generic AI-related term—"artificial intelligence," "AI," or "machine intelligence"—and a term suggesting a task or application involving AI, such as "optimize," "sense," "personalize," "robotic," "chatbot" or "semiconductor."

This keyword-based method, while imperfect, improves on other ways of defining AI companies. Most importantly, keyword searches are transparent and replicable. In contrast, many other analyses either rely on commercial databases' proprietary and non-replicable categorizations of companies as AI or not-AI,[89] or simply do not describe how they identified AI companies. Compared to other potential keyword searches, our query improves precision by excluding at least some pure "buzzword" mentions of AI—that is, company descriptions that mention AI, but fail to describe (even in vague terms) how it is being applied to a real-world problem.[90]

We ran a validation exercise, discussed in the next section of this appendix, on our search query, then ran it over all company descriptions in Crunchbase and in Refinitiv's private equity data feed.[91] We de-duplicated the two lists and identified 9,036 companies with one or more investment transactions in Crunchbase between 2015 and 2019, inclusive. (Excluded from this number are 311 AI companies without records in Crunchbase—that is, the company was identified as an AI company based on its record in Refinitiv but could not be matched to Crunchbase—and 75 additional companies whose Crunchbase records had no data on the company's geographic location.) This set of 9,036 companies defines the universe of "AI companies" in our analysis.[92]

VALIDATING THE AI COMPANY SEARCH QUERY

To validate our search query, we tested it against a "ground truth" dataset of 127 privately held companies identified by *Forbes* magazine and *Leiphone*, a leading Chinese technology news website, as important AI companies.[93] Our query achieved 74 percent recall: it recovered 94 of the 127 companies, comparable to or better than three leading data vendors' black-box categorization schemes.[94] A simpler keyword search had slightly better recall, but we expect it would have worse precision (that is, return many false positives) outside the validation set.

CLASSIFICATION METHOD	CLASSIFICATION METHOD
Restrict to CB Insights AI "expert collection"[95]	55%
CSET regular expression-based keyword search over Crunchbase and Refinitiv company descriptions	74%
Restrict to Crunchbase AI category group[96]	65%
Simple keyword search over Crunchbase and Refinitiv company descriptions for "AI," "A.I.," "artificial intelligence," "deep learning," and "machine learning"	76%
Restrict to Pitchbook AI "vertical"[97]	74%

SOURCE: CSET ANALYSIS.

Assessing the precision of our search query—that is, how many of the companies returned by our query are truly "AI companies"—is harder, because we have no "ground truth" dataset of *non*-AI companies to test against. When earlier iterations of the query returned companies with very little apparent connection to AI, we adjusted the query to exclude them.[98] Based on manual review, our final query returns few companies with little apparent connection to AI, based on their descriptions in commercial datasets. To be sure, some of these descriptions may reflect "AI hype,"[99] and our keyword-based search captures companies with varying degrees of AI sophistication—many, if not most, are likely applying "off-the-shelf" AI toolkits, rather than developing general purpose AI techniques and computing hardware (for example). Still, we believe our method is a reasonable—and, importantly, transparent and replicable—initial means of identifying most companies with a strong connection to AI.

IDENTIFYING AI COMPANIES IN INVESTMENT DATABASES

Although we used multiple datasets to identify AI companies, we use only Crunchbase data to identify and aggregate investment transactions involving those companies. Prior research confirms that Crunchbase is a relatively comprehensive and accurate source.[100] Consistent with that research, CSET analysts located records in Crunchbase for 78 percent of companies whose descriptions in Refinitiv matched our AI keyword search, but only 23 percent of companies whose Crunchbase descriptions matched our search could be connected with reasonable effort to a record in Refinitiv.[101] This prevented us from using Refinitiv data in our investment count and value calculations.

To check Crunchbase's reliability at a high level, we compared its and Refinitiv's per-year, per-company investment totals from 2013 to 2019 for 1,907 AI companies that could be definitively identified in both datasets.[102] In 31 percent of cases, Crunchbase's per-year investment total for a given target and Refinitiv's per-year investment total for the same target matched exactly. In another 26 percent of cases, the databases differed by $500,000 or less; these relatively small disparities may reflect either differences in currency conversion between the two datasets or small rounds being omitted in one of the datasets. In 26 percent of cases, the Crunchbase total was more than $500,000 higher than the corresponding number in Refinitiv. And in the remaining 17 percent, Refinitiv's per-year, per-target investment total was more than $500,000 higher than the corresponding number in Crunchbase. Overall, for the

1,907 companies examined, the median per-year, per-target difference between Crunchbase and Refinitiv was $0. The average was about $713,000 in Crunchbase's favor; that is, on average, Crunchbase recorded $713,000 more investment in a given company in a given year than Refinitiv for companies identified in both databases.

We then manually reviewed a sample of the largest per-year, per-target discrepancies. Some discrepancies arose from differences in how transactions were recorded between Refinitiv and Crunchbase, rather than actual missing data in one of the databases. Others arose from missing data in one of the databases. From our limited review, Refinitiv was just as or perhaps more likely than Crunchbase to be missing high-value transactions.

In sum, Crunchbase covers significantly more AI companies than Refinitiv. For companies covered in both databases, Refinitiv and Crunchbase most often had similar data, and Crunchbase was not obviously less accurate when they did disagree. Given these findings, we believe that Crunchbase's coverage of AI investment transactions (as defined in this paper), although imperfect, compares favorably to at least one of its leading competitors.

IDENTIFYING AI INVESTMENTS

For purposes of this paper, we define an AI investment as an equity investment transaction with a privately held AI company target. This definition includes venture capital (VC) rounds, private equity (PE) investments, and mergers and acquisitions (M&A). It excludes debt finance, grants, crowdfunding, and in-kind contributions. Notably, we also exclude public offerings. As discussed in Section 2, because public companies tend to be larger and more diversified, IPO proceeds are more likely to be used to support activity in a variety of technological domains, not just AI. Excluding IPOs therefore helps narrow the analysis to AI-related investments.

Our investment calculations are based on Crunchbase data, which we believe are comprehensive enough to support the analysis in this paper.[103] As applied to Crunchbase, our definition of AI investments includes "Funding Round" and "Acquisition" transactions in which the target was a privately held AI company with a confirmed Crunchbase URL and (in the case of Funding Rounds) the investment was an equity investment.[104] We group investments into years based on the date they were announced, according to Crunchbase, and we count Hong Kong-based AI companies as Chinese. Finally, in our count-based calculations, we count venture capital rounds and private equity transactions with multiple investors as single transactions, not as multiple one-to-one investments.

ESTIMATING UNDISCLOSED INVESTMENT AMOUNTS

The "disclosed value" totals in Section 3 are based on Crunchbase transaction values. However, equity investment transaction values are often kept confidential. In all, 3,973 of the 13,107 venture capital and private equity transactions associated with the AI companies in our dataset, and 786 of the 893 M&A transactions, lacked values in Crunchbase. To produce the estimated totals in Section 3, we used a multistage estimation process. For venture capital rounds with undisclosed values, we assigned each round the median amount for funding rounds of the same investment stage,[105] target country and year.[106] Where one or more of these data points were missing, we performed the same calculation using transactions of the same investment stage and target country, investment stage and year, or year alone, in order of preference. For M&A transactions, we assumed each undisclosed-value transaction had a total value equal to the median disclosed value of all M&A transactions with the same year and target country (as available).

