Artificial Intelligence Index Report 2022

CHAPTER 4:

The Economy and Education

CHAPTER 4:
Chapter Preview

ACCESS THE PUBLIC DATA

Overview

The growing use of artificial intelligence (AI) in everyday life, across industries, and around the world generates numerous questions about how AI is shaping the economy and education—and, conversely, how the economy and education are adapting to AI. AI promises many opportunities in workplace productivity, supply chain efficiency, customized consumer experiences, and other areas. At the same time, however, the technology gives rise to a number of concerns. How do businesses adapt to recruiting and retaining AI talent? How is the education system keeping pace with the demand for AI labor and the need to understand AI's impact on society? All of these questions and more are inextricable from AI today.

This chapter examines the economy and education, using data from Emsi Burning Glass, NetBase Quid, and LinkedIn to capture AI trends in the global economy and data from the annual Computing Research Association Taulbee Report to analyze trends in AI and computer science PhD graduates. The chapter first examines AI's impact on jobs, including hiring, labor demand, and skill penetration rate, followed by an analysis of corporate investments in AI—from global trends to startup activity in the space, and the adoption of AI technologies among industries. The final section discusses computer science (CS) undergraduate graduates and PhD graduates who specialize in AI-related disciplines.

CHAPTER HIGHLIGHTS

- New Zealand, Hong Kong, Ireland, Luxembourg, and Sweden are the countries or regions with the highest growth in AI hiring from 2016 to 2021.
- In 2021, California, Texas, New York, and Virginia were states with the highest number of AI job postings in the United States, with **California having over 2.35 times the number of postings as Texas**, the second greatest. Washington, D.C., had the greatest rate of AI job postings compared to its overall number of job postings.
- **The private investment in AI in 2021 totaled around $93.5 billion—more than double the total private investment in 2020**, while the number of newly funded AI companies continues to drop, from 1051 companies in 2019 and 762 companies in 2020 to 746 companies in 2021. **In 2020, there were 4 funding rounds worth $500 million or more; in 2021, there were 15.**
- "Data management, processing, and cloud" received the greatest amount of private AI investment in 2021—**2.6 times the investment in 2020,** followed by "medical and healthcare" and "fintech."
- In 2021, the United States led the world in both total private investment in AI and the number of newly funded AI companies, **three and two times higher,** respectively, than China, the next country on the ranking.
- Efforts to address ethical concerns associated with using AI in industry remain limited, according to a McKinsey survey. **While 29% and 41% of respondents recognize "equity and fairness" and "explainability" as risks while adopting AI, only 19% and 27% are taking steps to mitigate those risks.**
- In 2020, **1 in every 5 CS students who graduated with PhD degrees specialized in artificial intelligence/machine learning,** the most popular specialty in the past decade. From 2010 to 2020, the majority of AI PhDs in the United States headed to industry while a small fraction took government jobs.

4.1 JOBS

AI HIRING

The AI hiring data draws on a dataset from LinkedIn of skills and jobs listings on the platform. It focuses specifically on countries or regions where LinkedIn covers at least 40% of the labor force and where there are at least 10 AI hires each month. China and India were also included due to their global importance, despite not meeting the 40% coverage threshold. Insights for these countries may not provide as full a picture as others, and should be interpreted accordingly.

Figure 4.1.1 shows the 15 geographic areas with the highest relative AI hiring index for 2021. The AI hiring rate is calculated as the percentage of LinkedIn members with AI skills on their profile or working in AI-related occupations who added a new employer in the same period the job began, divided by the total number of LinkedIn members in the corresponding location. This rate is then indexed to the average month in 2016; for example, an index of 1.05 in December 2021 points to a hiring rate that is 5% higher than the average month in 2016. LinkedIn makes month-to-month comparisons to account for any potential lags in members updating their profiles. The index for a year is the number in December of that year.

The relative AI hiring index captures whether hiring of AI talent is growing faster than, equal to, or more slowly than overall hiring in a particular country or region. New Zealand has the highest growth in AI hiring—2.42 times greater in 2021 compared with 2016, followed by Hong Kong (1.56), Ireland (1.28), Luxembourg (1.26), and Sweden (1.24). Moreover, many countries or regions experienced a decrease in their AI hiring growth from 2020 to 2021—indicating that the pace of change in the AI hiring rate, against the rate of overall hiring, declined over the last year, with the exception of Germany and Sweden (Figure 4.1.2).

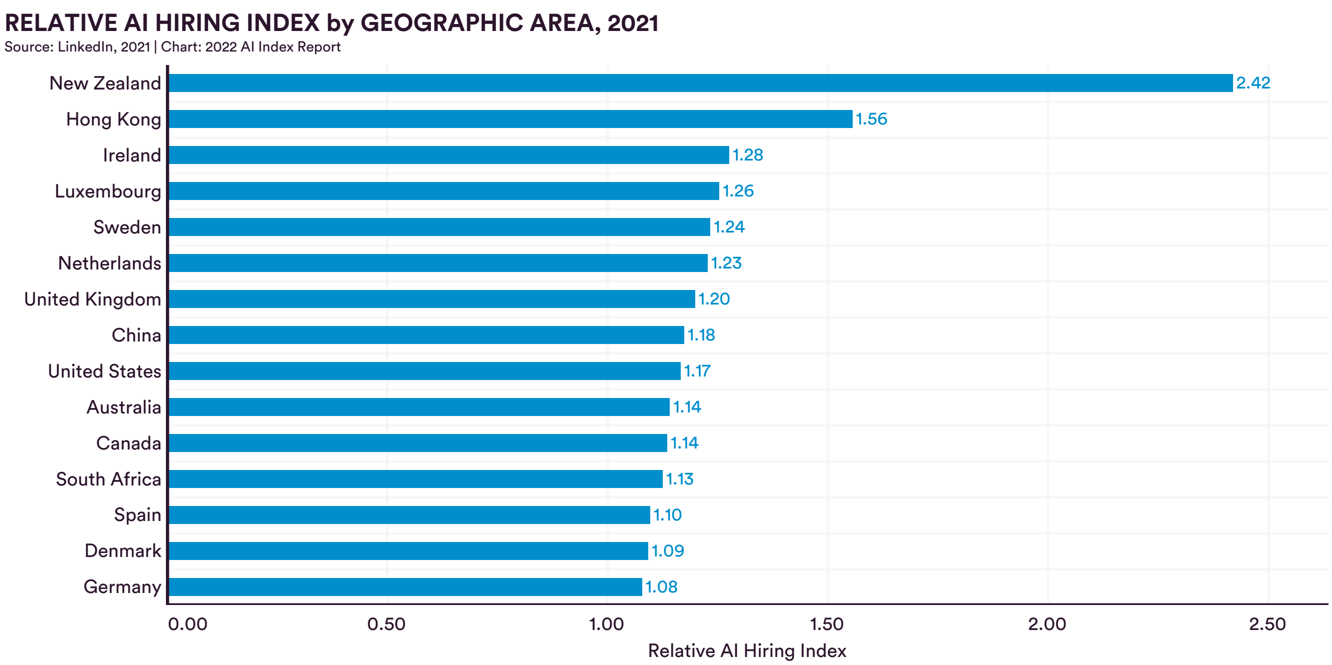

Figure 4.1.1

RELATIVE AI HIRING INDEX by GEOGRAPHIC AREA, 2016–21
Source: LinkedIn, 2021 | Chart: 2022 AI Index Report

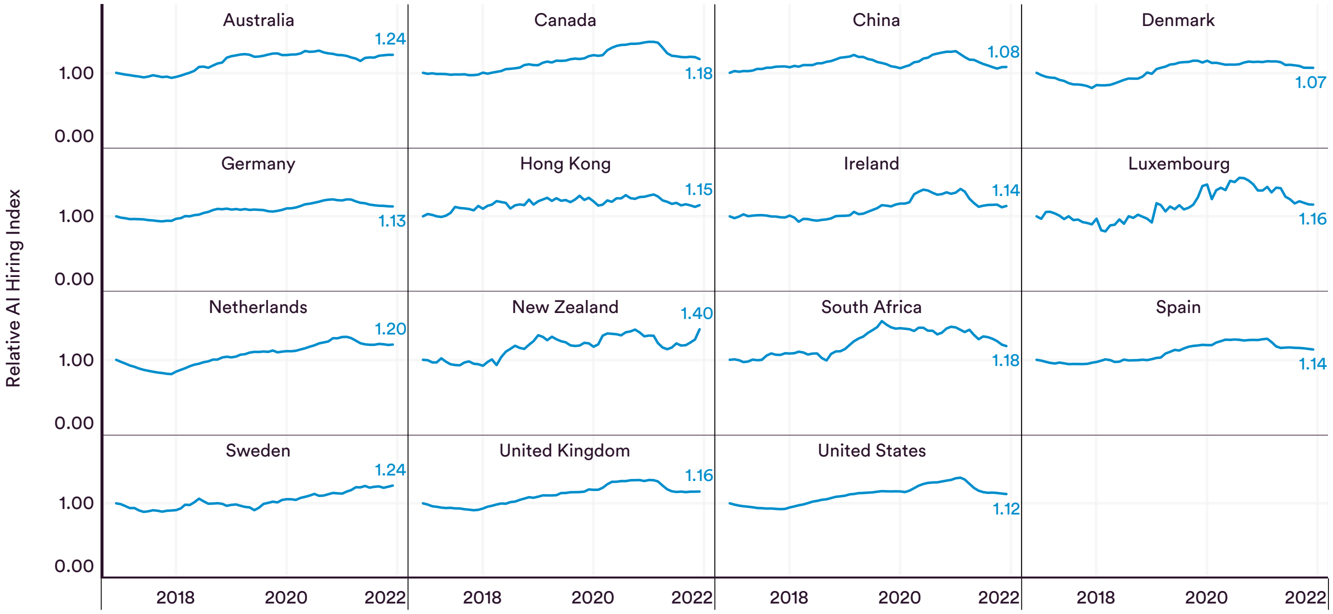

Figure 4.1.2

AI LABOR DEMAND

To analyze demand for specific AI labor skills, Emsi Burning Glass mined millions of job postings collected from over 45,000 websites since 2010 and flagged all listings calling for AI skills.

Global AI Labor Demand

Figure 4.1.3 shows that the percentage of AI job postings among all job postings in 2021 was greatest in Singapore (2.33% of all job listings), followed by the United States (0.90%), Canada (0.78%), and the United Kingdom (0.74%). AI job postings increased in the United States, Canada, Australia, and New Zealand from 2020 to 2021, while they declined in Singapore and the United Kingdom.

AI JOB POSTINGS (% of ALL JOB POSTINGS) by GEOGRAPHIC AREA, 2013–21

Source: Emsi Burning Glass, 2021 | Chart: 2022 AI Index Report

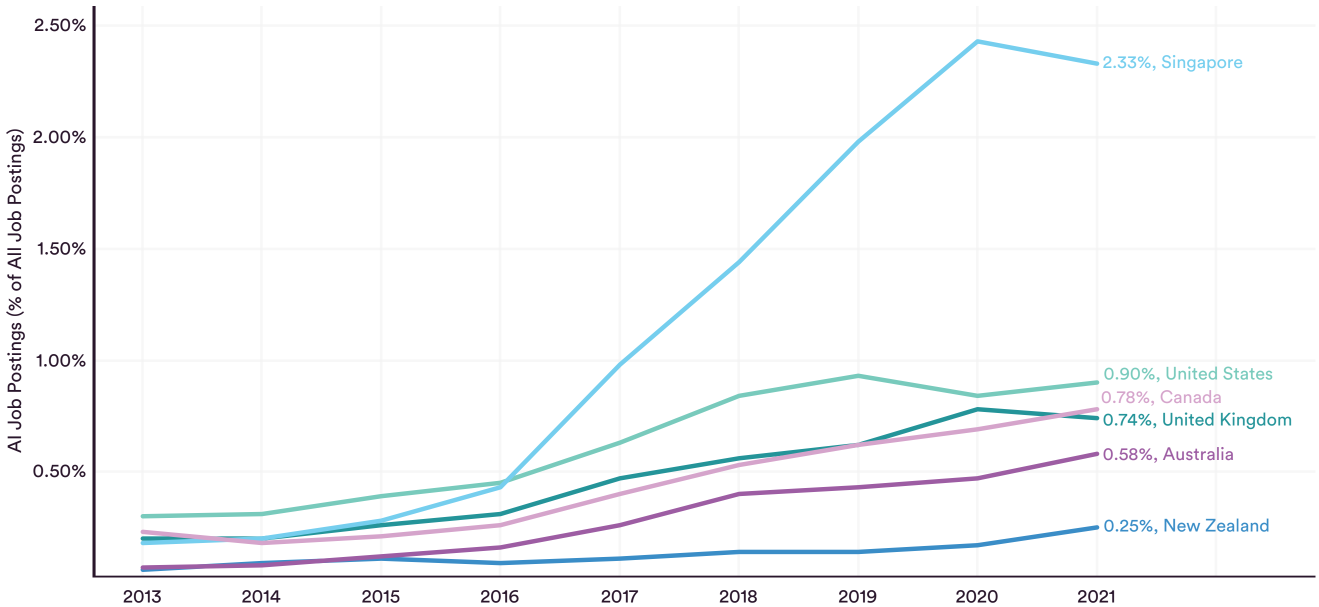

Figure 4.1.3

U.S. AI Labor Demand: By Skill Cluster

Figure 4.1.4 shows the U.S. labor demand from 2010 to 2021 by skill cluster. Each skill cluster consists of a list of AI-related skills; for example, the neural network skill cluster includes skills like deep learning and convolutional neural networks.[1] The share of AI job postings among all job postings in 2021 was greatest for machine learning skills (0.6% of all job postings), followed by artificial intelligence (0.33%), neural networks (0.16%), and natural language processing (0.13%). Postings for AI jobs in machine learning and artificial intelligence have significantly increased in the past couple of years, despite small declines in both categories from 2019–2020. Machine learning jobs are at nearly three times the level, and artificial intelligence jobs are at around 1.5 times the level they each reached, respectively, in 2018.

The share of AI job postings among all job postings in 2021 was greatest for machine learning skills (0.6% of all job postings), followed by artificial intelligence (0.33%), neural networks (0.16%), and natural language processing (0.13%).

AI JOB POSTINGS (% of ALL JOB POSTINGS) in the UNITED STATES by SKILL CLUSTER, 2010–21
Source: Emsi Burning Glass, 2021 | Chart: 2022 AI Index Report

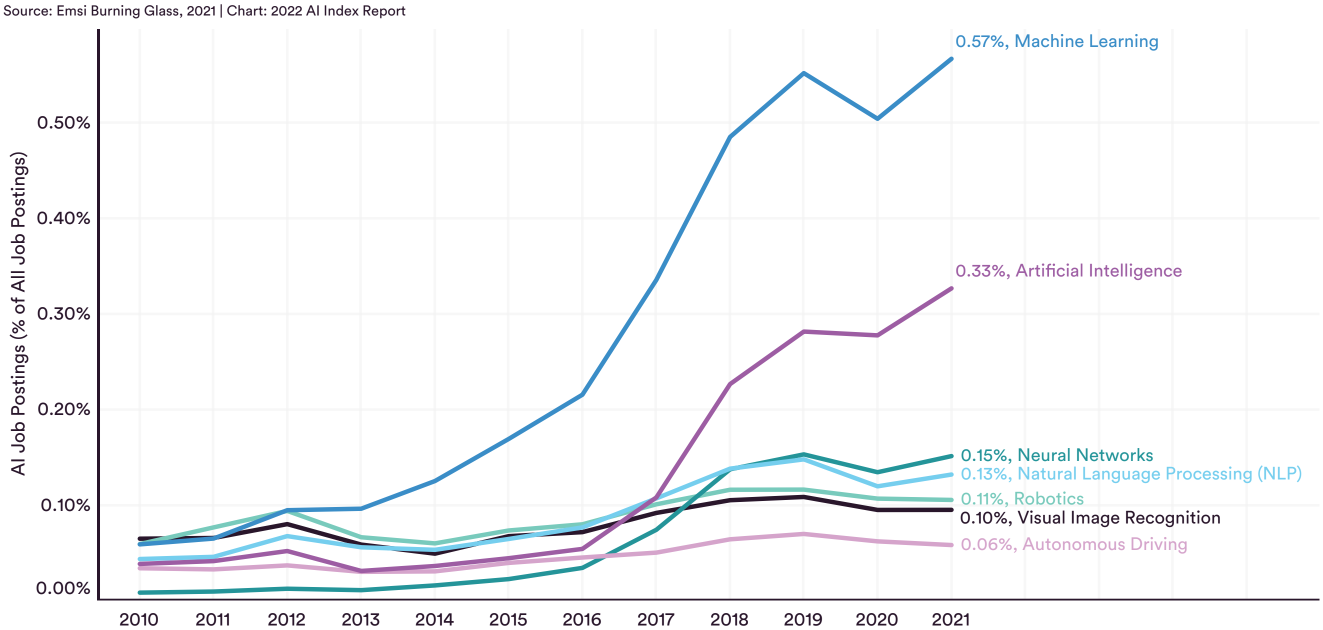

Figure 4.1.4

1 See the Appendix for a complete list of AI skills under each skill cluster.

U.S. Labor Demand: By Sector

Figure 4.1.5 shows that 3.30% of all job postings in the information sector in the United States were AI-related, followed by professional, scientific, and technical services (2.59% of all listings), manufacturing (2.02%), and finance and insurance (1.81%).