IDENTIFYING CHINESE INVESTMENTS

In any given investment involving multiple investors, whether or not the aggregate amount of the investment is publicly disclosed, the amounts invested by each investor *individually* are very often kept confidential and investors' identities also sometimes withheld. Without investor-specific data at the individual transaction level, it's generally not possible to determine how much a particular investor or type of investor spends in the aggregate. Therefore, we can't directly calculate how much Chinese investors are investing in AI companies (in the United States or elsewhere). Instead, in Section 3, we assess investment flows from China by calculating the number and value of investments with at least one publicly disclosed Chinese investor participating. (We count Hong Kong as part of China in this analysis.) For national security policymakers, this method roughly indicates the extent of potentially concerning influence over AI companies: in each such investment, the Chinese investor(s) probably would have received material information about the target company and its technology both before and after investing, and would stand to have at least some involvement with (and leverage over) the target as an equity holder after the investment closed.[107]

There are two important sources of uncertainty in our calculations. First, as discussed in Section 2, because we classify investments based on disclosed investors, all investments with zero disclosed Chinese investors are counted as transactions without Chinese involvement, even if they had one or more undisclosed investors. For example, 1,403 U.S.-based companies in our dataset had zero disclosed Chinese investors and at least one investor whose identity is listed as undisclosed in Crunchbase. Because some of those undisclosed investors may have been Chinese, our calculations may undercount investments involving Chinese investors, though such undercounting is probably insignificant.[108]

Second, determining which *disclosed* investors should be considered "Chinese" is not straightforward.[109] Organizational investors such as corporations, venture capital funds, and private equity firms often have complicated and opaque ownership structures; actual control over the investor may not neatly track ownership.[110] Especially in the context of venture capital and private equity, each investor may have many owners from different countries, and the investor itself may have operations around the world.[111]

In this paper, we assume each organizational investor has the nationality of the country where it (in the case of corporate investors) or its managing entity (in the case of VC and PE funds) is headquartered according to Crunchbase. For example, we assume that prominent VC firm Silver Lake Partners and its subsidiary investment vehicles (wherever located) are American investors because the firm's headquarters are in Silicon Valley, even though Silver Lake has offices and investors of its own from around the world.[112] Similarly, we place VC firm IDG Capital and its subsidiaries in China given the firm's Beijing headquarters, even though it was founded in the United States and raises money worldwide.[113]

We take this approach both because it is practical and because it gives meaningful insight into influence. In most cases, an organization's headquarters indicates where its key personnel live and its most meaningful decisions take place, where its most important contacts, suppliers, and affiliated organizations tend to be located, and—critically—which nation has jurisdiction over the organization.[114] Nonetheless, our approach could misplace investors formally headquartered in one country, but controlled or heavily influenced by entities or individuals in another. Research into investors' beneficial ownership was beyond the scope of this project, yet we acknowledge that these issues add some uncertainty to the analysis. For perspective, a recent Rhodium Group analysis counted 25 percent more venture capital rounds involving Chinese investors and U.S. targets (from 2000 to 2019, across all industries and technologies) when it assigned each investor the nationality of its ultimate controlling entity (as determined by Rhodium Group), rather than its headquarters location.[115]

IDENTIFYING PRIMARY APPLICATIONS

The estimates in Section 3 are based on CSET's own "TINA" (Taxonomy of INtelligence Applications) code system, which divides AI companies into 17 different primary application areas.[116]

TINA CODE	PRIMARY APPLICATION AREA	RELEVANCE
1	Medicine and life sciences	Higher
2	Agriculture	Lower
3	Transportation	Higher
4	Process automation	Higher
5	Consumer goods	Lower
6	Utilities	Lower
7	Construction and field services	Lower
8	Security and biometrics	Higher
9	Finance	Lower
10	Sales, retail, and customer relations	Lower
11	Business services and analytics	Lower
12	Broadcasting and media production	Lower
13	Arts, sports, leisure, travel, and lifestyle	Lower
14	Education	Lower
15	Military, public safety, and government	Higher
16	General purpose	Higher
17	Diversified/NOS/Unclear	Higher

Appendix 3 explains these categories in further detail, with special attention to the relatively broader "business services and analytics" and "general purpose" categories.

CSET analysts assigned each AI company a code after reviewing the company's Crunchbase and Refinitiv descriptions (as available) and, if those descriptions were vague or unclear, the company's website. Analysts classified each company into the category best describing the company's activity taken as a whole. To assess consistency, two different analysts coded a sample of 526 of the companies into the 17 categories. Intercoder agreement, the percentage of classifications that were the same, was 64 percent, reflecting moderate uncertainty; the probability of intercoder agreement by chance alone is low (due to the number of categories), and the boundaries between some pairs of categories can be ambiguous (particularly "general purpose" or "diversified" and the others). When classifications were aggregated into the higher- and lower-relevance groups, intercoder agreement was 82 percent. We took the uncertainty in company categorization into account when reporting the level of confidence associated with our related conclusions.

Appendix 2. AI company search query

The following is a simplified (pseudocode) version of the regular expression-based search filter used to identify AI companies. The original query was implemented in SQL in a Google BigQuery environment.[117]

```
    (
    ((?i)(machine|artificial)(\W*\w*){0,2}intelligence)|\WAI\W|A\.I(\W|\b)

    AND

    (
    (?i)analy|predict|robot|cluster|adapt|diagnos|automat|detect|
personaliz|label|augment|autonom|sensor|sensing|recommend|optimiz
    OR (?i)chatbot|\bbot(s|\b)|(digital|virtual) assistant
    OR (?i)semiconductor|chipset|\bGPU|\bASIC|\bFPGA|high( |-)performance computing
    OR (?i)knowledge graph
    )
    )

    OR

    (?i)(reinforcement|transfer|one-shot|one shot|zero-shot|zero shot|
supervised|unsupervised) ?-?(machine )?learning
    OR (?i)(self(-| )driving|driverless|
    autonomous)(\W*\w*\W*){0,4}(vehicle|truck|car|vehicle|automobile|
technolog|
    navig|transport|robot|machine)
    OR (?i)(driverless|autonomous|automat)\w*(\W*\w*\W*){0,2}(driv|navig)
    OR (?i)(machine|deep)( |-)learning
    OR (?i)cognitive computing
    OR (?i)synthetic data
    OR (?i)neural net
    OR (?i)predictive analytic
    OR (?i)(computer|machine) vision
    OR (?i)generative adversarial network
    OR \b(R|D)NN\b|\bGAN\b
    OR (?i)(natural language|speech) (processing|understanding)|\bNLP\b
```

```
    OR (?i)feature (extraction|learning|matching|selection)
    OR (?i)autoencod|tensorflow|\bkeras\b|\btheano\b
    OR (?i)q(-| )(learning|value|network)
    OR (?i)hyperparameter
    OR (?i)(support vector|Boltzmann) machine
    OR (?i)machine (translation|perception)
    OR (?i)(facial|speech|face|voice|music|image|character|text|
emotion|video|gesture)  (recogni|classif)|(recogni|classif)\w*
(facial|speech|face|voice|music|image|character|text|emotion|video|gesture)
```

Appendix 3. Taxonomy of primary applications of AI

This table is an adapted version of the TINA (Taxonomy of INtelligence Applications) coding guide used by CSET analysts to classify companies' primary applications of AI. The notes in the table are illustrative, not exhaustive.

CATEGORY		NOTES
1	Medicine and life sciences	Includes physiological monitoring, imaging and diagnostics, public health, and drug discovery. Companies whose products and services relate to the "back-office" business and logistical needs of healthcare providers—for example, medical billing and coding, or transcription of doctors' notes—are classified in category 11, not category 1.
2	Agriculture	Includes agricultural sensing and analytics as well as autonomous farm machinery.
3	Transportation	Includes autonomous vehicles, aerospace, avionics, and related components. This category also includes producers of AI-enabled unmanned aerial vehicles, drones, and mobile robots for the logistics and warehousing industries.
4	Process automation	Includes companies focused on automating production and processing of tangible goods, and on monitoring and maintenance of related equipment.
5	Consumer goods	Includes companies that design or produce consumer goods and devices.
6	Utilities	Includes companies whose products serve utility producers (e.g., oil and gas companies or electric power producers) or utility consumers. This would include (for example) companies that produce software to help businesses understand and reduce their electricity or water consumption.
7	Construction and field services	Includes AI-enabled software and equipment for monitoring construction sites and civil infrastructure (e.g., power lines and pipelines) and planning construction projects.

8	Security and biometrics	Includes cybersecurity and authentication, including biometric authentication. Companies focused on facial recognition, gait recognition, voiceprinting, and similar biometric identity resolution techniques are classified in this category.
9	Finance	Includes investing, lending, insurance, cryptocurrency, credit rating, and personal finance. Companies focused on accounting are classified in category 11, not category 9.
10	Sales, retail, and customer relations	Includes marketing, lead generation, customer service, and customer relationship management. This category generally includes sales and marketing tools even if the tools' intended users might otherwise be captured in another category. For example, an online insurance marketplace or a customer service platform for use by airlines would be properly classified in this category, not category 3.
11	Business services and analytics	Includes business analytics not captured in category 10, logistics and supply chain management, human resources (including job search websites and recruiting platforms), enterprise reputation management, and accounting and legal services. "Business analytics" means "business intelligence" tools and similar analytic applications not generally visible to the user's customers. This category also includes "back-office" tools even if the tools' intended users might otherwise be captured in another category. For example, billing or human resources software with special features for universities or hospital systems are generally classified in this category, because accounting and human resources are relatively generic functions that exist in many different types of organizations.
12	Broadcasting and media production	Includes AI-enabled platforms for recommending and disseminating digital media.
13	Arts, sports, leisure, travel, and lifestyle	Includes personal social media platforms.
14	Education	Includes AI-enabled instruction and assessment tools.
15	Military, public safety, and government	Includes companies whose products are designed specifically for use by governments and militaries or relate to services strongly associated with governments (e.g., traffic management).

16	General purpose	A catch-all category for companies whose goods and services are not developed specifically for one of the above categories, or seem useful for more than one of the above categories. Generally, this category includes companies focused on computing hardware (chips, semiconductors, etc.),[118] robotics, sensors, cloud computing, networking and IoT, software development, tools for cleaning and structuring data, human-computer interface (including AR/VR), speech and text processing, and image and video processing—but only when not tailored to an application described in categories 1–15. For example, a company that produces sensors specifically for use in UAVs would be classified in category 3, not category 16.
17	Diversified/NOS/Unclear	Includes companies that cannot reasonably be placed in any other category, or that lack sufficient information to categorize.

Appendix 4. Other analyses of investment flows related to AI

Many other analyses of international AI investment have been published; the table below includes several notable examples. These analyses use a variety of methods and data sources and reach a variety of results. Although most credible analyses produce estimates on the same orders of magnitude as our numbers, in some cases, they differ significantly from each other and from the estimates presented in this paper.

It's often difficult to determine why a particular analysis produces results different from ours. Many do not explain their methodologies in detail, or rely on proprietary data and methods that cannot be fully disclosed and examined. In general, there are several common reasons why our numbers might differ from other analyses. These include:

- **Different types of transactions counted:** Our analysis includes M&A and private equity deals and excludes public offerings. Other analyses make different choices; many include only venture capital transactions.
- **Different definitions of AI-related transactions:** Other analyses may define AI-related transactions more broadly or narrowly than we do—for example, by excluding investments in hardware producers. They may also operationalize these definitions in different ways—for example, by using human annotation rather than keyword searching to identify AI-related target companies.
- **Different data sources:** We rely on Crunchbase and (to a lesser extent) Refinitiv data; other data sources may have different coverage.
- **Different approaches to missing data:** Many transactions are partially or fully undisclosed; in particular, many transactions have undisclosed values. Other analyses may estimate missing data points differently or exclude them altogether.
- **Different geographic scope or time span:** Some analyses focus on specific years, quarters, or regions.

SOURCE	DATE	SCOPE OF ANALYSIS	DATA SOURCES	SELECTED FINDINGS
China Institute for Science and Technology Policy, Tsinghua University[119]	July 2018	Annual "global AI investment" from 2013 to 2017	Data scraped from various public and private sources by China Academy of Information and Communications Technology[120]	"In 2017, global AI investment reached US$39.5 billion, including 1,208 investment transactions, with China alone posting US$27.71 billion of investment and 369 investment transactions."[121]
CB Insights[122]	2018	"Equity deals" in AI from 2013 to 2017, excluding "hardware-focused startups"	CB Insights commercial data platform	$15.2 billion in investment, and 1,349 discrete investment transactions, globally in 2017

Center for Data Innovation[123]	August 2019	AI venture capital and private equity funding "between 2017 and 2018"	CB Insights commercial data platform	$33.2 billion in investment, and 2,320 discrete investment transactions, in China, the U.S. and the EU "between 2017 and 2018"
CB Insights[124]	July 2019	"Funding for AI startups" from 2014 to Q2 2019	CB Insights commercial data platform	$7.4 billion in investment, and 488 discrete investment transactions, globally in Q2 2019
OECD[125]	December 2018	"Total estimated equity investments in AI start-ups"	Crunchbase commercial data platform	More than $16 billion in investment, and over 1,400 discrete investment transactions, globally in 2017
AI Index (Stanford University)[126]	December 2019	Investment (including M&A and IPO) into AI companies with over $400,000 in capital raised in the past 10 years	Quid, CapitalIQ and Crunchbase commercial data platforms	$40.4 billion in investment into more than 3,000 companies in 2018
McKinsey & Company[127]	June 2017	Unclear, but includes venture capital and private equity	Unclear	$18–27 billion in "internal corporate investment," $2–3 billion in M&A activity, and $6–9 billion in venture capital, private equity, and "other external funding," in 2016
Pitchbook/National Venture Capital Association[128]	January 2020	Venture capital investment into AI-related companies	Pitchbook commercial data platform	$18.457 billion in venture capital funding into 1,356 AI-related U.S. companies in 2019
Tech Nation[129]	March 2020	Investment into AI-related companies	Crunchbase commercial data platform	$11.2 billion GBP (~$13 billion) in investment into U.S. companies in 2019, across 663 transactions

Endnotes

1. See generally National Security Commission on Artificial Intelligence, *Interim Report* (Washington, DC: NSCAI, 2019), https://drive.google.com/file/d/153OrxnuGEjsUvlxWsFYauslwNeCEkvUb/view; Congressional Research Service, *Artificial Intelligence and National Security* (Washington, DC: CRS, updated 2019), https://fas.org/sgp/crs/natsec/R45178.pdf.
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3. See, e.g., Jill Aitoro, "Forget Project Maven. Here are a Couple Other DoD Projects Google is Working On," *Federal Times*, March 13, 2019, https://www.federaltimes.com/it-networks/2019/03/13/forget-project-maven-here-are-a-couple-other-dod-projects-google-is-working-on/; "Elevate Your Mission with Artificial Intelligence," Booz Allen Hamilton, accessed March 4, 2020, https://www.boozallen.com/expertise/analytics/elevate-your-agency-with-artificial-intelligence.html; Jacob Ward and Chiara Sottile, "Inside Anduril, the Startup that is Building AI-powered Military Technology," *NBC News*, October 3, 2019, https://www.nbcnews.com/tech/security/inside-anduril-startup-building-ai-powered-military-technology-n1061771.
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6. See, e.g., C. Richard Neu and Charles Wolf Jr., "The Economic Dimensions of National Security," (RAND, 1994), https://www.rand.org/pubs/monograph_reports/MR466.html; "Economic Security: Neglected Dimension of National Security," (National Defense University, 2011), https://ndupress.ndu.edu/Portals/68/Documents/Books/economic-security.pdf; Michele Flournoy and Richard Fontaine, "Economic Growth is a National Security Issue," *Wall Street Journal*, May 26, 2015, https://www.wsj.com/articles/economic-growth-is-a-national-security-issue-1432683397.
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9. See, e.g., Angus Loten, "U.S. Government Urged to Boost Technology R&D," *The Wall Street Journal*, May 22, 2019, https://www.wsj.com/articles/u-s-government-urged-to-boost-technology-r-d-11558555895.
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11. See generally Michael Brown and Pavneet Singh, "China's Technology Transfer Strategy: How Chinese Investments in Emerging Technology Enable a Strategic Competitor to Access the Crown Jewels of U.S. Innovation," (Defense Innovation Unit Experimental, January 2018), 23-26, https://admin.govexec.com/media/diux_chinatechnologytransferstudy_jan_2018_(1).pdf.
12. Common issues include: using unexplained and/or proprietary methods for defining relevant transactions or companies; using overly broad or narrow definitions of AI companies receiving investment; arbitrarily excluding major types of investments, such as mergers and acquisitions, or not explaining which types of investment were included or excluded; and using questionable or undisclosed data sources. Also, to our knowledge, no systematic analysis of AI transactions involving Chinese *investors* has been published, and only one analysis—Stanford's AI Index report—distinguishes between different types of AI companies receiving investment.
13. Replication data and code are available at https://github.com/georgetown-cset/private_investment_in_ai.
14. See above.
15. See Appendix 1 for a detailed discussion of our estimation method.
16. COVID-19 is probably the most important development in the AI investment landscape since 2019, but the market continues to evolve in other ways. See, e.g., Josh Horwitz and Samuel Shen, "Sino-U.S. tech race turbo-charges China chip investment, triggering bubble fear," *Reuters*, June 24, 2020, https://www.reuters.com/article/us-china-semiconductors-analysis/sino-u-s-tech-race-turbo-charges-china-chip-investment-triggering-bubble-fear-idUSKBN23V3DW (describing the recent boom in semiconductor-related investment in China).
17. See validation discussion in Appendix 1.
18. See, e.g., Kenneth Rogoff, "Mapping the COVID-19 Recession," *Project Syndicate*, April 7, 2020, https://www.project-syndicate.org/commentary/mapping-covid19-global-recession-worst-in-150-years-by-kenneth-rogoff-2020-04; Alexander Davis, "Investors are cautious on private markets during shutdowns, PitchBook survey shows," *PitchBook*, April 9, 2020, https://pitchbook.com/news/articles/investors-are-cautious-on-private-markets-during-shutdowns-pitchbook-survey-shows.
19. See, e.g., "A Guide to Going Public" (KPMG, 2015), https://assets.kpmg/content/dam/kpmg/pdf/2015/06/KPMG-A-Guide-to-Going-Public-Interactive.pdf; Yakov Amihud, Baruch Lev, and Nickolaos G. Travlos, "Corporate Control and the Choice of Investment Financing: the Case of Corporate Acquisitions," *The Journal of Finance* 45, No. 2 (June 1990), https://www.jstor.org/stable/2328673?seq=2#metadata_info_tab_contents. See generally Curtis J. Milhaupt and Wentong Zheng, "Beyond Ownership: State Capitalism and the Chinese Firm," 103, *Georgetown Law Journal* 665, 667 & n.3 (2015) (collecting sources demonstrating that "[t]he identity of a corporation's equity owners has enormous significance for the oversight and incentives of management, the corporate governance challenges it faces, and ultimately, the goals it pursues").
20. See, e.g., Cory Bennett and Bryan Bender, "How China Acquires 'The Crown Jewels' of U.S. Technology," *Politico*, May 22, 2018, https://www.politico.com/story/2018/05/22/china-us-tech-companies-cfius-572413.
21. See, e.g., Sabrina T. Howell et al., "Financial Distancing: How Venture Capital Follows the Economy Down and Curtails Innovation," *National Bureau of Economic Research*, NBER Working Paper No. 27150, (December 2019), 4, http://www.nber.org/papers/w27150 ("[P]atents filed by VC-backed startups are of higher quality and economic importance than the average patent . . . VC-backed firms are disproportionately likely to have more original patents, more general patents, and patents more closely related to fundamental science."); William R. Kerr, Josh Lerner, and Antoinette Schoar, "The Consequences of Entrepreneurial Finance: Evidence from Angel Financings," *Review of Financial Studies* 27, no. 1 (January 2014), https://www.hbs.edu/faculty/Pages/item.aspx?num=40781; Yael V. Hochberg, Alexander Ljungqvist, and Yang Lu, "Whom You Know Matters: Venture Capital Networks and Investment Performance," *Journal of Finance* 62, no. 1 (January 2007), https://onlinelibrary.wiley.com/doi/full/10.1111/j.1540-6261.2007.01207.x.