AI JOB POSTINGS (% of ALL JOB POSTINGS) in the UNITED STATES by SECTOR, 2021
Source: Emsi Burning Glass, 2021 | Chart: 2022 AI Index Report

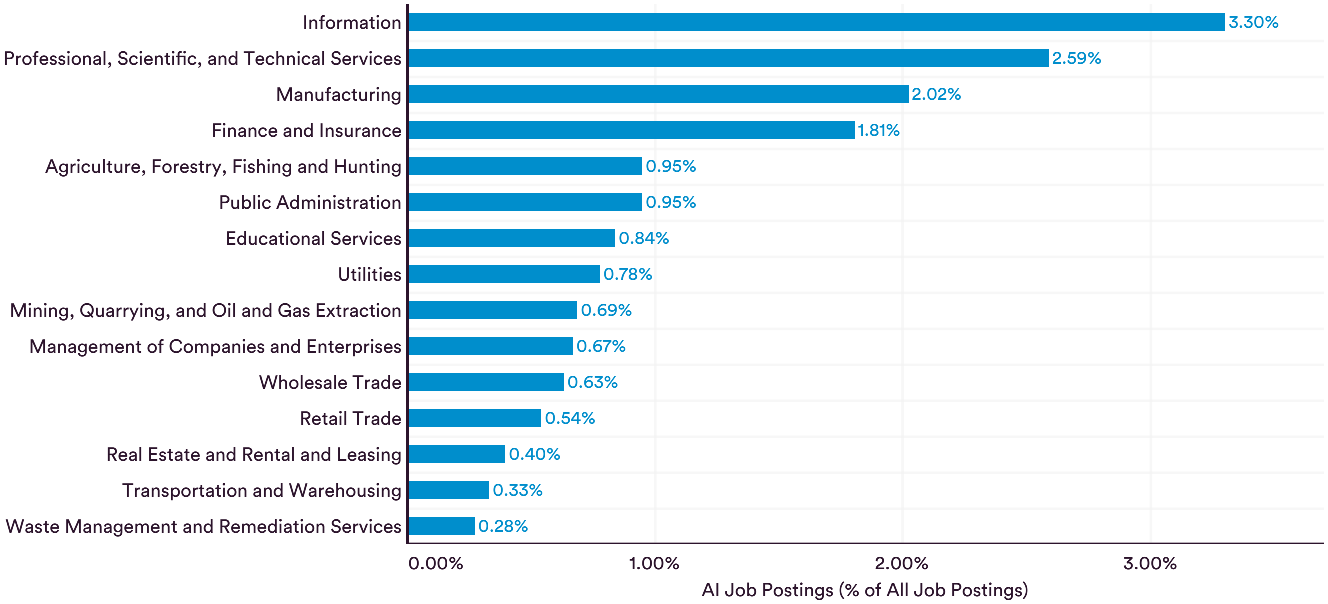

Figure 4.1.5

U.S. Labor Demand: By State

Figure 4.1.6 breaks down the U.S. AI labor demand by state. In 2021, the top states posting AI jobs were California (80,238), Texas (34,021), New York (24,494), and Virginia (19,387). California, in first, had over 2.35 times the number of postings as Texas, the second greatest. Proportionally, however, Washington, D.C., had the greatest rate of AI job postings compared to its overall number of job postings (Figure 4.1.7). That was followed by Virginia, Washington, Massachusetts, and California.

NUMBER of AI JOB POSTINGS in the UNITED STATES by STATE, 2021
Source: Emsi Burning Glass, 2021 | Chart: 2022 AI Index Report

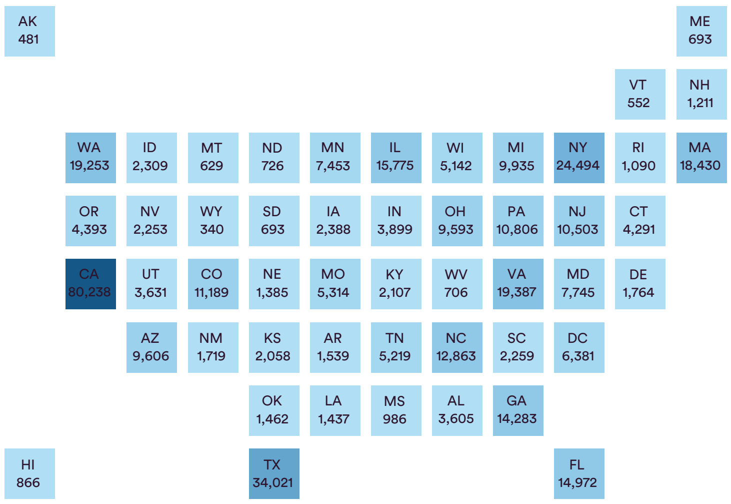

Figure 4.1.6

AI JOB POSTINGS (TOTAL and % of ALL JOB POSTINGS) by U.S. STATE and DISTRICT, 2021
Source: Emsi Burning Glass, 2021 | Chart: 2022 AI Index Report

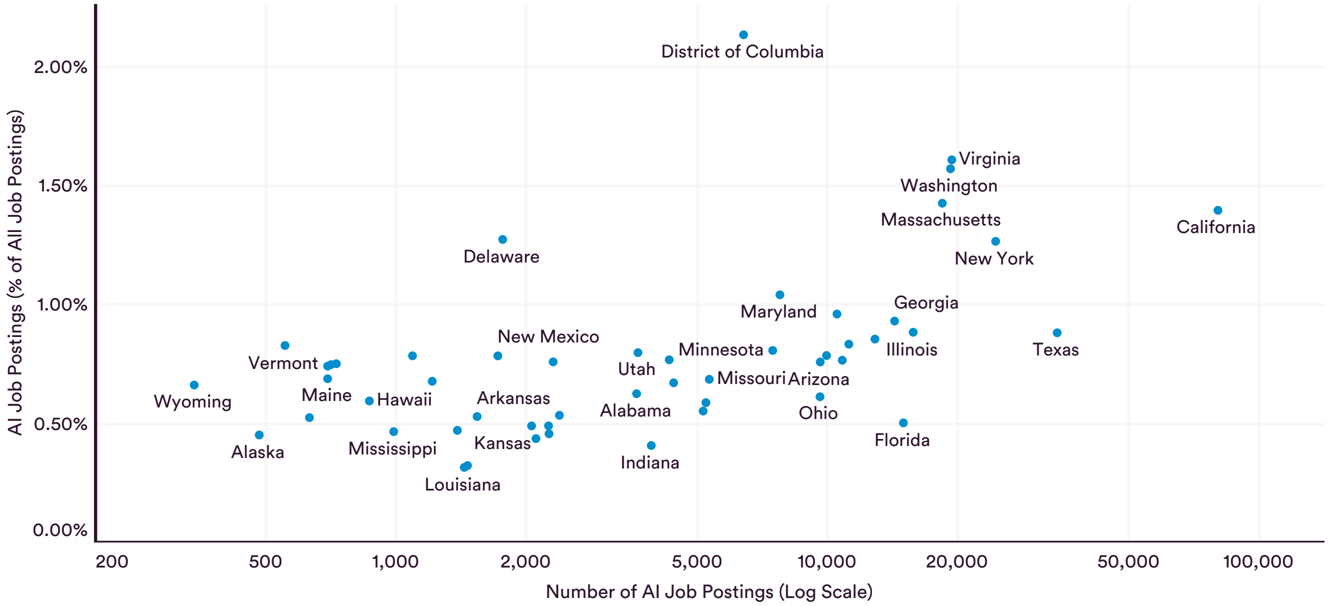

Figure 4.1.7

AI SKILL PENETRATION

The AI skill penetration rate shows the prevalence of AI skills across occupations, or the intensity with which LinkedIn members use AI skills in their jobs. It is calculated by computing the frequencies of LinkedIn users' self-added skills in a given area from 2015–2021, then reweighting those figures by using a statistical model to get the top 50 representative skills in that occupation.

Global Comparison

For global comparison, the relative penetration rate of AI skills is measured as the sum of the penetration of each AI skill across occupations in a given country or region, divided by the global average across the same occupations. For example, a relative penetration rate of 2 means that the average penetration of AI skills in that country or region is 2 times the global average across the same set of occupations. Figure 4.1.8 shows that India led the world in the rate of AI skill penetration—3.09 times the global average from 2015 to 2021—followed by the United States (2.24) and Germany (1.7). After that came China (1.56), Israel (1.52), and Canada (1.41).[2]

RELATIVE AI SKILL PENETRATION RATE by GEOGRAPHIC AREA, 2015–21

Source: LinkedIn, 2021 | Chart: 2022 AI Index Report

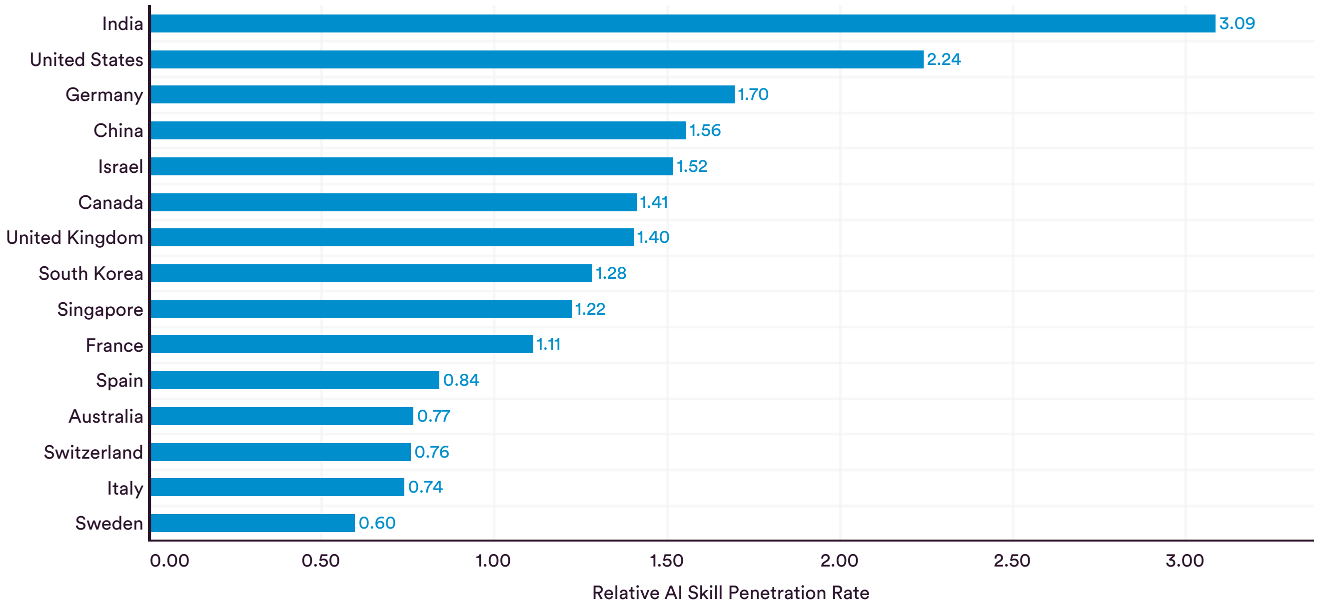

Figure 4.1.8

Global Comparison: By Industry

India and the United States had the highest relative AI skill penetration across the board—leading the other countries or regions in skill penetration rates in software and IT services, hardware and networking, manufacturing, education, and finance (Figure 4.1.9). Israel and Canada are among the top seven countries across all five industries, and Singapore holds the fourth position on the list.

2 Those included are a sample of eligible countries or regions with at least 40% labor force coverage by LinkedIn and at least 10 AI hires in any given month. China and India were also included in this sample because of their increasing importance in the global economy, but LinkedIn coverage in these countries does not reach 40% of the workforce. Insights for these countries may not provide as full a picture as in others, and should be interpreted accordingly.

RELATIVE AI SKILL PENETRATION RATE by INDUSTRY across GEOGRAPHIC AREA, 2015–21
Source: LinkedIn, 2021 | Chart: 2022 AI Index Report

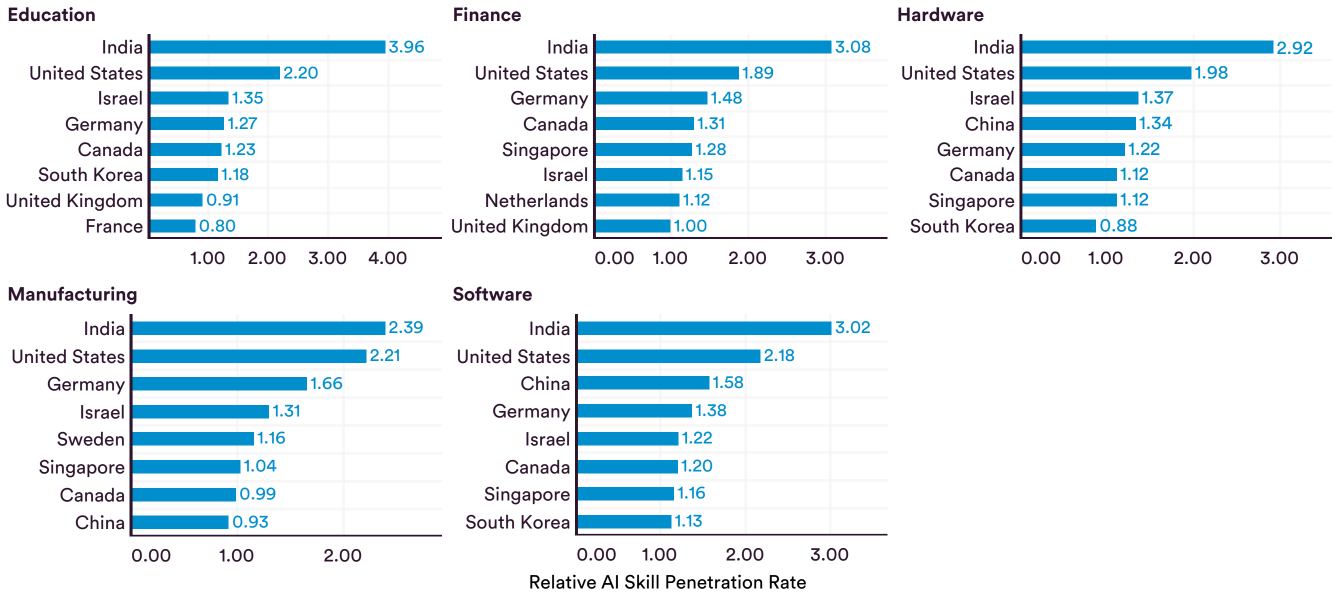

Figure 4.1.9

Global Comparison: By Gender

Figure 4.1.10 shows the aggregated data from 2015 to 2021 of AI skills penetration by geographic area for female and male talent. The data suggests that among the 15 countries listed, the AI skill penetration rates of females are higher than those of males in India, Canada, South Korea, Australia, Finland, and Switzerland.

RELATIVE AI SKILL PENETRATION RATE by GENDER, 2015–21
Source: LinkedIn, 2021 | Chart: 2022 AI Index Report

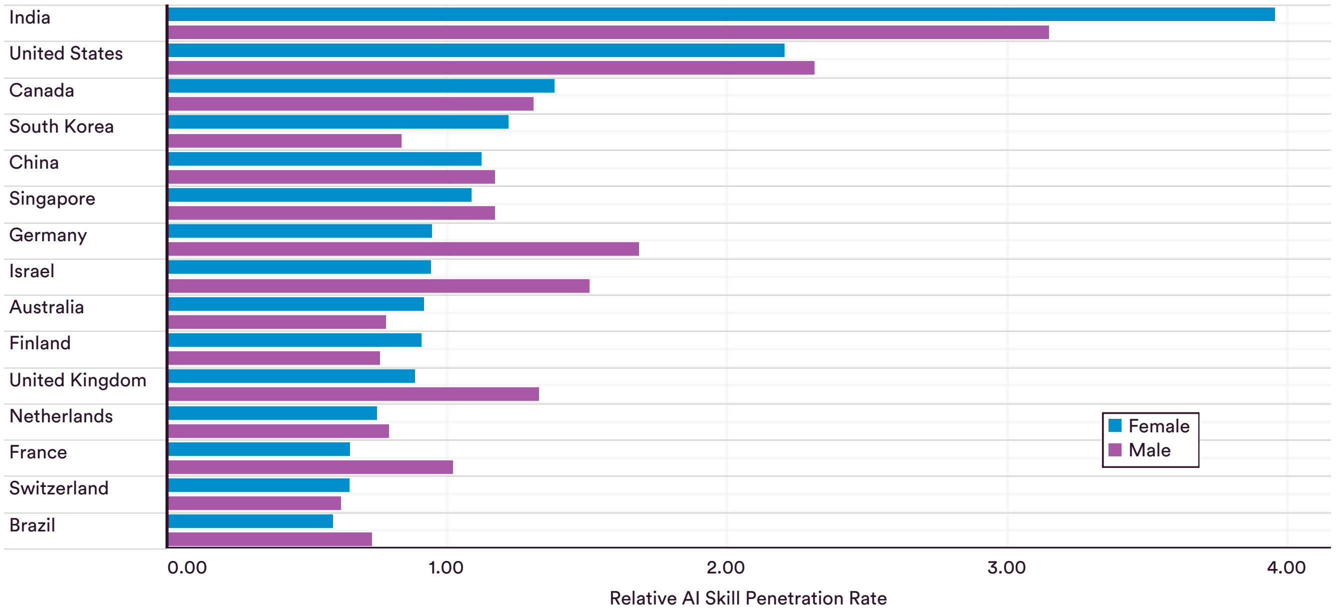

Figure 4.1.10

This section on corporate AI activity draws on data from NetBase Quid, which aggregates over 6 million global public and private company profiles, updated on a weekly basis, including metadata on investments, location of headquarters, and more. NetBase Quid also applies natural language processing technology to search, analyze, and identify patterns in large, unstructured datasets, like aggregated blogs, company and patent databases.

4.2 INVESTMENT

CORPORATE INVESTMENT

Corporate investment in artificial intelligence, from mergers and acquisitions to public offerings, is a key contributor to AI research and development. It also contributes to AI's impact on the economy. Figure 4.2.1 highlights overall global corporate investment in AI from 2013–2021. In 2021, companies made the greatest AI investment through private investment (totaling around $93.5 billion), followed by mergers and acquisitions (around $72 billion), public offerings (around $9.5 billion), and minority stake (around $1.3 billion). In 2021, investments from mergers and acquisitions grew by 3.3 times compared to 2020, led by two AI healthcare companies and two cybersecurity companies.[3]

GLOBAL CORPORATE INVESTMENT in AI by INVESTMENT ACTIVITY, 2013–21
Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

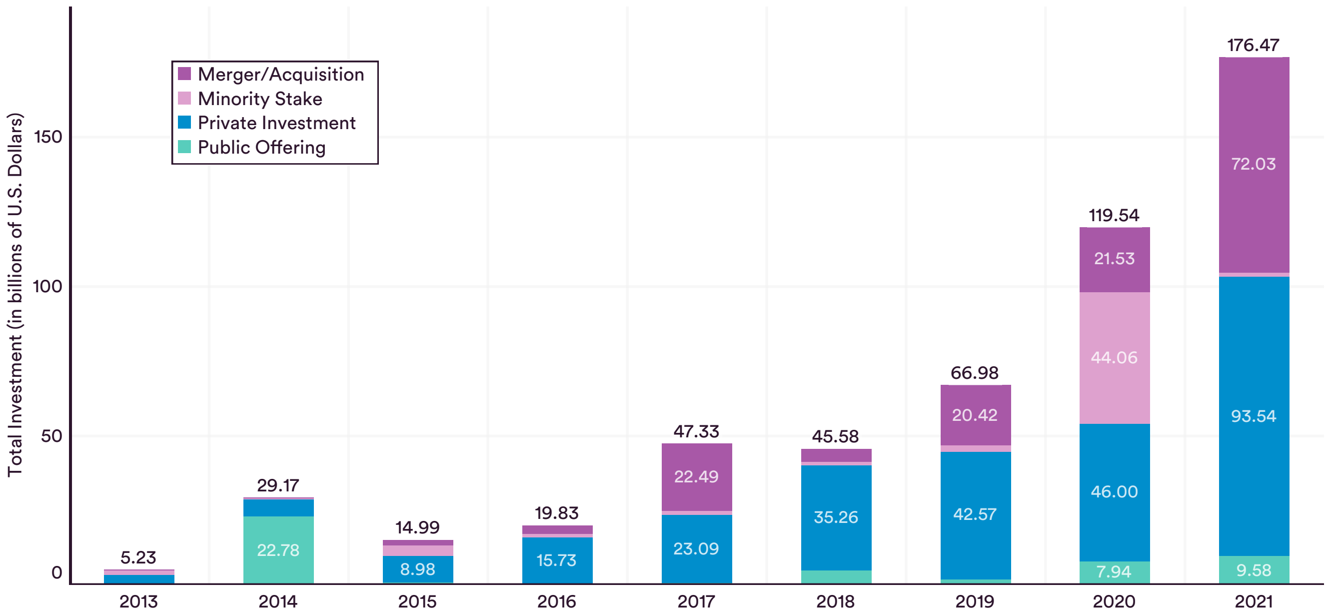

Figure 4.2.1

3 Nuance Communications (by Microsoft, $19.8 billion), Varian Medical Systems (Siemens, $17.2 billion), and Proofpoint (Thoma Bravo, $12.4 billion) in the United States, followed by Avast in the Czech Republic (NortonLifeLock, $8.0 billion).

STARTUP ACTIVITY

The following section analyzes artificial intelligence and machine learning companies globally that have received more than $1.5 million in investment from 2013 to 2021.

Global Trend

In 2021, global private investment in AI totaled around $93.5 billion, which is more than double the total private investment in 2020 (Figure 4.2.2). That marks the greatest year-over-year increase since 2014 (when investment from 2013 to 2014 more than doubled).

Among companies that disclosed the amount of funding, the number of AI funding rounds that ranged from $100 million to $500 million more than doubled in 2021 compared to 2020, while funding rounds that were between $50 million and $100 million more than doubled as well (Table 4.2.1). In 2020, there were only four funding rounds worth $500 million or more; in 2021, that number grew to 15. Companies attracted significantly higher investment in 2021, as the average private investment deal size in 2021 was 81.1% higher than in 2020.

However, Figure 4.2.3 shows that the number of newly funded AI companies continues to drop, from 762 companies in 2020 to 746 companies in 2021—the third year of a decline that started in 2018. The largest private investments in 2021 have been led by two data management companies and two robotics/autonomous driving companies.[4]

In 2021, global private investment in AI totaled around $93.5 billion, which is more than double the total private investment in 2020.

PRIVATE INVESTMENT in AI, 2013–21

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

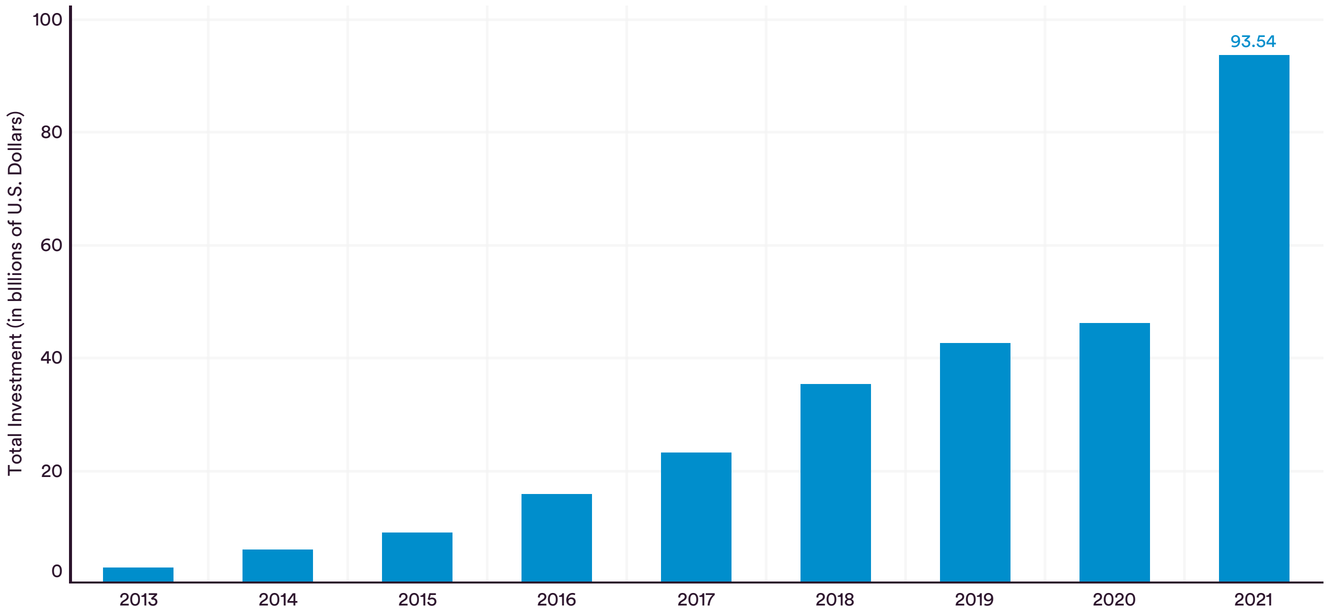

Figure 4.2.2

4 The largest private investments have been Databricks (United States), Beijing Horizon Robotics Technology (China), Oxbotica Limited (United Kingdom), and Celonis (Germany).

NUMBER of NEWLY FUNDED AI COMPANIES in the WORLD, 2013–21

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

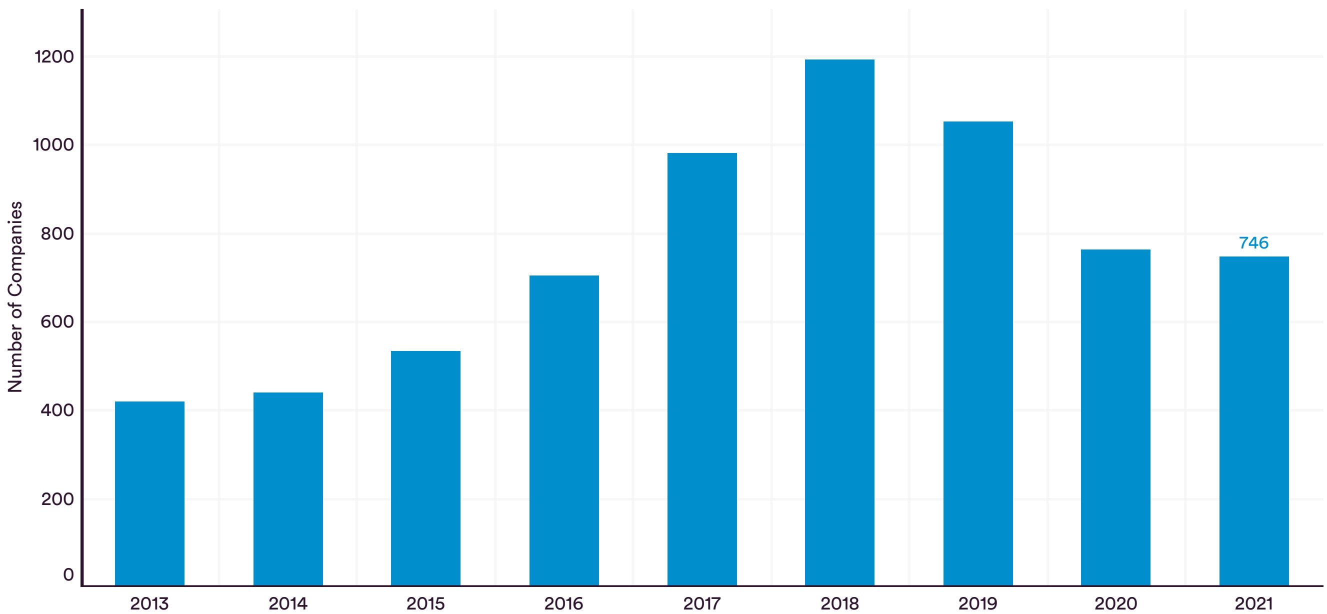

Figure 4.2.3

Funding Size	2020	2021	Total
Over $1 billion	3	5	8
$500 million – $1 billion	1	10	11
$100 million – $500 million	93	235	328
$ 50 million – $100 million	85	194	279
Under $50 million	2,102	2,120	4,222
Undisclosed	354	395	749
Total	**2,638**	**2,959**	**5,597**

Table 4.2.1

Regional Comparison by Funding Amount

In 2021, as captured in Figure 4.2.4, the United States led the world in overall private investment in funded AI companies—at approximately $52.9 billion—over three times the next country on the list, China ($17.2 billion). In third place was the United Kingdom ($4.65 billion), followed by Israel ($2.4 billion) and Germany ($1.98 billion). Figure 4.2.5 shows that when combining total private investment from 2013 to 2021, the same ranking applies: U.S. investment totaled $149 billion and Chinese investment totaled $61.9 billion, followed by the United Kingdom ($10.8 billion), India ($10.77 billion), and Israel ($6.1 billion). Notably, U.S. private investment in AI companies from 2013–2021 was more than double the total in China, which itself was about six times the total investment from the United Kingdom in the same period. Broken out by geographic area, as shown in Figure 4.2.6, the United States, China, and the European Union all grew their investments from 2020 to 2021, with the United States leading China and the European Union by 3.1 and 8.2 times the investment amount, respectively.