22. See, e.g., Will Gornall and Ilya A. Strebulaev, "The Economic Impact of Venture Capital: Evidence from Public Companies," *Stanford Business*, Working Paper No. 3362, November 1, 2015, https://www.gsb.stanford.edu/faculty-research/working-papers/economic-impact-venture-capital-evidence-public-companies; Asli Demirguc-Kunt and Ross Levine, "Stock Market, Corporate Finance, and Economic Growth: An Overview," *The World Bank Economic Overview* 10, no. 2 (May 1996), https://www.jstor.org/stable/3990061?seq=1#metadata_info_tab_contents.
23. See generally "Private Equity vs. Venture Capital: What's the Difference?" *PitchBook*, January 2, 2020, https://pitchbook.com/blog/private-equity-vs-venture-capital-whats-the-difference.
24. Note that many core AI resources are either open-source (e.g., software frameworks) or widely accessible (e.g., cloud computing), so the link between funding and performance may be more attenuated than usual for some AI companies. For a recent cautionary tale involving an unusually well-funded (non-AI) startup, see Greg Putnam, "WeWork Debacle Exposes Why Investing in a Charismatic Founder can be Dangerous," *The Conversation*, October 25, 2019, http://theconversation.com/wework-debacle-exposes-why-investing-in-a-charismatic-founder-can-be-dangerous-125785.
25. See, e.g., "American Tech Giants Are Making Life Tough For Startups," *The Economist*, June 2, 2018, https://www.economist.com/business/2018/06/02/american-tech-giants-are-making-life-tough-for-startups; David Dayen, "The Cause and Consequences of the Retail Apocalypse," *The New Republic*, November 14, 2017, https://newrepublic.com/article/145813/cause-consequences-retail-apocalypse; Nathan Bomey, "Former Sears company sues ex-CEO Lampert, Treasury's Steven Mnuchin over 'asset stripping'," *USA Today*, April 18, 2019, https://www.usatoday.com/story/money/2019/04/18/sears-lawsuit-eddie-lampert-esl-investments/3507382002/.
26. In particular, private companies rarely disclose their R&D spending, and essentially zero companies disclose data that would allow a direct measurement of *AI* R&D spending.
27. See, e.g., Deborah Poff and Heather Tierney, "Citation Manipulation" (COPE, July 2019), https://publicationethics.org/files/COPE_DD_A4_Citation_Manipulation_Jul19_SCREEN_AW2.pdf; Richard Van Noorden and Dalmeet Singh Chawla, "Hundreds of Extreme Self-Citing Scientists Revealed in New Database," *Nature*, August 19, 2019, https://www.nature.com/articles/d41586-019-02479-7; Alberto Baccini, Giuseppe De Nicolao, Eugenio Petrovich, "Citation Gaming Induced by Bibliometric Evaluation: A Country-Level Comparative Analysis," *PLoS One* 14, No. 9 (September 2019), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0221212; Ana Maria Santacreu and Heting Zhu, "What Does China's Rise in Patents Mean? A Look at Quality vs. Quantity," *Economic Research Federal Reserve Bank of St. Louis*, May 2018, https://research.stlouisfed.org/publications/economic-synopses/2018/05/04/what-does-chinas-rise-in-patents-mean-a-look-at-quality-vs-quantity.
28. For example, Chinese facial recognition company Megvii is considered "privately held," and is included in our analysis, because its shares are not publicly traded. But Megvii could reasonably be considered "public" in other respects; for example, some of its investors are Chinese SOEs, and the Chinese government promotes the company as a "national champion." See Sarah Dai, "China adds Huawei, Hikvision to expanded 'national team' spearheading country's AI efforts," *South China Morning Post*, August 30, 2019, https://www.scmp.com/tech/big-tech/article/3024966/china-adds-huawei-hikvision-expanded-national-team-spearheading; see generally Milhaupt and Zheng, "Beyond Ownership," 669 ("[A] focus on ownership alone is likely to mislead in the Chinese context, and policies pivoting on equity ownership [of Chinese companies] are likely to miss the mark.").
29. Some of these companies would be excluded anyway because they are publicly traded. See, e.g., Bernard Marr, "The Brilliant Ways UPS Uses Artificial Intelligence, Machine Learning and Big Data," Forbes, June 15, 2018, https://www.forbes.com/sites/bernardmarr/2018/06/15/the-brilliant-ways-ups-uses-artificial-intelligence-machine-learning-and-big-data. However, there are many privately held companies with significant AI operations. See, e.g., Gregory Meyer, "Cargill Hunts for Scientists to Use AI and Sharpen Trade Edge," *Financial Times*, January 28, 2018, https://www.ft.com/content/72bcbbb2-020d-11e8-9650-9c0ad2d7c5b5; Chloe Sorvino, "Silent Giant: America's Biggest Private Company Reveals its Plan to get Even Bigger," *Forbes*, October 22, 2018, https://www.forbes.com/sites/chloesorvino/2018/10/22/silent-giant-americas-biggest-private-company-reveals-its-plan-to-get-even-bigger-1.

30. See, e.g., Chris Walton, "Alibaba's New Retail Could be What Makes American Retail Great Again," *Forbes*, August 8, 2018, https://www.forbes.com/sites/christopherwalton/2018/08/08/alibabas-new-retail-could-be-what-makes-american-retail-great-again/#37c532646079; Jane Zhang, "Alibaba Invests an Additional US $3.3 Billion in its Logistics Arm Cainiao, Raising Take to 63 PCT," *South China Morning Post*, November 8, 2019, https://www.scmp.com/tech/big-tech/article/3036965/alibaba-invests-additional-us33-billion-its-logistics-arm-cainiao.
31. Josh Noble, "Alibaba Boosts IPO Size to World Record $25bn," *Financial Times*, September 22, 2014, https://www.ft.com/content/0f97cc70-4208-11e4-a7b3-00144feabdc0.
32. Strictly speaking, although they are not counted as investment proceeds in the first instance, Alibaba's IPO proceeds are indirectly included in our calculations to the extent Alibaba used them to invest in other companies.
33. Another potential concern is that restricting our analysis to investments in privately held companies could bias our measurements. If (for example) Chinese AI companies are more often publicly traded than U.S. AI companies, our measurements would be distorted in favor of the United States and the rest of the world. Relevant data are scarce, so we can't rule this out. Provisionally, however, we think any such bias is unlikely to materially affect our bottom-line conclusions. For the most part, in China, the United States, and elsewhere, we believe that large, successful AI-related companies have pursued (or avoided) IPOs for similar reasons and at roughly similar stages of development in recent years. For example, the ongoing trend toward venture capital "mega-rounds," which may displace IPOs to some extent, appears to be having roughly similar effects across regions. See Jason D. Rowley, "Supergiant VC Rounds Aren't Just Raised in China," *Crunchbase News*, August 7, 2018, https://news.crunchbase.com/news/supergiant-vc-rounds-arent-just-raised-in-china/; "3 Data Points that Suggest the IPO Market May Never Come Back," (CBINSIGHTS, January 2019), https://www.cbinsights.com/research/tech-ipo-dead/; Michael Ewens and Joan Farre-Mensa, "The Deregulation of the Private Equity Markets and the Decline in IPOs," *National Bureau of Economic Research*, NBER Working Paper No. 26317 (December 2019), https://www.nber.org/papers/w26317.
34. See generally Ryan Decker, John Haltiwanger, Ron Jarmin, and Javier Miranda, "The Role of Entrepreneurship in US Job Creation and Economic Dynamism," *Journal of Economic Perspectives*, vol 28, no. 3 (Summer 2014): 3-24, https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.28.3.3; Paul Almeida, "Semiconductor Startups and the Exploration of New Technological Territory," in *Are Small Firms Important? Their Role and Impact* (Boston, MA: Springer, 1999), https://link.springer.com/chapter/10.1007%2F978-1-4615-5173-7_3; Jillian D'Onfro, "AI 50: America's Most Promising Artificial Intelligence Companies," *Forbes*, September 17, 2019, https://www.forbes.com/sites/jilliandonfro/2019/09/17/ai-50-americas-most-promising-artificial-intelligence-companies/; Bughin, et. al, "Artificial Intelligence The Next Digital Frontier?" 11; Jeffrey Ding, "ChinAI #63: Who is Ultrapower? Introducing ChinAI Company Profiles," *ChinAI Newsletter*, August 25, 2019, https://chinai.substack.com/p/chinai-63-who-is-ultrapower-introducing; Zheping Huang, "Forget BAT, China's next-generation tech giants are TMD," *Quartz*, January 24, 2018, https://qz.com/1177465/forget-bat-chinas-next-generation-tech-giants-are-tmd/.
35. For perspective, in 2017, there were 3,671 companies traded on U.S. exchanges across all industries. See Jason M. Thomas, "Where Have All the Public Companies Gone?" *Wall Street Journal*, November 16, 2017, https://www.wsj.com/articles/where-have-all-the-public-companies-gone-1510869125. According to our dataset, 3,314 privately-held, U.S.-based AI companies received equity investment between 2015 and 2019.
36. See, e.g., Bennett and Bender, "How China Acquires 'the Crown Jewels' of U.S. Technology"; Hannas and Chang, "China's Access to Foreign AI Technology," 9-10, 18-19.
37. See "Identifying Chinese Investments" in Appendix 1.
38. See Appendix 1.
39. See, e.g., "Artificial Intelligence software market to reach $126.0 billion in annual worldwide revenue by 2025," *Omdia*, January 6, 2020, https://tractica.omdia.com/newsroom/press-releases/artificial-intelligence-software-market-to-reach-126-0-billion-in-annual-worldwide-revenue-by-2025/.
40. See discussion in Section 1.

41. Dollar comparisons between the United States and other countries are presented without adjusting for purchasing power. In theory, lower domestic input costs could give China's AI spending greater impact, for example, but it's not clear how general purchasing power differences map onto the AI sector. See, e.g., Makiko Takakura et al., "Chinese tech salaries jump in global race for talent," *Nikkei Asian Review*, February 16, 2019, https://asia.nikkei.com/Business/Business-trends/Chinese-tech-salaries-jump-in-global-race-for-talent (reporting rapidly rising salaries for Chinese AI and tech professionals). Carefully assessing the disparity in impact between a dollar spent on AI in the United States and a dollar spent in China (or any other country) is beyond the scope of this paper.
42. See, e.g., DorAemon, "Is the Name of the Investment Institution Dead? Here is a Copy of Financing Dara and Investor Statements" (投资机构名存实亡？这里有份融资数据和投资人说法), WeiXin, published October 10, 2018, https://mp.weixin.qq.com/s/SlVWvkcV-0mgEPitFzPi3Q; "The Inflow of Funds into the Primary Market Has Been Reduced by 50%. Have You Been "Optimized"?" (流入一级市场资金减少50%, 你被"优化"了吗), WeiXin, published January 3, 2019, https://mp.weixin.qq.com/s/um1vlYLfgPo85FJ2_YUg8Q; "Investors Escape Artificial Intelligence" (投资人逃离人工智能), 36kr, published September 26, 2019, https://36kr.com/p/5250586; Rita Liao, "China Startup Deals Shrink as Fundraising for Investors Plummets," *TechCrunch*, July 16, 2019, https://techcrunch.com/2019/07/16/vc-pe-funding-slows-in-china/; "China's Venture Capital Boom May Be Turning into a Bust," *The Straits Times*, July 9, 2019, https://www.straitstimes.com/business/banking/chinas-venture-capital-boom-may-be-turning-into-a-bust. On economic headwinds in China generally, see, e.g., James T. Areddy and Chao Deng, "China's Slowing Growth Underlines Stress Facing Its Economy in 2020," *The Wall Street Journal*, January 17, 2020, https://www.wsj.com/articles/chinas-economic-growth-slows-to-6-1-as-trade-and-business-confidence-suffer-11579236022.
43. Counts are harder to interpret than value totals because they lump together small, relatively unimportant transactions with more significant investments. Generally, however, we expect that countries with high transaction volume will tend to have more dynamic AI sectors and financing opportunities for entrepreneurs (especially at early stages), so transaction count is a meaningful way to gauge overall competitiveness.
44. In our counts, we treat venture capital rounds and private equity transactions with multiple investors as single transactions, not as multiple one-to-one investments.
45. For example, Tencent's corporate venture capital fund invested in seven early-stage, China-based tech companies in March and April 2020. As of the time of writing, Crunchbase had no record of any of these investments. See Sun Henan, "Tencent bets big on AI development with investment in two startups," *KrASIA*, April 14, 2020, https://kr-asia.com/tencent-bets-big-on-ai-development-with-investment-in-two-startups; "Tencent Industry Win-Win Fund" (Crunchbase, accessed April 15, 2020), https://www.crunchbase.com/organization/tencent-industry-win-win-fund.
46. If undercounting is concentrated among early-stage transactions, it should have less of an impact on our value-based calculations, because early-stage transactions are typically smaller than later investments.
47. See Appendix 1 for details on our estimation methodology.
48. As discussed in Appendix 1, our estimated values for undisclosed-value transactions are based on transactions that have disclosed values and are otherwise comparable in terms of country, funding stage, and timing (as available).
49. See, e.g., Graham Allison, "Is China Beating America to AI Supremacy?" *The National Interest*, December 22, 2019, https://nationalinterest.org/feature/china-beating-america-ai-supremacy-106861 ("Financial markets reflect these realities. . . . Of every ten venture capital dollars invested in AI in 2018, five went to Chinese startups; four to American firms."); Thomas H. Davenport, "China is overtaking the U.S. as the leader in artificial intelligence," *MarketWatch*, March 7, 2019, https://www.marketwatch.com/story/china-is-overtaking-the-us-as-the-leader-in-artificial- intelligence-2019-02-27.
50. See sources cited in note 42; see also Coco Feng, "China's AI start-ups are closing more funding deals, yet they're still attracting less money than the US," *South China Morning Post*, January 22, 2020, https://www.scmp.com/tech/venture-capital/article/3047161/chinas-ai-start-ups-are-closing-more-funding-deals-yet-theyre. Chinese transaction count rose steadily, but from a small baseline, as discussed above.
51. In our dataset, the average disclosed value for transactions with Chinese targets (excluding M&A transactions) was $76 million in 2015, $149 million in 2017, and $32 million in 2019. For perspective, the

average disclosed value for transactions with U.S.-based targets (excluding M&A transactions) was $9 million in 2015, $10 million in 2017, and $24 million in 2019.