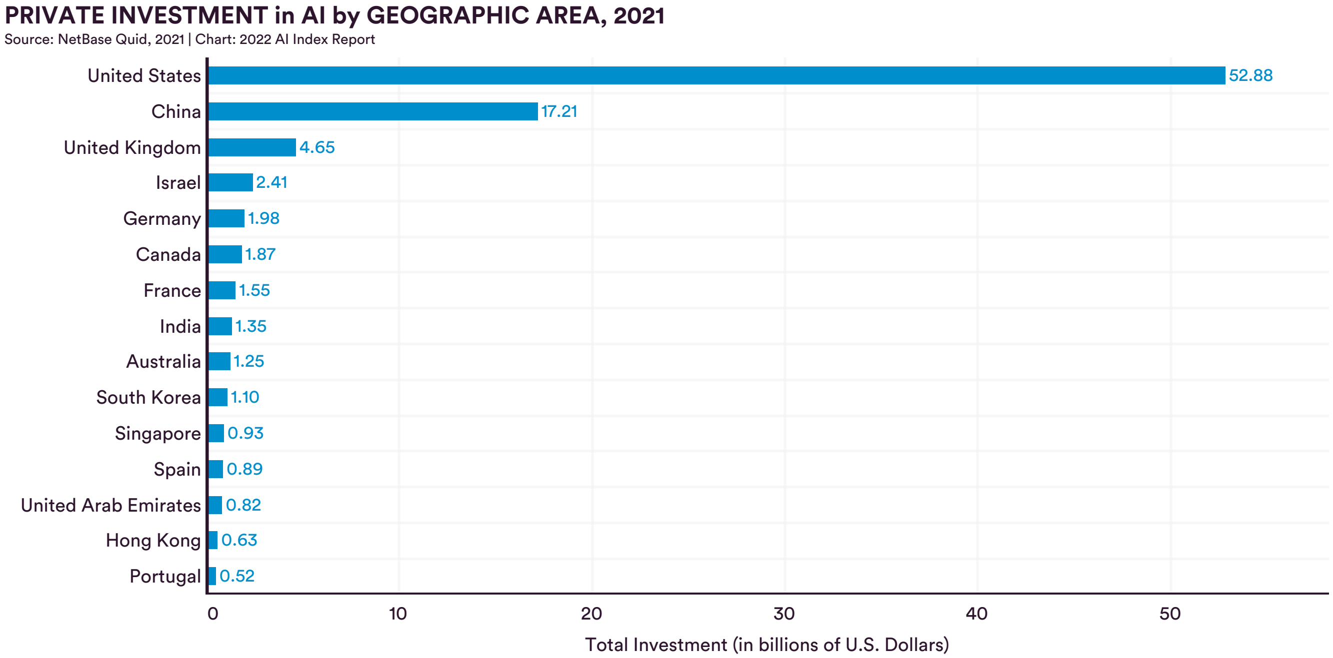

Figure 4.2.4

PRIVATE INVESTMENT in AI by GEOGRAPHIC AREA, 2013–21

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

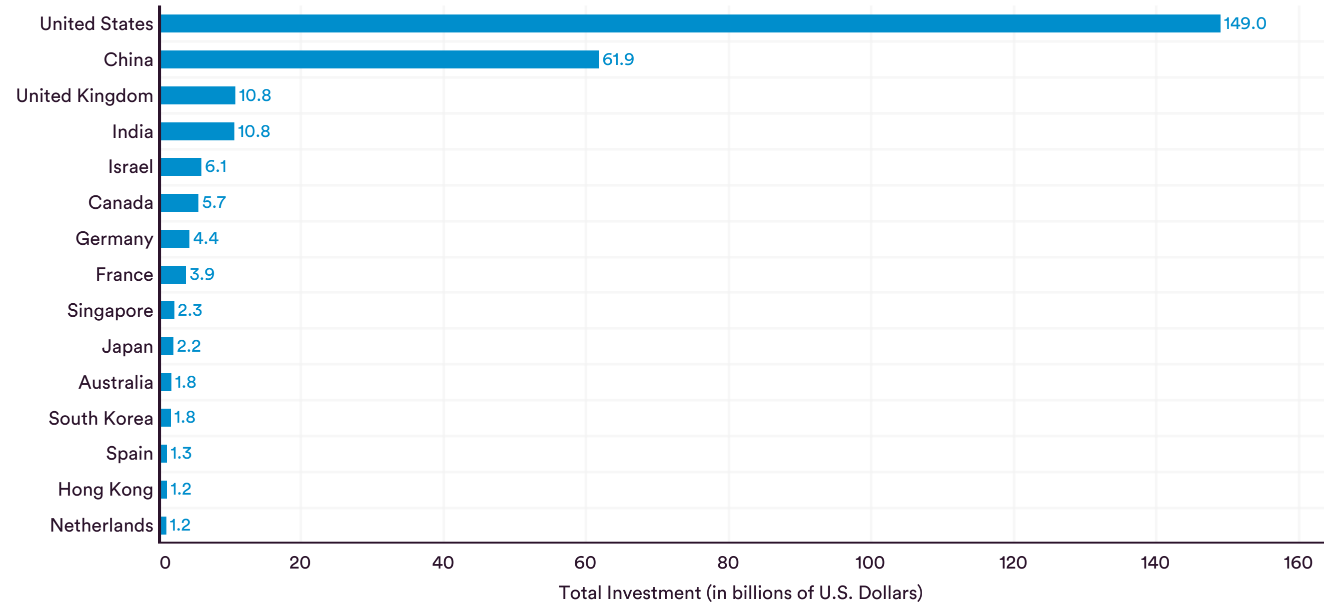

Figure 4.2.5

PRIVATE INVESTMENT in AI by GEOGRAPHIC AREA, 2013–21

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

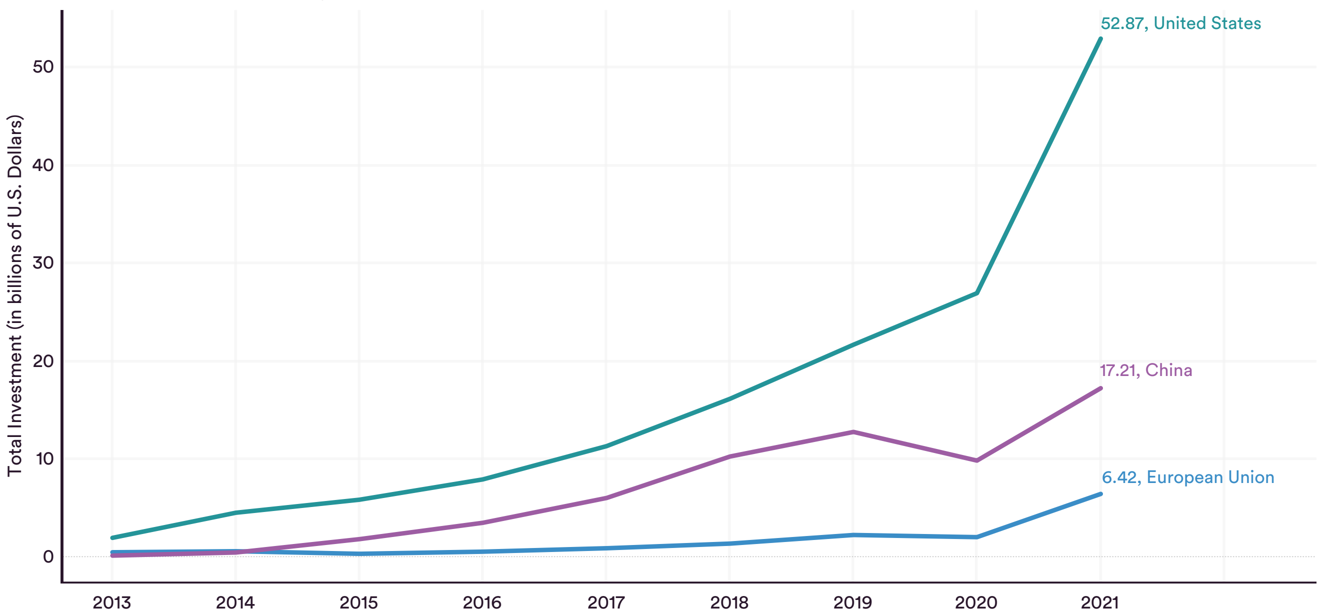

Figure 4.2.6

Regional Comparison by Newly Funded AI Companies

This section breaks down the investment data by the number of newly funded AI companies in each region. For 2021, Figure 4.2.7 shows that the United States led with 299 companies, followed by China with 119, the United Kingdom with 49, and Israel with 28. The gaps between each are significant. Aggregated data from 2013 to 2021 shows a similar trend (Figure 4.2.8).

However, the number of newly funded AI companies has declined in both the United States and China since 2018 and 2019 (Figure 4.2.9). Despite that downward trend, the United States still leads in the number of newly funded companies, with 299 funded in 2021, followed by China (119) and the European Union (96).

NUMBER of NEWLY FUNDED AI COMPANIES by GEOGRAPHIC AREA, 2021
Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

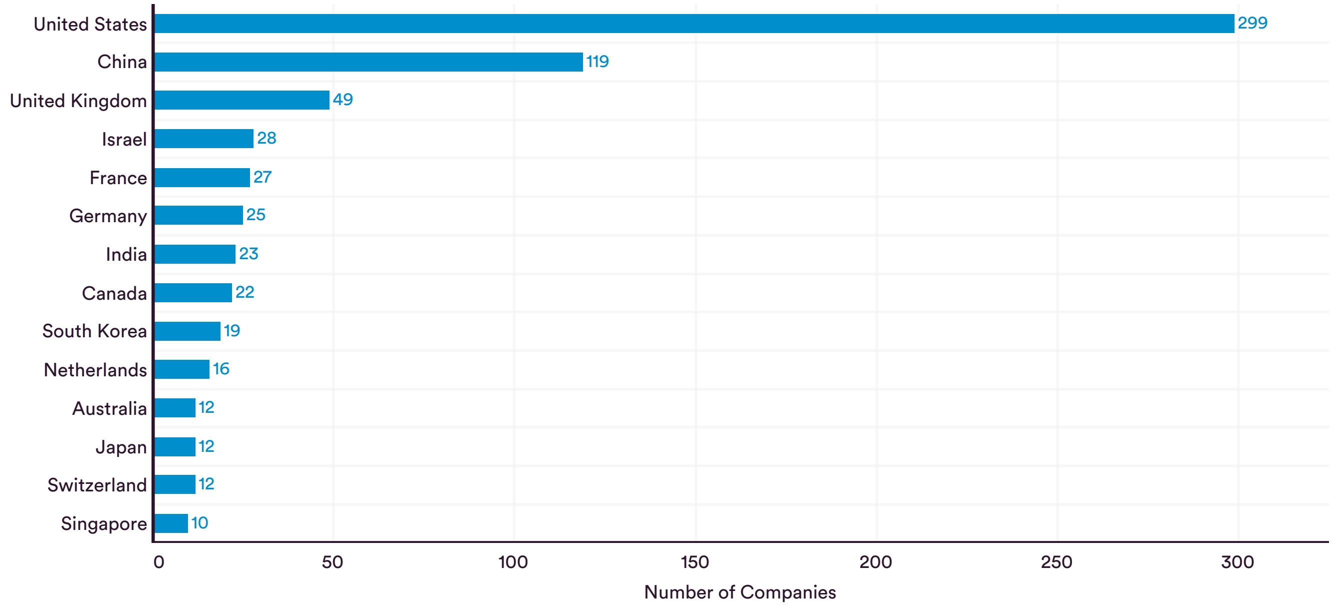

Figure 4.2.7

NUMBER of NEWLY FUNDED AI COMPANIES by GEOGRAPHIC AREA, 2013–21 (SUM)
Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

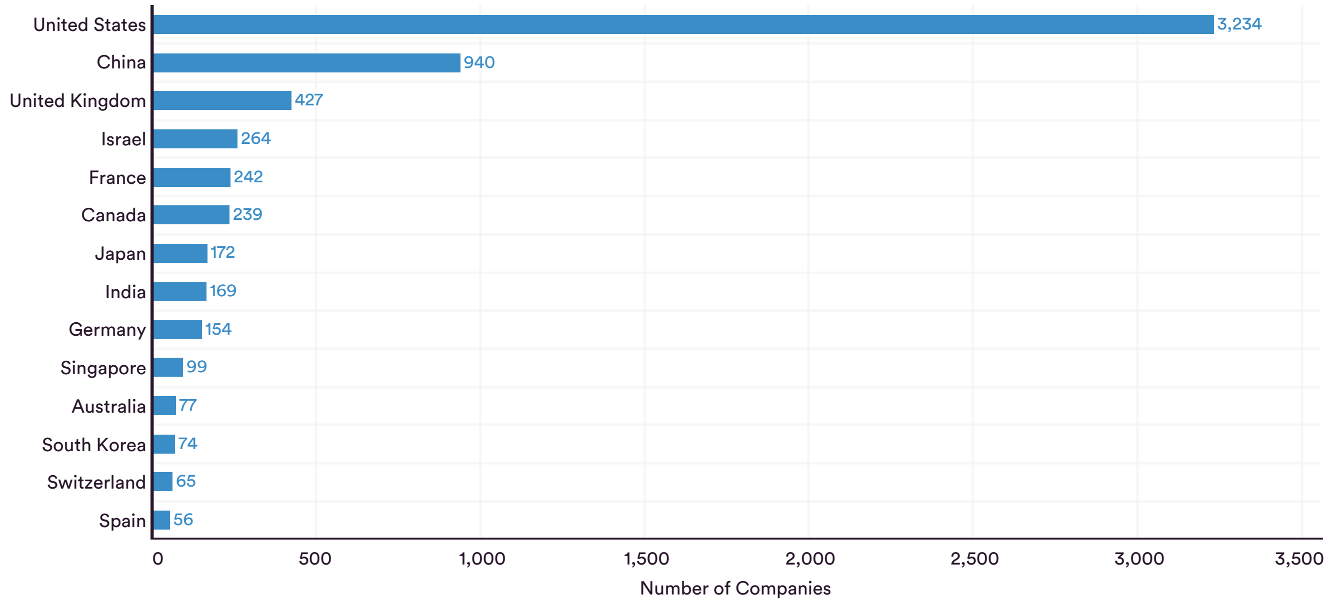

Figure 4.2.8

NUMBER of NEWLY FUNDED AI COMPANIES by GEOGRAPHIC AREA, 2013–21
Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

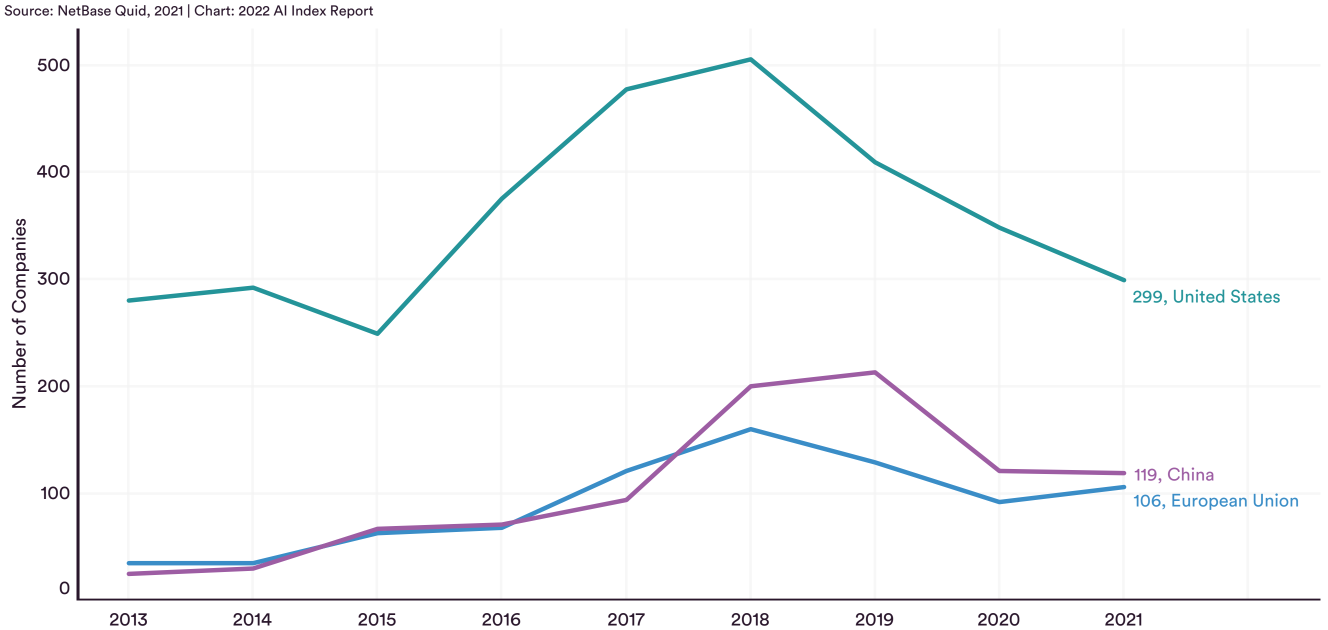

Figure 4.2.9

Focus Area Analysis

Private AI investment also varies by focus area. According to Figure 4.2.10, the greatest private investment in AI in 2021 was in data management, processing, and cloud (around $12.2 billion). Notably, this was 2.6 times the investment in 2020 (around $4.69 billion) as two of the four largest private investments made in 2021 are data management companies. In second place was private investment in medical and healthcare ($11.29 billion), followed by fintech ($10.26 billion), AV ($8.09 billion), and semiconductors ($6.0 billion).

Aggregated data in Figure 4.2.11 shows that in the last five years, the medical and healthcare category received the largest private investment globally ($28.9 billion); followed by data management, processing, and cloud ($26.9 billion); fintech ($24.9 billion); and retail ($21.95 billion). Moreover, Figure 4.2.12 shows the overall trend in private investment by industries from 2017–2021 and reveals a steady increase in AV, cybersecurity and data protection, fitness and wellness, medical and healthcare, and semiconductor industries.