52. After reviewing, we believe this estimated value is likely far too high, and because it occurs early in the underlying series, it disproportionately affects the normalized trend. We believe the adjusted data probably better reflect real-world values.
53. "Intel Acquires Artificial Intelligence Chipmaker Habana Labs," *Intel Newsroom*, December 16, 2019, https://newsroom.intel.com/news-releases/intel-ai-acquisition/#gs.04xss9.
54. See, e.g., Brown and Singh, "China's Technology Transfer Strategy."
55. At least one source suggests the actual gap probably isn't so large. A recent Rhodium Group analysis counted 25 percent more venture capital rounds involving Chinese investors and U.S. targets (from 2000 to 2019, across all industries and technologies) when it assigned each investor the nationality of its ultimate controlling entity (as determined by Rhodium Group), rather than its headquarters location. Lysenko et al, "Disruption: US-China Venture Capital in a New Era of Strategic Competition," 34. Also, as discussed above, our data likely undercount investments in Chinese AI companies to some extent. Most of those investments presumably involved Chinese investors, so the undercounting makes outbound investment by Chinese investors seem *more* common than it really is (all else equal). This counteracts other dynamics that would lead us to underestimate that activity.
56. In relative terms, transactions with disclosed Chinese investors account for about a quarter of all disclosed transaction value worldwide, but only 7 percent of transaction count. This disparity has a simple explanation: Chinese investors are much more likely to participate in transactions involving Chinese targets, and as discussed above, those were much larger on average than transactions elsewhere over the period we analyzed.
57. See generally "The Committee on Foreign Investment in the United States (CFIUS)," U.S. Department of the Treasury, last accessed March 20, 2020, https://home.treasury.gov/policy-issues/international/the-committee-on-foreign-investment-in-the-united-states-cfius; Brown and Singh, "China's Technology Transfer Strategy."
58. Thilo Hanemann, Daniel H. Rosen, Cassie Gao, and Adam Lysenko, "Two-Way Street: 2019 Update US-China Direct Investment Trends" (Rhodium Group, May 2019), https://rhg.com/research/two-way-street-2019-update-us-china-direct-investment-trends/.
59. See "Rising Tension: Assessing China's FDI drop in Europe and North America" (Baker McKenzie, 2018), 4, 6-7, https://www.bakermckenzie.com/-/media/files/insight/publications/2018/04/rising_tension_china_fdi.pdf; "The Committee on Foreign Investment in the United States (CFIUS)," U.S. Department of the Treasury; Brown and Singh, "China's Technology Transfer Strategy."
60. See generally William Hanlon, "How to Get Seed Funding and How It Is Different from Series A" (MassChallenge, January 8, 2019), https://masschallenge.org/article/How-Get-Seed-Funding-Different-Series-A; William Hanlon, "Understanding the Differences of Series A, Series B, and Series C Funding (with Examples)" (MassChallenge, November 30, 2018), https://masschallenge.org/article/understanding-difference-series-a-series-b-series-c-funding-examples.
61. See, e.g., Shuly Galili, "Is Seed Investing Still a Local Business?" *TechCrunch*, June 20, 2019, https://techcrunch.com/2019/06/20/is-seed-investing-still-a-local-business/ ("In years past, raising a seed round often boiled down to finding a local VC or angels that would invest a few hundred thousand dollars on just an idea for a company."); David Beisel, "Seed Fundraising is No Longer a Local Game," *Forbes*, January 4, 2019, https://www.forbes.com/sites/valleyvoices/2019/01/04/seed-fundraising-is-no-longer-a-local-game/.
62. See Section 2.
63. 786 of the 893 M&A transactions in our dataset have undisclosed values.
64. See discussion in Appendix 1.
65. See, e.g., "A new era of liberalised inbound investment," Linklaters, last accessed March 20, 2020, https://www.linklaters.com/en-us/insights/thought-leadership/china-report/china-inbound-investment-a-new-era-of-liberalised-inbound-deal-flow.
66. See, e.g., Jason Del Rey, "Antitrust Officials Ordered Facebook, Amazon, and other Tech Giants to Disclose 10 Years of Acquisition Documents," *Vox*, February 11, 2020, https://www.vox.com/

recode/2020/2/11/21133308/ftc-big-tech-acquisition-information-request-amazon-apple-google-facebook-microsoft.

67. See Grace Maral Burnett, "U.S. M&A Mega Year in Review," *Bloomberg Law*, January 10, 2020, https://news.bloomberglaw.com/bloomberg-law-analysis/analysis-u-s-m-a-mega-year-in-review; Grace Maral Burnett, "China, Hong Kong M&A Already Ailing; Virus Won't Help," *Bloomberg Law*, January 29, 2020, https://news.bloomberglaw.com/bloomberg-law-analysis/analysis-china-hong-kong-m-a-already-ailing-virus-wont-help.
68. Many of China's best-known "startups," such as facial recognition developer SenseTime and ridesharing company Didi Chuxing, are valued in the billions of dollars; few could afford to buy them. See, e.g., James Crabtree, "Didi Chuxing Took on Uber and Won. Now it's Taking on the World," *Wired*, February 9, 2018, https://www.wired.co.uk/article/didi-chuxing-china-startups-uber (as of 2018, "Didi [was] the planet's most valuable startup (for now), with a $56bn valuation").
69. For example, a search on data platform ITJuzi for acquisitions of AI companies (according to ITJuzi's classification) based in China returned only three results in 2019. Search conducted March 7, 2020.
70. See, e.g., Allison, "Is China Beating America to AI Supremacy?".
71. See Figure 1 and related discussion.
72. Transportation-focused AI companies based in China raised nearly $20 billion in disclosed investment from 2015 to 2019, while U.S.-based, transportation-focused AI companies raised about $14 billion.
73. "投资人逃离人工智能," 36Kr, September 25, 2019, https://36kr.com/p/5250586; "China's Sharp Eyes surveillance system puts the security focus on public shaming," *South China Morning Post*, October 30, 2018, https://www.scmp.com/news/china/politics/article/2170834/chinas-sharp-eyes-surveillance-system-puts-security-focus-public; see generally "2021年中国人脸识别市场规模将达530亿元," December 13, 2019, https://www.iyiou.com/intelligence/insight120190.html.
74. "The world's leading electric-car visionary isn't Elon Musk," *Bloomberg*, September 26, 2018, https://www.bloomberg.com/news/features/2018-09-26/world-s-electric-car-visionary-isn-t-musk-it-s-china-s-wan-gang; see generally Scott Kennedy, "China's Risky Drive into New-Energy Vehicles" (Center for Strategic and International Studies, November 2018), http://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/181127_Kennedy_NEV_WEB_v3.pdf.
75. Steve Hanley, "NIO Reports Record Sales in June," *CleanTechnica*, July 3, 2020, https://cleantechnica.com/2020/07/03/nio-reports-record-sales-in-june/; Ding Yi, "Xpeng Gets Green Light to Test Autonomous Vehicles in U.S.," CX Tech, March 16, 2020, https://www.caixinglobal.com/2020-03-16/xpeng-gets-green-light-to-test-autonomous-vehicles-in-us-101529011.html. See generally David J. Teece, "China and the Reshaping of the Auto Industry: A Dynamic Capabilities Perspective," *Management and Organization Review*, vol 15, no. 1 (March 2019), available at https://pdfs.semanticscholar.org/777a/9b3b8dfa2346201f32c96edc0751d47a34fe.pdf, 185-87.
76. Peter Elstrom, "China's venture capital boom shows signs of turning into a bust," *Bloomberg Technology*, July 9, 2019, https://www.bloomberg.com/news/articles/2019-07-09/china-s-venture-capital-boom-shows-signs-of-turning-into-a-bust; Tianlei Huang, "Government-guided funds in China: Financing vehicles for state industrial policy," *Peterson Institute for International Economics*, June 17, 2019, https://www.piie.com/blogs/china-economic-watch/government-guided-funds-china-financing-vehicles-state-industrial-policy.
77. See generally Hugh MacArthur, "Private Equity: Still booming, but is the cycle near its end?" *Bain & Company*, February 25, 2019, https://www.bain.com/insights/year-in-review-global-private-equity-report-2019/; Christine Idzelis, "Venture capital struggles to meet hurdle rate," *Institutional Investor*, July 15, 2019, https://www.institutionalinvestor.com/article/b1g92ldh2p8k2r/Venture-Capital-Struggles-to-Meet-Hurdle-Rate.
78. For one notable venture capitalist's comments on this general trend, see "Founders Fund," *Founders Fund*, accessed July 22, 2020, https://foundersfund.com/the-future/.
79. See, e.g., "北京科创基金董事长刘克峰：聚焦"耐心资本"，助力硬科技企业跨越死亡谷," 投中网, October 24, 2019, https://www.chinaventure.com.cn/news/80-20191024-349530.html; see generally Stephen B. Kaplan, "The Rise of Patient Capital: The Political Economy of Chinese Global Finance," *Institute for International Economic Policy*, Working Paper Series IIEP-WP-2018-2, July 2018, https://www2.gwu.edu/~iiep/assets/docs/papers/2018WP/KaplanIIEP2018-2.pdf.

80. See, e.g., Kelsey D. Atherton, "Will China Win the Military AI Race on the Back of Commercial Technology?" *C4ISRNET*, June 10, 2019, https://www.c4isrnet.com/artificial-intelligence/2019/06/10/will-china-leapfrog-the-us-in-ai-on-the-back-of-commercial-technology/; Eric Johnson, "Former Defense Secretary Ash Carter Says AI Should Never Have the "True Autonomy" to Kill," *Vox*, May 13, 2019, https://www.vox.com/recode/2019/5/13/18617081/secretary-defense-ash-carter-ai-lethal-kill-ethics-harvard-facebook-kara-swisher-decode-podcast/.
81. See generally Maaike Verbruggen, "The Role of Civilian Innovation in the Development of Lethal Autonomous Weapons Systems," *Global Policy* 10, no. 3 (September 2019), https://onlinelibrary.wiley.com/doi/abs/10.1111/1758-5899.12663.
82. See generally Brown and Singh, "China's Technology Transfer Strategy"; Bennett and Bender, "How China Acquires 'the Crown Jewels' of U.S. Technology"; "Open Arms: Evaluating Global Exposure to China's Defense-Industrial Base," (C4ADS, 2019), https://static1.squarespace.com/static/566ef8b4d8af107232d5358a/t/5d95fb48a0bfc672d825e346/1570110297719/Open+Arms.pdf.
83. Brown and Singh, "China's Technology Transfer Strategy"; Jodi Xu Klein, "US Plans to Restrict Foreign Investments in AI and Biotech May Curb China's Tech Ambitions," *South China Morning Post*, November 21, 2018, https://www.scmp.com/news/world/united-states-canada/article/2174229/us-restrict-foreign-investments-ai-biotech-curbing; Bennett and Bender, "How China Acquires 'the Crown Jewels' of U.S. Technology."
84. See discussions in Section 2 and Appendix 1.
85. Unless otherwise specified, we extracted data and performed analyses on May 5, 2020.
86. See Jean-Michel Dalle, Matthijs den Besten, and Carlo Menon, "Using Crunchbase for Economic and Managerial Research," *OECD Science, Technology and Industry Working Paper*, No. 2017/08, (November 2017), 16-19, https://www.oecd-ilibrary.org/industry-and-services/using-crunchbase-for-economic-and-managerial-research_6c418d60-en.
87. See "Frequently Asked Questions," Refinitiv, last accessed March 5, 2020, https://www.refinitiv.com/en/about-us/faq. For this analysis, we extracted information from Refinitiv's bulk private equity (PE) data feed, which includes venture capital transactions.
88. Sherwin Santos, customer support, Refinitiv, emails to author, September 27, 2019 and October 1, 2019; "What are the Guidelines for Adding Content to Crunchbase?", Crunchbase, last updated March 1, 2020, https://support.crunchbase.com/hc/en-us/articles/115011260487-What-are-the-guidelines-for-adding-content-to-Crunchbase-.
89. See, e.g., "Crunchbase Knowledge Center," Crunchbase, last accessed March 5, 2020, https://support.crunchbase.com/hc/en-us/articles/360001531787-How-are-categories-organized-; "What are Industry Verticals?" PitchBook Blog, December 11, 2019, https://pitchbook.com/blog/what-are-industry-verticals.
90. See generally Ariel Procaccia, "Beware of Geeks Bearing AI Gifts," *Bloomberg*, July 10, 2019, https://www.bloomberg.com/opinion/articles/2019-07-10/ai-hype-fools-a-lot-of-the-people-a-lot-of-the-time.
91. Search conducted May 5, 2020. Crunchbase has two different fields for company descriptions: one brief, one long. Most companies have both, but some only have a brief description. We ran our search on a concatenation of the two fields. We limited the search to organizations identified as "companies" in Crunchbase (as opposed to "investors," "schools," and "groups"). See "Organization," Crunchbase Data, last accessed March 5, 2020, https://data.crunchbase.com/docs/organization. For Refinitiv, we extracted target companies and their business descriptions from Refinitiv's data feed of private equity transactions. "Datafeeds from Refinitiv Investing & Advisory," (Refinitiv, 2019), 12-13, https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/ia-datafeeds-catalogue-2019.pdf.
92. We excluded 311 AI companies without records in Crunchbase (i.e., the company was identified as an AI company based on its record in Refinitiv but could not be matched to Crunchbase), and 75 additional companies whose Crunchbase records had no data on the company's geographic location.
93. The dataset includes the companies listed in Jillian D'Onfro, "AI 50: America's Most Promising Artificial Intelligence Companies," *Forbes*, September 17, 2019, https://www.forbes.com/sites/jilliandonfro/2019/09/17/ai-50-americas-most-promising-artificial-intelligence-companies/#34c219c1565c and Jeffrey Ding, "ChinAI #63: Who is Ultrapower? Introducing ChinAI

Company Profiles," *ChinAI Newsletter*, August 25, 2019, https://chinai.substack.com/p/chinai-63-who-is-ultrapower-introducing. Of the 167 companies listed in these articles, 21 are publicly traded and were excluded from the validation tests, consistent with our broader analysis. An additional 19 companies could not be located in one or more of the test databases and were also excluded. See also Jillian D'Onfro, "AI 50 Methodology: How We Chose Our Honorees," *Forbes*, September 17, 2019, https://www.forbes.com/sites/jilliandonfro/2019/09/17/ai-50-methodology-how-we-selected-our-top-startups/.

94. There is a temporal mismatch between the CB Insights, Pitchbook, and Crunchbase category data we used (extracted in or around late December 2019) and our keyword results, which are based on Crunchbase and Refinitiv data extracted in early May 2020. This adds some uncertainty to our analysis: the former data may have changed in the meantime. It's not clear whether any such change would materially affect the results of the comparison.
95. See "Collections Overview," CBINSIGHTS, last updated June 17, 2019, https://cbinsights.drift.help/article/collections-overview/. CB Insights data were extracted in late December 2019.
96. See "Crunchbase Knowledge Center," Crunchbase, last accessed March 5, 2020, https://support.crunchbase.com/hc/en-us/articles/360001531787-How-are-categories-organized-
97. See "What are Industry Verticals?" PitchBook Blog, December 11, 2019, https://pitchbook.com/blog/what-are-industry-verticals. Pitchbook data were extracted in December 2019.
98. We also excluded general AI-related buzzwords such as "big data," "data mining," "smart," and "intelligent," which returned large numbers of apparently AI-unrelated companies.
99. See, e.g., Will Knight, "Nine Charts that Really Bring Home Just How Fast AI is Growing," *MIT Technology Review*, December 12, 2018, https://www.technologyreview.com/s/612582/data-that-illuminates-the-ai-boom/. We expect the same is also true of commercial vendors' lists of AI companies.
100. See, e.g., Stephen G. Dimmock, Jiekun Huang, and Scott J. Weisbenner, "Give Me Your Tired, Your Poor, Your High-Skilled Labor: H-1B Lottery Outcomes and Entrepreneurial Success," National Bureau of Economic Research, NBER Working Paper No. 26392 (October 2019), 10-11, https://www.nber.org/papers/w26392 (discussing, among others, Jean-Michel Dalle, Matthijs den Besten, and Carlo Menon, "Using Crunchbase for Economic and Managerial Research," *OECD Science, Technology and Industry Working Paper*, No. 2017/08, (November 2017), https://ideas.repec.org/p/oec/stiaaa/2017-08-en.html; Jorn H. Block, Christian Fisch, Alexander Hahn, Philipp G. Sandner, "Why Do SMEs File Trademarks? Insights from Firms in Innovative Industries," *Research Policy* 44 (June 2015), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2317515); Stefano Breschi, Julie Lassebie, and Carlo Menon, "A Portrait of Innovative Start-ups Across Countries," *OECD Science, Technology and Industry Working Papers*, No. 2018/02 (February 2018), https://www.oecd-ilibrary.org/docserver/f9ff02f4-en.pdf).
101. See "Record Matching," PermID Thomson Reuters, last accessed March 5, 2020, permid.org. Analysts used automatic entity matching tools provided by Crunchbase and Refinitiv as well as manual review. See Jade Foon-Domingo, "How Do I Import a List?" Crunchbase, last updated January 2020, https://support.crunchbase.com/hc/en-us/articles/360034230054-How-do-I-Import-a-List-; "Record Matching," PermID Thomson Reuters, last accessed March 5, 2020, https://permid.org/match. Analysis conducted February 2020.
102. Analysis conducted May 2020.
103. The calculations rely on Refinitiv data in one limited respect. Crunchbase and Refinitiv sometimes disagree about where multinational companies are headquartered, with Crunchbase typically placing them in the United States rather than abroad. For example, Crunchbase counts Israel-based semiconductor company Habana Labs as American because it was recently purchased by Intel. "Habana" (Crunchbase, accessed May 6, 2020), https://www.crunchbase.com/organization/habana. In these instances, we believe Refinitiv's data, which are based in part on legal records, are generally more reliable. However, because only a minority of the AI companies we analyzed could be located in Refinitiv, we have no choice but to rely on Crunchbase's location data in most cases.
104. Search conducted May 2020. In terms of Crunchbase's funding stage schema, we counted investments classified as Angel, Convertible Note, Corporate Round, Pre-Seed, Private Equity, Seed, Series A, Series B, Series C, Series D, Series E, Series F, Series G, Series H, Series I, Series J, Series Unknown. See "Glossary of Funding Types," Crunchbase, last accessed March 5, 2020, https://support.crunchbase.com/hc/en-