PRIVATE INVESTMENT in AI by FOCUS AREA, 2020 vs. 2021

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

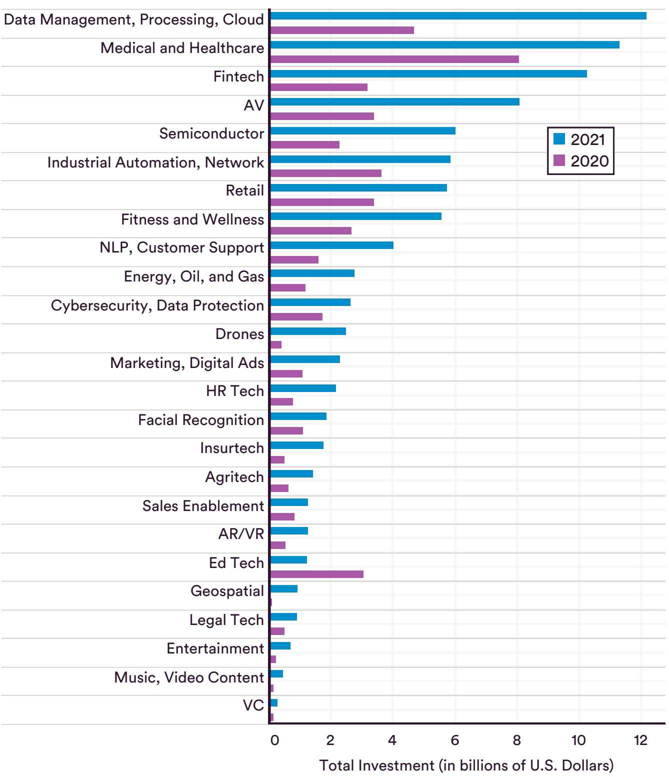

Figure 4.2.10

PRIVATE INVESTMENT in AI by FOCUS AREA, 2017–21 (SUM)

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

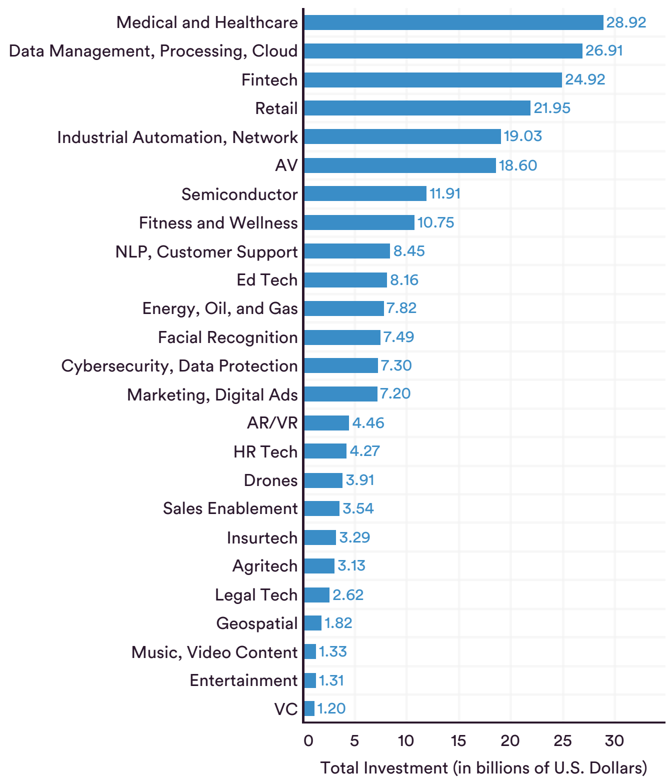

Figure 4.2.11

PRIVATE INVESTMENT in AI by FOCUS AREA, 2017–21

Source: NetBase Quid, 2021 | Chart: 2022 AI Index Report

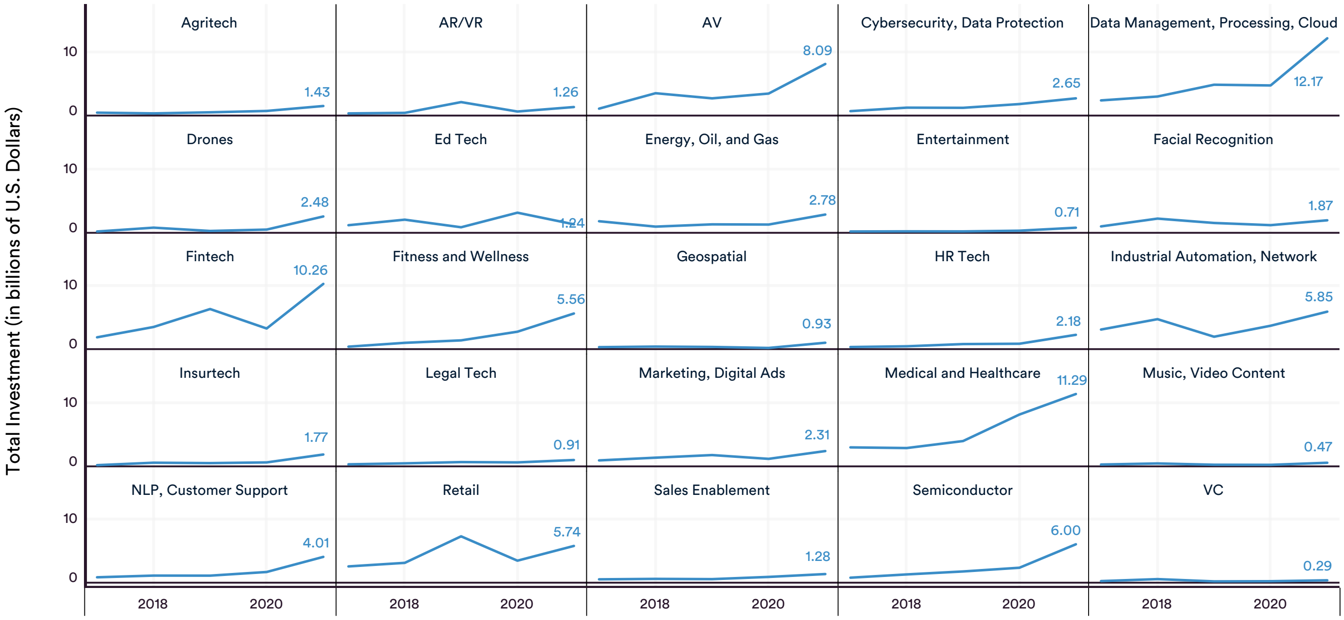

Figure 4.2.12

4.3 CORPORATE ACTIVITY

INDUSTRY ADOPTION

This section on corporate AI activity draws on McKinsey's "The State of AI in 2021" report from December 2021. The report based its conclusions on a global online survey of 1,843 participants conducted earlier in 2021. Survey respondents came from a range of industries, companies, functional specialties, tenures, and regions of the world—and each provided answers to questions about the state of artificial intelligence today.

Global Adoption of AI

Figure 4.3.1 shows AI adoption by organizations globally, broken out by geographic area. In 2021, India led with 65% adoption, followed by "Developed Asia-Pacific" (64%), "Developing markets (incl. China, MENA)" (57%), and North America (55%). The average adoption rate across all geographies was 56%, up 6% from 2020. Notably, "Developing markets (incl. China, MENA)" registered a 21% increase from 2020, and India had an 8% increase from 2020.

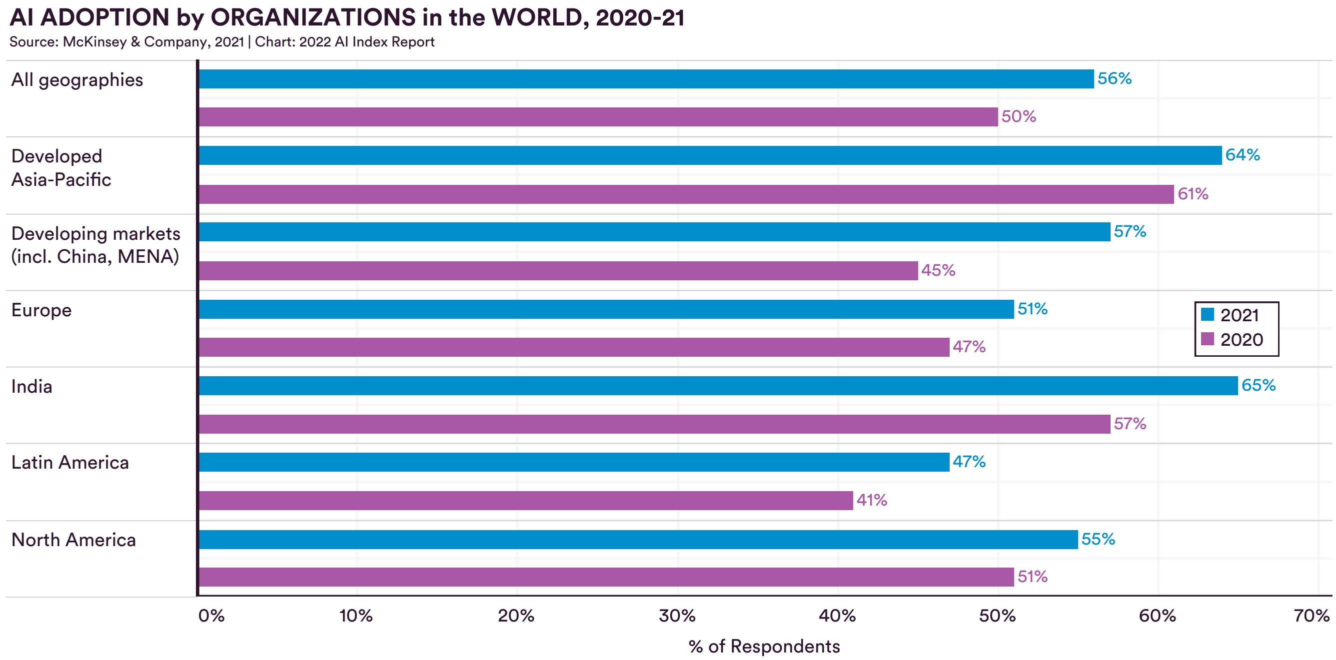

Figure 4.3.1

AI Adoption by Industry and Function

Figure 4.3.2 shows AI adoption by industry and function in 2021. The greatest adoption was in product and/or service development for high tech/telecommunications (45%), followed by service operations for financial services (40%), service operations for high tech/telecommunications (34%), and risk function for financial services (32%).

AI ADOPTION by INDUSTRY and FUNCTION, 2021

Source: McKinsey & Company, 2021 | Chart: 2022 AI Index Report

Industry	Human Resources	Manufacturing	Marketing and Sales	Product and/or Service Development	Risk	Service Operations	Strategy and Corporate Finance	Supply-chain Management
All Industries	9%	12%	20%	23%	13%	25%	9%	13%
Automotive and Assembly	11%	26%	20%	15%	4%	18%	6%	17%
Business, Legal, and Professional Services	14%	8%	28%	15%	13%	26%	8%	13%
Consumer Goods/Retail	2%	18%	22%	17%	1%	15%	4%	18%
Financial Services	10%	4%	24%	20%	32%	40%	13%	8%
Healthcare Systems/Pharma and Medical Products	9%	11%	14%	29%	13%	17%	12%	9%
High Tech/Telecom	12%	11%	28%	45%	16%	34%	10%	16%

% of Respondents (Function)

Figure 4.3.2

Type of AI Capabilities Adopted

With respect to the type of AI capabilities embedded in standard business processes in 2021, as indicated by Figure 4.3.3, the highest rate of embedding was in natural language text understanding for the high tech/telecommunications industry (34%), followed by robotic process automation for both the financial services and automotive and assembly industry (33%) and natural language text understanding for financial services (32%).

AI CAPABILITIES EMBEDDED in STANDARD BUSINESS PROCESSES, 2021

Source: McKinsey & Company, 2021 | Chart: 2022 AI Index Report

Industry	Computer Vision	Deep Learning	Facial Regonition	Knowledge Graphs	NL Generation	NL Speech Un-derstanding	NL Text Un-derstanding	Physical Robotics	Recom-mender Systems	Reinforce-ment Learning	Robotic Process Automation	Simulations	Transfer Learning	Virtual Agents
All Industries	23%	19%	11%	17%	12%	14%	24%	12%	17%	16%	26%	17%	12%	23%
Automotive and Assembly	15%	14%	9%	16%	3%	11%	12%	24%	12%	5%	33%	27%	6%	12%
Business, Legal, and Professional Services	29%	24%	15%	20%	23%	18%	19%	13%	22%	27%	31%	18%	21%	19%
Consumer Goods/Retail	23%	12%	14%	17%	11%	13%	14%	4%	8%	8%	16%	9%	1%	15%
Financial Services	17%	16%	11%	16%	12%	18%	32%	4%	13%	16%	33%	12%	12%	28%
Healthcare Systems/Pharma and Medical Products	30%	25%	12%	19%	10%	8%	26%	28%	22%	13%	28%	22%	19%	31%
High Tech/Telecom	28%	22%	6%	17%	17%	18%	34%	5%	19%	15%	23%	14%	11%	25%

% of Respondents (AI Capability)

Figure 4.3.3

Consideration and Mitigation of Risks From Adopting AI

The risk from adopting AI that survey respondents identified as most relevant in 2021 was cybersecurity (55% of respondents), followed by regulatory compliance (48%), explainability (41%), and personal/individual privacy (41%) (Figure 4.3.4). Fewer organizations found AI risks from cybersecurity to be relevant in 2021 than in 2020, declining from just over 60% of respondents expressing concern in 2020 to 55% in 2021. Concern over AI regulatory compliance risks, meanwhile, remained virtually unchanged from 2020.

Figure 4.3.5 shows risks from AI that organizations are taking steps to mitigate. Cybersecurity was the most frequent response (47% of respondents), followed by regulatory compliance (36%), personal/individual privacy (28%), and explainability (27%). It is worth noting the gaps between risks that organizations find relevant and risks that organizations take steps to mitigate—a gap of 10 percentage points with equity and fairness (29% to 19%), 12 percentage points with regulatory compliance (48% to 36%), 13 percentage points with personal/individual privacy (41% to 28%), and 14 percentage points with explainability (41% to 27%).

RISKS from ADOPTING AI that ORGANIZATIONS CONSIDER RELEVANT, 2019–21
Source: McKinsey & Company, 2021 | Chart: 2022 AI Index Report

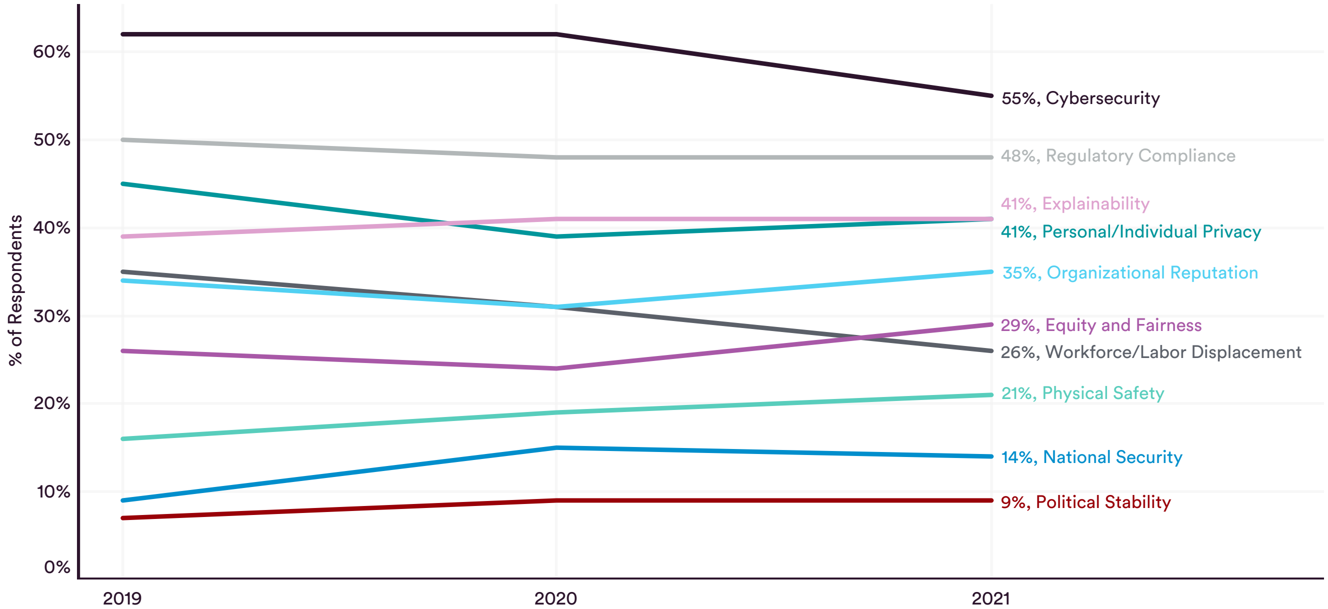

Figure 4.3.4

RISKS from ADOPTING AI that ORGANIZATIONS TAKE STEPS to MITIGATE, 2019–21
Source: McKinsey & Company, 2021 | Chart: 2022 AI Index Report

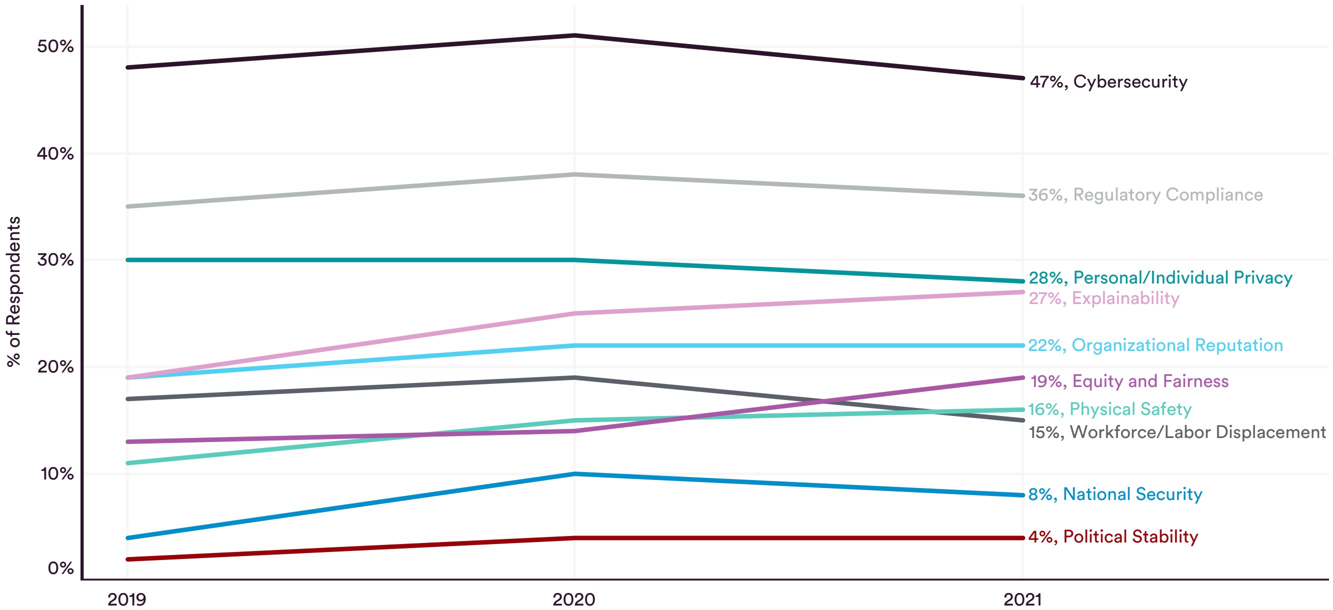

Figure 4.3.5

The following section draws on data from the annual Computing Research Association (CRA) Taulbee Survey. For the latest survey featured in this section, CRA collected data in Fall 2020 by reaching out to over 200 PhD-granting departments in the United States and Canada. Results are published in May 2021. The CRA survey documents trends in student enrollment, degree production, employment of graduates, and faculty salaries in academic units in the United States and Canada that grant doctoral degrees in computer science (CS), computer engineering (CE), or information (I). Academic units include departments of CS and CE or, in some cases, colleges or schools of information or computing.

4.4 AI EDUCATION

CS UNDERGRADUATE GRADUATES IN NORTH AMERICA

In North America, most AI-related courses are offered as part of the CS curriculum at the undergraduate level.

The number of new CS undergraduate graduates at doctoral institutions in North America has grown 3.5 times from 2010 to 2020 (Figure 4.4.1). More than 31,000 undergraduates completed CS degrees in 2020—an 11.60% increase from the number in 2019.

NUMBER of NEW CS UNDERGRADUATE GRADUATES at DOCTORAL INSTITUTIONS in NORTH AMERICA, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

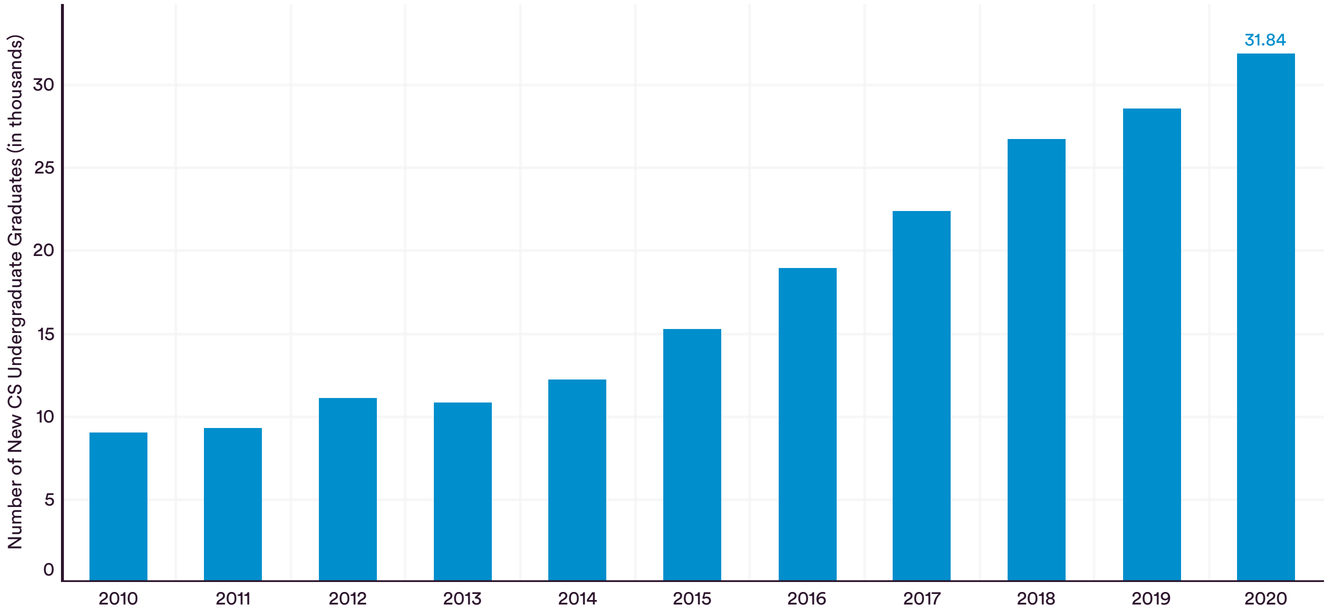

Figure 4.4.1

NEW CS PHDS IN NORTH AMERICA

The following sections show the trend of CS PhD graduates in North America with a focus on those with AI-related specialties.[5] The CRA survey includes 20 specialties in total, two of which are directly related to the field of AI: artificial intelligence/machine learning (AI/ML) and robotics/vision.

New CS PhDs by Specialty

In 2020, 1 in every 5 CS students who graduated with PhD degrees specialized in AI/ML, the most popular specialty in the past decade (Figure 4.4.2). It is also the speciality that exhibits the most significant growth from 2010 to 2021, relative to 18 other specializations (Figure 4.4.3). Robotics/vision is also among the most popular CS specialties of PhD graduates in 2020, registering a 1.4 percentage point change in the share of total new CS PhDs in the past 11 years.

In 2020, 1 in every 5 CS students who graduated with PhD degrees specialized in AI/ML, the most popular specialty in the past decade.

NEW CS PHDS (% of TOTAL) in the UNITED STATES by SPECIALITY, 2020
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

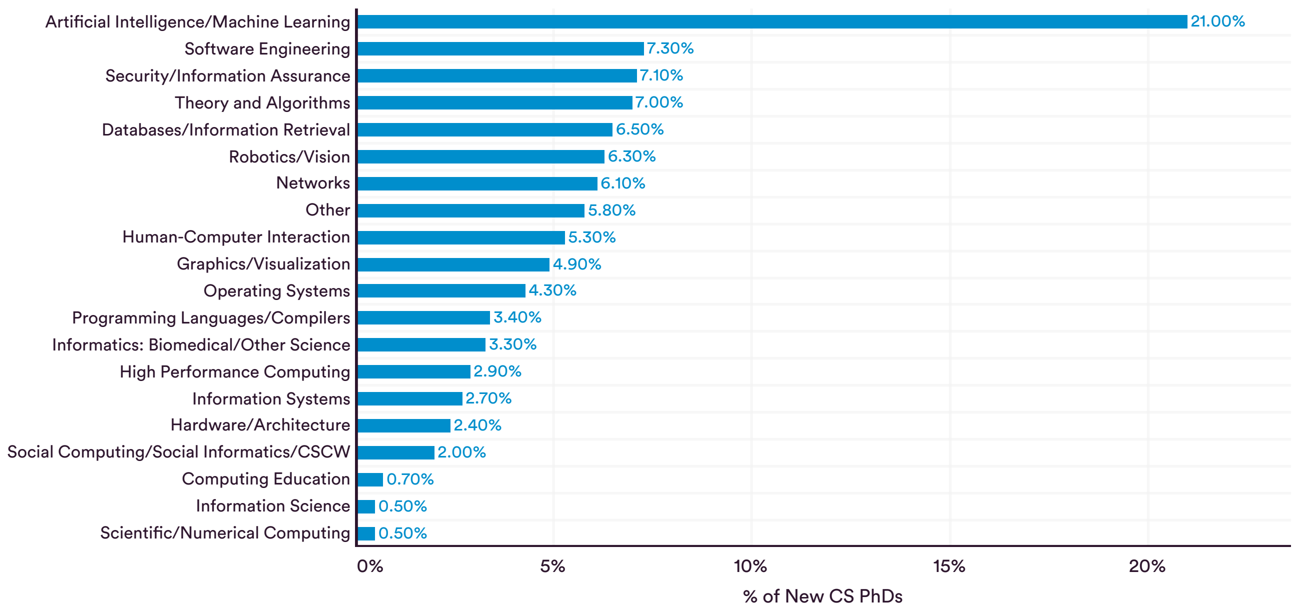

Figure 4.4.2

5 New CS PhDs in this section include PhD graduates from academic units (departments, colleges, or schools within universities) of computer science in the United States.

PERCENTAGE POINT CHANGE in NEW CS PHDS in the UNITED STATES by SPECIALTY, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

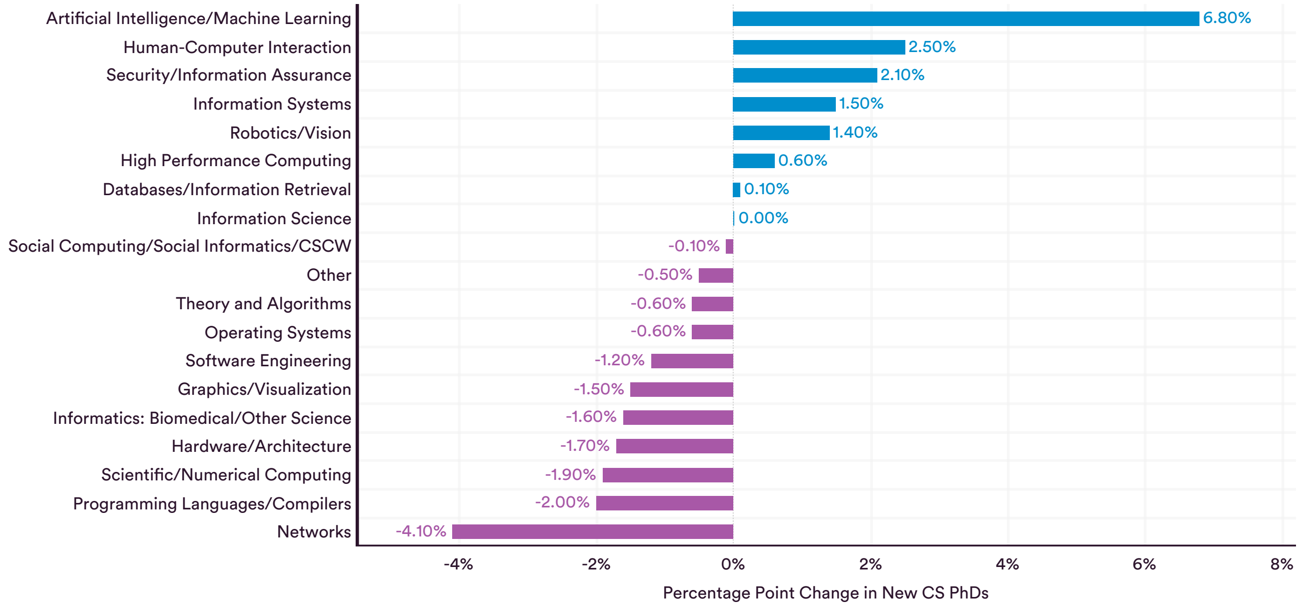

Figure 4.4.3

New CS PhDs with AI/ML and Robotics/Vision Specialties

Between 2010 and 2020, the number of CS PhD graduates with AI/ML and robotics/vision specialities grew by 72.05% and 50.91%, respectively. The slight decrease in the total number for both specialties from 2019 to 2020 may be due to the impact of the COVID-19 pandemic.

NEW CS PHDS with AI/ML and ROBOTICS/VISION SPECIALTY in the UNITED STATES, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

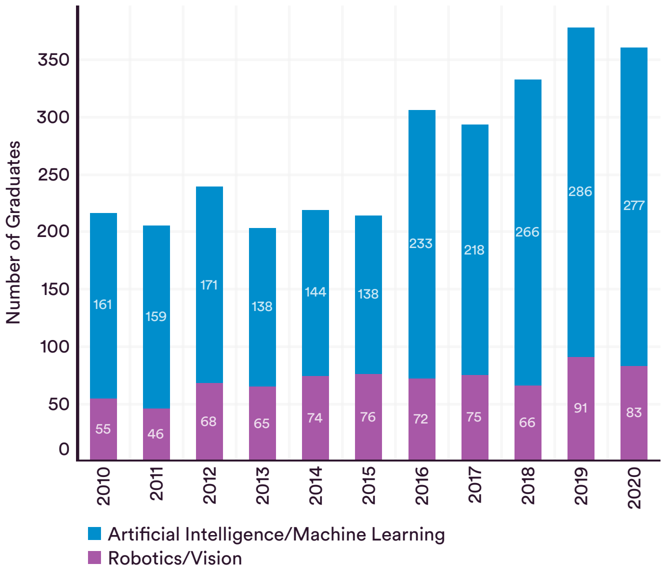

Figure 4.4.4a

NEW CS PHDS (% of TOTAL) with AI/ML and ROBOTICS/VISION SPECIALTY in the UNITED STATES, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

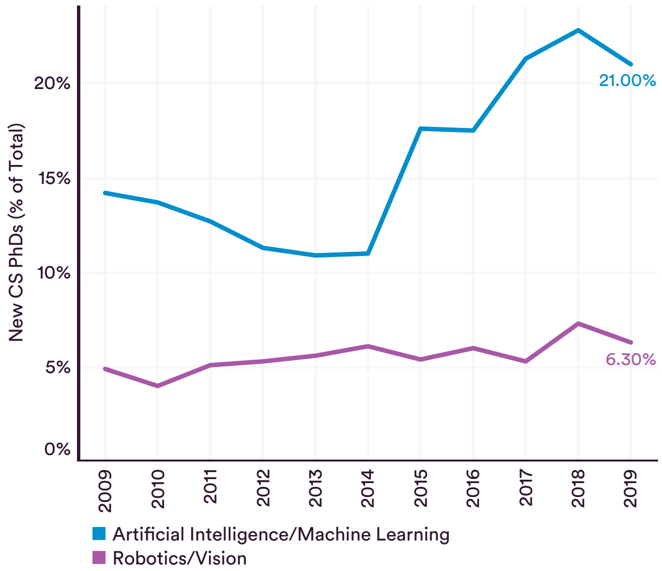

Figure 4.4.4b

NEW AI PHDS EMPLOYMENT IN NORTH AMERICA

Where do new AI PhDs choose to work following graduation? This section analyzes the employment trends of new AI PhDs across North America in academia, industry, and government.[6]

Academia vs. Industry vs. Government

In 2020, the share of new AI PhD graduates in North America who chose to work in the industry dipped slightly, with its share dropping from 65.7% in 2019 to 60.2% in 2020, whereas the share of new AI PhDs who went into academia and government changed little (Figure 4.4.5a and Figure 4.4.5b). Note that the 2020 data may be impacted by the increasing number of new AI PhDs who went abroad upon graduation, a number that grew from 19 in 2019 to 32 in 2020.