us/articles/115010458467-Glossary-of-Funding-Types. We excluded transactions where the target was classified by Crunchbase as public or post-IPO at the time of the transaction, as well as companies that had been acquired by a publicly traded firm prior to the transaction.

105. We relied on Crunchbase's venture capital funding stage determinations. See "Glossary of Funding Types," Crunchbase, last accessed March 5, 2020, https://support.crunchbase.com/hc/en-us/articles/115010458467-Glossary-of-Funding-Types.
106. Note that these medians were calculated based on investment into all companies, not just AI companies.
107. See. e.g., Bennett and Bender, "How China Acquires 'the Crown Jewels' of U.S. Technology"; Jacob Rund, "U.S. Investment Security Chief Warns of Threats Posed by AI (1)," *Bloomberg Government*, February 26, 2020, https://news.bloomberglaw.com/corporate-law/u-s-investment-security-chief-warns-of-threats-posed-by-a-i; "How to Perform Due Diligence for a VC Financing," LathamDrive, last accessed March 5, 2020, https://www.lathamdrive.com/resources/insights/how-to-perform-due-diligence-for-a-vc-financing.
108. Assume, for example, that transactions with Chinese investors are about as prevalent for this subset of U.S.-based companies as they are across our entire transaction dataset, in which about 7 percent of transactions had a disclosed Chinese investor. In that case, there would be nearly 100 more U.S.-based companies with Chinese investors—too small a number to materially affect our conclusions about Chinese investors' activity in the U.S. AI market (which saw about 7,000 discrete investment transactions from 2015 to 2019).
109. See Lysenko et al, "Disruption: US-China Venture Capital in a New Era of Strategic Competition," 16-18, for an overview of this issue in the venture capital context.
110. See, e.g., "Understanding Beneficial Ownership Structures" (Dun & Bradstreet, 2017), (https://www.dnb.co.uk/content/dam/english/dnb-solutions/supply-management/UBO-guide-170515_UK.pdf; Olivia Solon, "Open Data Platform Reveals Complex Corporate Structure of Banks," *Wired*, July 11, 2013, https://www.wired.co.uk/article/opencorporates. Firms with a presence in China can have especially complex structures. See, e.g., Raymond Zhong, "Who Owns Huawei? The Company Tried to Explain. It Got Complicated." *The New York Times*, April 25, 2019, https://www.nytimes.com/2019/04/25/technology/who-owns-huawei.html; John McDuling, "The Mind-Bendingly Complex Ownership Structure Behind Chinese Internet IPOs," *Quartz*, December 9, 2013, https://qz.com/155535/the-mind-bendingly-complex-ownership-structure-behind-chinese-internet-ipos/; Xiaochan Jia, "Complex Organizational Structure and Chinese Firm Value," *Wharton Research Scholars* 69 (April 2010), https://repository.upenn.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1072&context=wharton_research_scholars.
111. Private equity and venture capital funds typically raise money from external "passive" investors who do not actively participate in the selection and management of the fund's holdings. A single venture capital fund can have many such investors from different countries. See generally "Private Equity Funds Key Business, Legal, and Tax Issues" (Debevoise & Plimpton, 2015), 3-10, https://www.google.com/l?sa=t&rct=j&q=&esrc=s&source=web&cd=27&ved=2ahUKEwiRwZiO5b3nAhW3lHIEHajaD9UQFjAaegQIBhAB&url=https%3A%2F%2Fwww.debevoise.com%2F~%2Fmedia%2Ffiles%2Finsights%2Fnews%2F2015%2Fpe_fundskey%2520business_legal_tax_issues.pdf&usg=AOvVaw3KvFXY_fo-E7qwYGnIuEev.
112. Chris Witkowsky, "Silver Lake Raises $15 Bln for Fifth Tech Fund," *PE Hub*, April 18, 2017, https://www.pehub.com/3448604/.
113. "IDG Capital," World Economic Forum, last accessed March 5, 2020, https://www.weforum.org/organizations/idg-capital-partners.
114. Jurisdiction may be especially important for organizations headquartered in China, because the Chinese government has extensive power over private companies. See, e.g., Richard McGregor, "How the State Runs Business in China," *The Guardian*, July 25, 2019, https://www.theguardian.com/world/2019/jul/25/china-business-xi-jinping-communist-party-state-private-enterprise-huawei; Josh Horwitz, "China to Send State Officials to 100 Private Firms Including Alibaba," *Reuters*, September 23, 2019, https://www.reuters.com/article/us-alibaba-china-party/china-to-send-state-officials-to-100-private-firms-including-alibaba-idUSKBN1W80DO.
115. However, the analysis also found that the *amount* of investment by Chinese investors had been dramatically overstated in prior commentary. See See Adam Lysenko, Thilo Hanemann, and Daniel H. Rosen,

"Disruption: US-China Venture Capital in a New Era of Strategic Competition" (US-China Investment Project, January 2020), 34, https://arraysproduction-0dot22.s3.amazonaws.com/rhodiumgroup/assets/icon/RHG_Disruption_US-China-VC_January2020.pdf.

116. This taxonomy is very loosely based on a categorization system developed by the World Intellectual Property Organization. See "Data Collection Method and Clustering Scheme" (World Intellectual Property Organization, 2019), https://www.wipo.int/export/sites/www/tech_trends/en/artificial_intelligence/docs/techtrends_ai_methodology.pdf. "TINA" stands for Taxonomy of INtelligence Applications.
117. See generally "String Functions in Standard SQL," Google Cloud, last accessed March 5, 2020, https://cloud.google.com/bigquery/docs/reference/standard-sql/string_functions.
118. As such, this category would also include companies developing quantum computing hardware for AI, to the extent such companies are present in our dataset. Although it is in the early stages of development today, quantum computing has already attracted significant attention as a potential complement to AI. See, e.g., Emil Protalinski, "D-Wave: Quantum computing and machine learning are 'extremely well matched'," *VentureBeat*, March 12, 2020, https://venturebeat.com/2020/03/12/d-wave-quantum-computing-and-machine-learning-are-extremely-well-matched/; James Kobielus, "Quantum AI is still years from enterprise prime time," *InfoWorld*, May 28, 2020, https://www.infoworld.com/article/3546010/quantum-ai-is-still-years-from-enterprise-prime-time.html.
119. "China AI Development Report 2018," (China Institute for Science and Technology Policy at Tsinghua University, July 2018), http://www.sppm.tsinghua.edu.cn/eWebEditor/UploadFile/China_AI_development_report_2018.pdf.
120. See generally Paul Triolo and Graham Webster, "Profile: China Academy for Information and Communications Technology (CAICT)," *New America*, October 16, 2018, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/profile-china-academy-information-and-communications-technology-caict/.
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