EMPLOYMENT of NEW AI PHDS to ACADEMIA, GOVERNMENT, or INDUSTRY in NORTH AMERICA, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

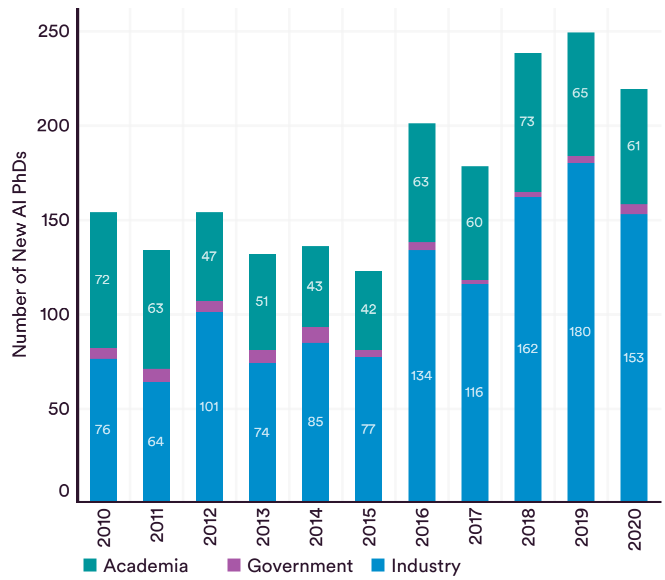

Figure 4.4.5a

EMPLOYMENT of NEW AI PHDS (% of TOTAL) to ACADEMIA, GOVERNMENT, or INDUSTRY in NORTH AMERICA, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

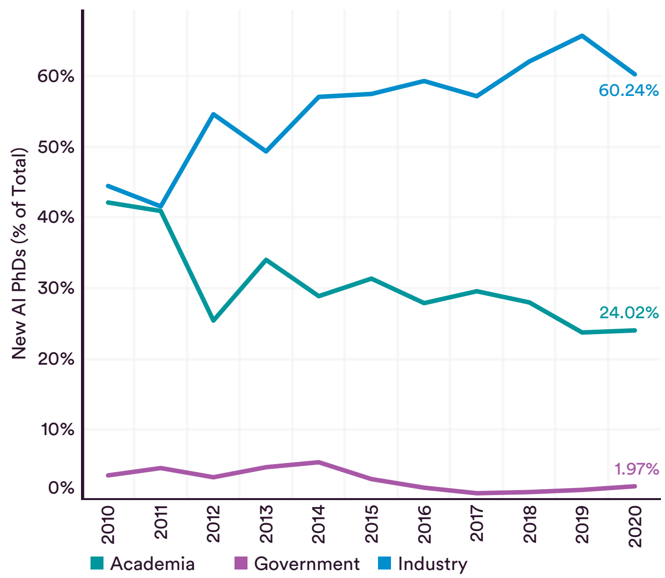

Figure 4.4.5b

6 New AI PhDs in this section include PhD graduates who specialize in artificial intelligence from academic units (departments, colleges, or schools within universities) of computer science, computer engineering, and information in the United States and Canada.

DIVERSITY OF NEW AI PHDS IN NORTH AMERICA

By Gender

Figure 4.4.6 shows that the share of new female AI and CS PhDs in North America remains low and has changed little from 2010 to 2020.

FEMALE NEW AI and CS PHDS (% of TOTAL NEW AI and CS PHDS) in NORTH AMERICA, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

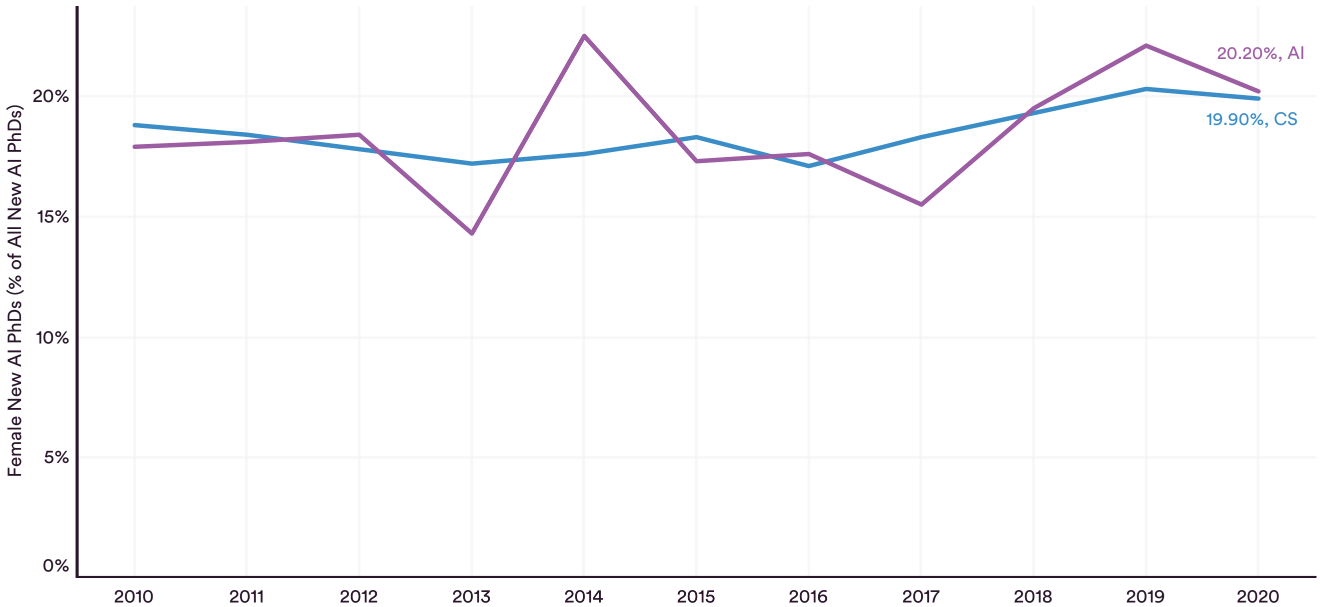

Figure 4.4.6

By Race/Ethnicity

According to Figure 4.4.7, among the new AI PhDs from 2010 to 2020 who are U.S. residents, the largest percentage has been non-Hispanic white and Asian—65.2% and 18.8% on average. By comparison, around 1.5% were Black or African American (non-Hispanic) and 2.9% were Hispanic on average over the past 11 years. Figure 4.4.8 shows all PhDs awarded in the United States to U.S. residents across departments of CS, CE, and information between 2010 and 2020. In the past 11 years, the share of new white (non-Hispanic) PhDs has changed little, while the percentage of new Black or African American (non-Hispanic) and Hispanic computing PhDs is significantly lower.

NEW U.S. AI RESIDENT PHDS (% of TOTAL) by RACE/ETHNICITY, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

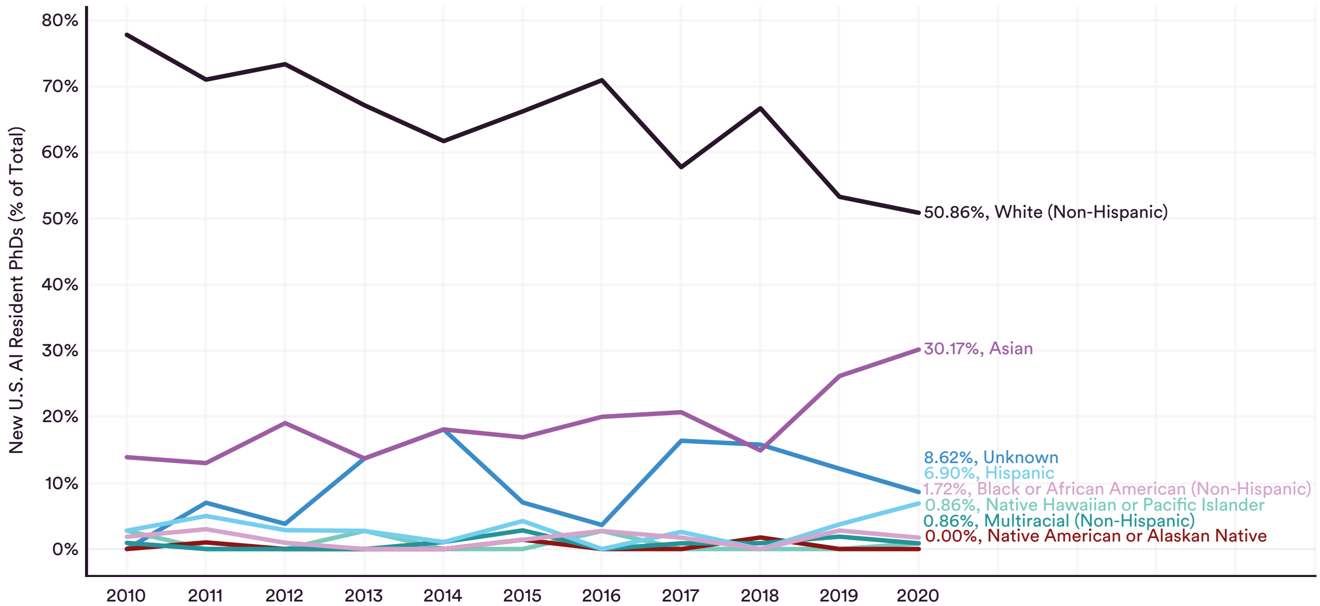

Figure 4.4.7

NEW COMPUTING PHDS, U.S. RESIDENT (% of TOTAL) by RACE/ETHNICITY, 2010–20
Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

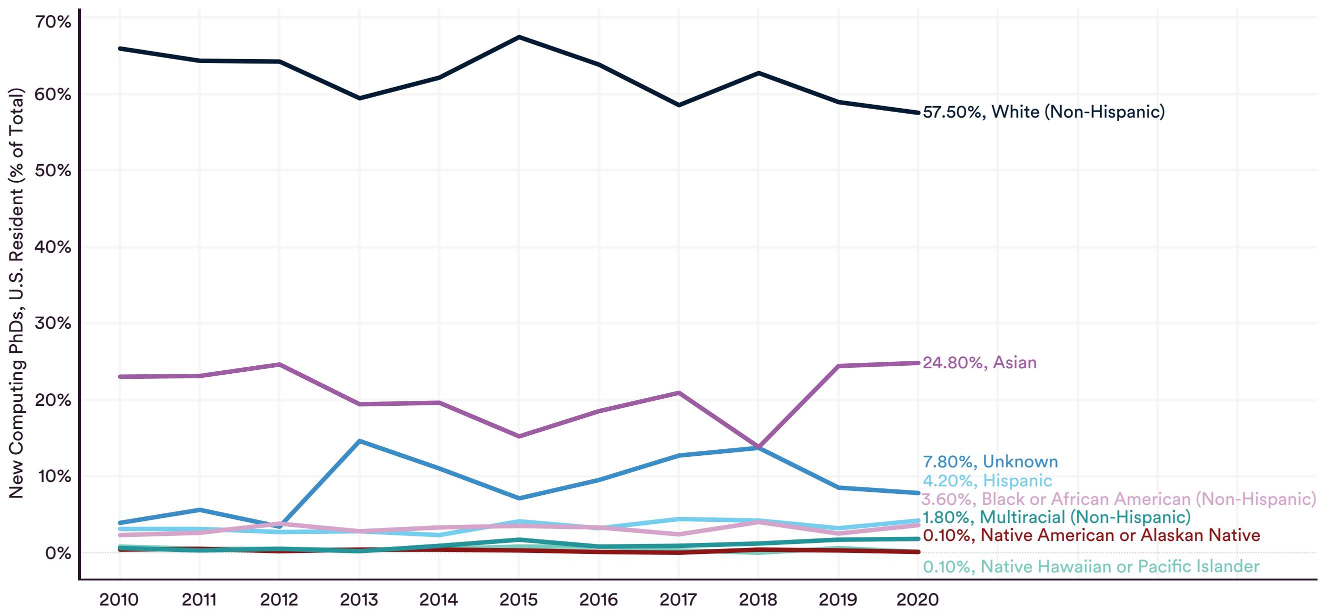

Figure 4.4.8

NEW INTERNATIONAL AI PHDS IN NORTH AMERICA

The share of international students among new AI PhDs in North America in 2020 decreased slightly from 64.3% in 2019 to 60.5% in 2020 (Figure 4.4.9). For comparison, of all computing PhDs graduating in 2022, 65.1% of them were international students. In addition, more international students—14.0% of all new AI PhDs—took jobs outside the United States in 2020, compared to 8.6% in 2019 (Figure 4.4.10).

NEW INTERNATIONAL AI PHDS (% of TOTAL NEW AI PHDS) in NORTH AMERICA, 2010–20

Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

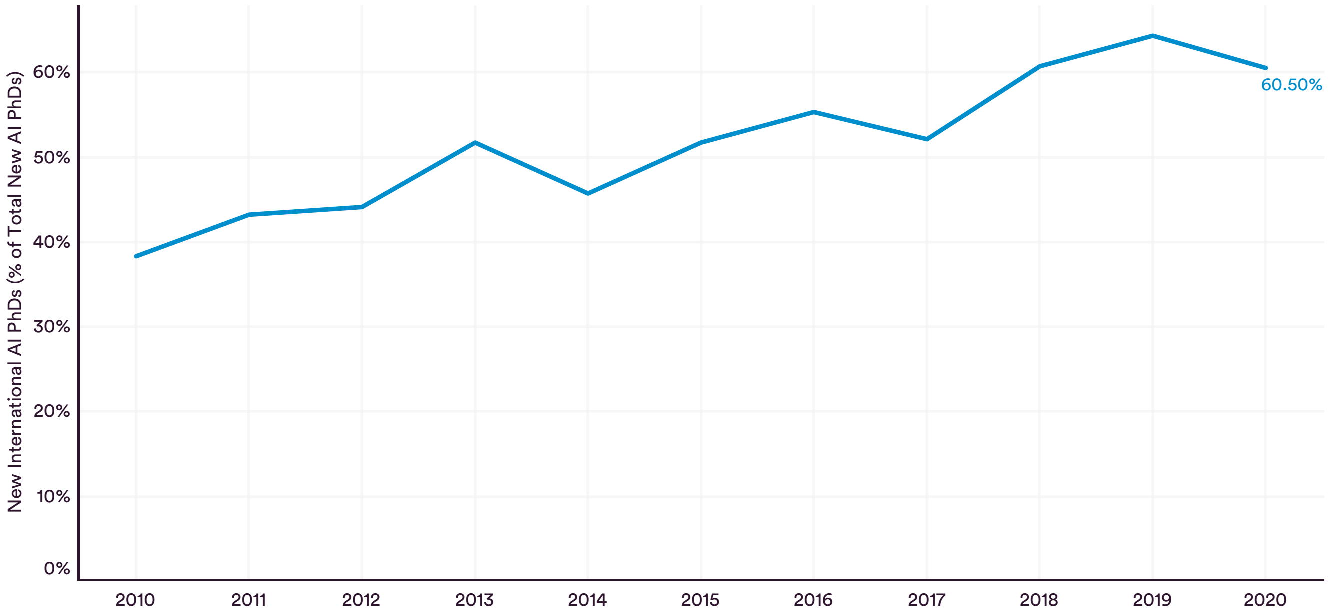

Figure 4.4.9

INTERNATIONAL NEW AI PHDS (% of TOTAL) in the UNITED STATES by LOCATION of EMPLOYMENT, 2020

Source: CRA Taulbee Survey, 2021 | Chart: 2022 AI Index Report

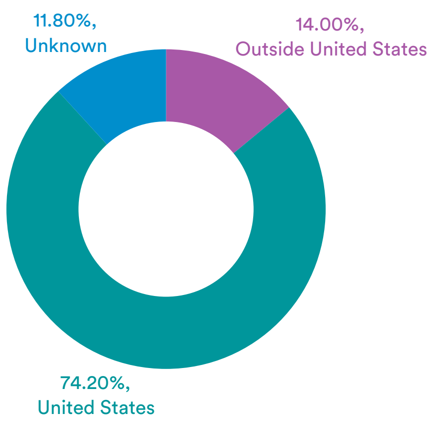

Figure 4.4.10

APPENDIX

EMSI BURNING GLASS

Prepared by Julia Nitschke, Summer Jasinski, Bledi Taska and Rucha Vankudre

Emsi Burning Glass delivers job market analytics that empower employers, workers, and educators to make data-driven decisions. The company's artificial intelligence technology analyzes hundreds of millions of job postings and real-life career transitions to provide insight into labor market patterns. This real-time strategic intelligence offers crucial insights, such as what jobs are most in demand, the specific skills employers need, and the career directions that offer the highest potential for workers. For more information, visit burning-glass.com.

Job Posting Data

To support these analyses, Emsi Burning Glass mined its dataset of millions of job postings collected since 2010. Emsi Burning Glass collects postings from over 45,000 online job sites to develop a comprehensive, real-time portrait of labor market demand. It aggregates job postings, removes duplicates, and extracts data from job postings text. This includes information on job title, employer, industry, and region, as well as required experience, education, and skills.

Job postings are useful for understanding trends in the labor market because they allow for a detailed, real-time look at the skills employers seek. To assess the representativeness of job postings data, Emsi Burning Glass conducts a number of analyses to compare the distribution of job postings to the distribution of official government and other third-party sources in the United States. The primary source of government data on U.S. job postings is the Job Openings and Labor Turnover Survey (JOLTS) program, conducted by the Bureau of Labor Statistics. Based on comparisons between JOLTS and Emsi Burning Glass, the labor market demand captured by Emsi Burning Glass data represents over 95% of the total labor demand. Jobs not posted online are usually in small businesses (the classic example being the "Help Wanted" sign in the restaurant window) and union hiring halls.

Measuring Demand for AI

In order to measure employers' demand for AI skills, Emsi Burning Glass uses its skills taxonomy of over 17,000 skills. The list of AI skills from Emsi Burning Glass data is shown below, with associated skill clusters. While some skills are considered to be in the AI cluster specifically, for the purposes of this report, all skills below were considered AI skills. A job posting was considered an AI job if it requested one or more of these skills.

Artificial Intelligence: Expert System, IBM Watson, IPSoft Amelia, Ithink, Virtual Agents, Autonomous Systems, Lidar, OpenCV, Path Planning, Remote Sensing

Natural Language Processing (NLP): ANTLR, Automatic Speech Recognition (ASR), Chatbot, Computational Linguistics, Distinguo, Latent Dirichlet Allocation, Latent Semantic Analysis, Lexalytics, Lexical Acquisition, Lexical Semantics, Machine Translation (MT), Modular Audio Recognition Framework (MARF), MoSes, Natural Language Processing, Natural Language Toolkit (NLTK), Nearest Neighbor Algorithm, OpenNLP, Sentiment Analysis/ Opinion Mining, Speech Recognition, Text Mining, Text to Speech (TTS), Tokenization, Word2Vec

Neural Networks: Caffe Deep Learning Framework, Convolutional Neural Network (CNN), Deep Learning, Deeplearning4j, Keras, Long Short-Term Memory (LSTM), MXNet, Neural Networks, Pybrain, Recurrent Neural Network (RNN), TensorFlow

Machine Learning: AdaBoost algorithm, Boosting (Machine Learning), Chi Square Automatic Interaction Detection (CHAID), Classification Algorithms, Clustering Algorithms, Decision Trees, Dimensionality Reduction, Google Cloud Machine Learning Platform, Gradient boosting, H2O (software), Libsvm, Machine Learning, Madlib, Mahout, Microsoft Cognitive Toolkit, MLPACK (C++ library), Mlpy, Random Forests, Recommender Systems, Scikit-learn, Semi-Supervised Learning, Supervised Learning (Machine Learning), Support Vector Machines (SVM), Semantic Driven Subtractive Clustering Method (SDSCM), Torch (Machine Learning), Unsupervised Learning, Vowpal, Xgboost

Robotics: Blue Prism, Electromechanical Systems, Motion Planning, Motoman Robot Programming, Robot Framework, Robotic Systems, Robot Operating System (ROS), Robot Programming, Servo Drives / Motors, Simultaneous Localization and Mapping (SLAM)

Visual Image Recognition: Computer Vision, Image Processing, Image Recognition, Machine Vision, Object Recognition

LINKEDIN

Prepared by Akash Kaura and Murat Erer

Country Sample

Included countries represent a select sample of eligible countries with at least 40% labor force coverage by LinkedIn and at least 10 AI hires in any given month. China and India were included in this sample because of their increasing importance in the global economy, but LinkedIn coverage in these countries does not reach 40% of the workforce. Insights for these countries may not provide as full a picture as other countries, and should be interpreted accordingly.

Skills (and AI Skills)

LinkedIn members self-report their skills on their LinkedIn profiles. Currently, more than 38,000 distinct, standardized skills are identified by LinkedIn. These have been coded and classified by taxonomists at LinkedIn into 249 skill groupings, which are the skill groups represented in the dataset. The top skills that make up the AI skill grouping are machine learning, natural language processing, data structures, artificial intelligence, computer vision, image processing, deep learning, TensorFlow, Pandas (software), and OpenCV, among others.

Skill groupings are derived by expert taxonomists through a similarity-index methodology that measures skill composition at the industry level. Industries are classified according to the ISIC 4 industry classification (Zhu et al., 2018).

Skills Genome

For any entity (occupation or job, country, sector, etc.), the skill genome is an ordered list (a vector) of the 50 “most characteristic skills” of that entity. These most characteristic skills are identified using a TF-IDF algorithm to identify the most representative skills of the target entity, while down-ranking ubiquitous skills that add little information about that specific entity (e.g., Microsoft Word).

TF-IDF is a statistical measure that evaluates how representative a word (in this case a skill) is to a selected entity. This is done by multiplying two metrics:

1. The term frequency of a skill in an entity (TF).
2. The logarithmic inverse entity frequency of the skill across a set of entities (IDF). This indicates how common or rare a word is in the entire entity set. The closer IDF is to 0, the more common a word is.

So, if the skill is very common across LinkedIn entities, and appears in many job or member descriptions, the IDF will approach 0. If, on the other hand, the skill is unique to specific entities, the IDF will approach 1. Details available at LinkedIn’s Skills Genome and LinkedIn-World Bank Methodology note.

AI Skills Penetration

The aim of this indicator is to measure the intensity of AI skills in an entity (in a particular country, industry, gender, etc.) through the following methodology:

- Compute frequencies for all self-added skills by LinkedIn members in a given entity (occupation, industry, etc.) in 2015–2021.
- Re-weight skill frequencies using a TF-IDF model to get the top 50 most representative skills in that entity. These 50 skills compose the “skill genome” of that entity.
- Compute the share of skills that belong to the AI skill group out of the top skills in the selected entity.

Interpretation: The AI skill penetration rate signals the prevalence of AI skills across occupations, or the intensity with which LinkedIn members utilize AI skills in their jobs. For example, the top 50 skills for the occupation of engineer are calculated based on the weighted frequency with which they appear in LinkedIn members’ profiles. If four of the skills that engineers possess belong to the AI skill group, this measure indicates that the penetration of AI skills is estimated to be 8% among engineers (e.g., 4/50).

Jobs or Occupations

LinkedIn member titles are standardized and grouped into approximately 15,000 occupations. These are not sector or country specific. These occupations are further standardized into approximately 3,600 occupation representatives. Occupation representatives group occupations with a common role and specialty, regardless of seniority.

AI Jobs or Occupations

An AI job (technically, occupation representative) is an occupation representative that requires AI skills to perform the job. Skills penetration is used as a signal for whether AI skills are prevalent in an occupation representative, in any sector where the occupation representative may exist. Examples of such occupations include (but are not limited to): machine learning engineer, artificial intelligence specialist, data scientist, computer vision engineer, etc.

AI Talent

A LinkedIn member is considered AI talent if they have explicitly added AI skills to their profile and/or they are occupied in an AI occupation representative. The counts of AI talent are used to calculate talent concentration metrics (e.g. to calculate the country-level AI talent concentration, we use the counts of AI talent at the country level vis-a-vis the counts of LinkedIn members in the respective countries).

Relative AI Skills Penetration

To allow for skills penetration comparisons across countries, the skills genomes are calculated and a relevant benchmark is selected (e.g., global average). A ratio is then constructed between a country’s and the benchmark’s AI skills penetrations, controlling for occupations.

Interpretation: A country’s relative AI skills penetration of 1.5 indicates that AI skills are 1.5 times as frequent as in the benchmark, for an overlapping set of occupations.

Global Comparison

For cross-country comparison, we present the relative penetration rate of AI skills, measured as the sum of the penetration of each AI skill across occupations in a given country, divided by the average global penetration of AI skills across the overlapping occupations in a sample of countries.

Interpretation: A relative penetration rate of 2 means that the average penetration of AI skills in that country is two times the global average across the same set of occupations.

Global Comparison: By Industry

The relative AI skills penetration by country for industry provides an in-depth sectoral decomposition of AI skill penetration across industries and sample countries.

Interpretation: A country’s relative AI skill penetration rate of 2 in the education sector means that the average penetration of AI skills in that country is two times the global average across the same set of occupations in that sector.

Relative AI Hiring Index

- LinkedIn Hiring Rate or Overall Hiring Rate is a measure of hires normalized by LinkedIn membership. It is computed as the percentage of LinkedIn members who added a new employer in the same period the job began, divided by the total number of LinkedIn members in the corresponding location.
- AI Hiring Rate is computed following the overall hiring rate methodology, but only considering members classified as AI talent.
- Relative AI Hiring Index is the pace of change in AI Hiring Rate normalized by the pace of change in Overall Hiring Rate, providing a picture of whether hiring of AI talent is growing at a higher, equal, or lower rate than overall hiring in a market. The relative AI Hiring Index is equal to 1.0 when AI hiring and overall hiring are growing at the same rate year on year.

Interpretation: Relative AI Hiring Index shows how fast each country is experiencing growth in AI talent hiring relative to growth in overall hiring in the country. A ratio of 1.2 means the growth in AI talent hiring has outpaced the growth in overall hiring by 20%.

NETBASE QUID

Prepared by Julie Kim and Tejas Sirohi

NetBase Quid delivers AI-powered consumer and market intelligence to enable business reinvention in a noisy and unpredictable world. The software applies artificial intelligence to reveal patterns in large, unstructured datasets and to generate visualizations that enable users to make smart, data-driven decisions accurately, quickly, and efficiently. NetBase Quid uses Boolean query to search for focus areas, topics, and keywords within social, news, forums and blogs, companies, and patents data sources, as well as other custom datasets. NetBase Quid then visualizes these data points based on the semantic similarity.

Search, Data Sources, and Scope

Over 6 million global public and private company profiles from multiple data sources are indexed in order to search across company descriptions, while filtering and including metadata ranging from investment information to firmographic information, such as founded year, HQ location, and more. Company information is updated on a weekly basis. NetBase Quid algorithm reads a big amount of text data from each document to make links between different documents based on their similar language. This process is repeated at an immense scale, which produces a network with different clusters identifying distinct topics or focus areas. Trends are identified based on keywords, phrases, people, companies, institutions that NetBase Quid identifies, and the other metadata that is put into the software.

Data

Organization data is embedded from Capital IQ and Crunchbase. These companies include all types of companies (private, public, operating, operating as a subsidiary, out of business) throughout the world. The investment data includes private investments, M&A, public offerings, minority stakes made by PE/VCs, corporate venture arms, governments, and institutions both within and outside the United States. Some data is simply unreachable—for instance, when the investors or the funding amounts by investors are undisclosed. NetBase Quid also embeds firmographic information such as founding year and HQ location.

NetBase Quid embeds Capital IQ data as a default and adds in data from Crunchbase for the ones that are not captured in Capital IQ. This not only yields comprehensive and accurate data on all global organizations, but it also captures early-stage startups and funding events data. Company information is uploaded on a weekly basis.

Search Parameters

Boolean query is used to search for focus areas, topics, and keywords within the archived company database, within their business descriptions and websites. We can filter out the search results by HQ regions, investment amount, operating status, organization type (private/public), and founding year. NetBase Quid then visualizes these companies by the semantic similarity. If there are more than 7,000 companies from the search result, NetBase Quid selects the 7,000 most relevant companies for visualization based on the language algorithm.

Boolean Search: “artificial intelligence” or “AI” or “machine learning” OR “deep learning”

Companies:

- Chart 4.2.1: Global AI & ML companies that have been invested (private, IPO, M&A) from 01/01/2012 to 12/31/2021.
- Chart 4.2.2–4.2.12: Global AI & ML companies that have invested over $1.5M for the last 10 years (January 1, 2012 to December 31, 2021)—7,000 companies out of 7,500 companies have been selected through Quid’s relevance algorithm.

Target Event Definitions

- Private investments: A private placement is a private sale of newly issued securities (equity or debt) by a company to a selected investor or a selected group of investors. The stakes that buyers take in private placements are often minority stakes (under 50%), although it is possible to take control of a company through a private placement as well, in which case the private placement would be a majority stake investment.
- Minority investment: These refer to minority stake acquisitions in Quid, which take place when the buyer acquires less than 50% of the existing ownership stake in entities, asset product, and business divisions.
- M&A: This refers to a buyer acquiring more than 50% of the existing ownership stake in entities, asset product, and business divisions.

COMPUTING RESEARCH ASSOCIATION (CRA TAULBEE SURVEY)

Prepared by Betsy Bizot (CRA senior research associate)

Source

Computing Research Association (CRA) members are 200-plus North American organizations active in computing research: academic departments of computer science and computer engineering; laboratories and centers in industry, government, and academia; and affiliated professional societies (AAAI, ACM, CACS/AIC, IEEE Computer Society, SIAM USENIX). CRA’s mission is to enhance innovation by joining with industry, government, and academia to strengthen research and advanced education in computing. Learn more about CRA here.

Methodology

CRA Taulbee Survey gathers survey data during the fall of each academic year by reaching out to over 200 PhD-granting departments. Details about the Taulbee Survey can be found here. Taulbee doesn’t directly survey the students. The department identifies each new PhD’s area of specialization as well as their type of employment. Data is collected from September to January of each academic year for PhDs awarded in the previous academic year. Results are published in May after data collection closes. So the 2020 data points were newly available last spring, and the numbers provided for 2021 will be available in May 2020.

The CRA Taulbee Survey is sent only to doctoral departments of computer science, computer engineering, and information science/systems. Historically, (a) Taulbee covers 1/4 to 1/3 of total BS CS recipients in the United States; (b) the percent of women earning bachelor’s degrees is lower in the Taulbee schools than overall; and (c) Taulbee tracks the trends in overall CS production.

Nuances

- Of particular interest in PhD job market trends are the metrics on the AI PhD area of specialization. The categorization of specialty areas changed in 2008 and was clarified in 2016. From 2004-2007, AI and robotics were grouped; from 2008-present, AI is separate; 2016 clarified to respondents that AI includes ML.
- Notes about the trends in new tenure-track hires (overall and particularly at AAU schools): In the 2018 Taulbee Survey, for the first time we asked how many new hires had come from the following sources: new PhD, postdoc, industry, and other academic. Results indicated that 29% of new assistant professors came from another academic institution.
- Some may have been teaching or research faculty rather than tenure-track, but there is probably some movement between institutions, meaning the total number hired overstates the total who are actually new.