IN BRIEF

ARTIFICIAL INTELLIGENCE: THE NEXT DIGITAL FRONTIER?

Artificial intelligence is poised to unleash the next wave of digital disruption, and companies should prepare for it now. We already see real-life benefits for a few early-adopting firms, making it more urgent than ever for others to accelerate their digital transformations. Our findings focus on five AI technology systems: robotics and autonomous vehicles, computer vision, language, virtual agents, and machine learning, which includes deep learning and underpins many recent advances in the other AI technologies.

- AI investment is growing fast, dominated by digital giants such as Google and Baidu. Globally, we estimate tech giants spent $20 billion to $30 billion on AI in 2016, with 90 percent of this spent on R&D and deployment, and 10 percent on AI acquisitions. VC and PE financing, grants, and seed investments also grew rapidly, albeit from a small base, to a combined total of $6 billion to $9 billion. Machine learning, as an enabling technology, received the largest share of both internal and external investment.
- AI adoption outside of the tech sector is at an early, often experimental stage. Few firms have deployed it at scale. In our survey of 3,000 AI-aware C-level executives, across 10 countries and 14 sectors, only 20 percent said they currently use any AI-related technology at scale or in a core part of their businesses. Many firms say they are uncertain of the business case or return on investment. A review of more than 160 use cases shows that AI was deployed commercially in only 12 percent of cases.
- Adoption patterns illustrate a growing gap between digitized early AI adopters and others. Sectors at the top of MGI's Industry Digitization Index, such as high tech and telecom or financial services, are also leading adopters of AI. They also have the most aggressive AI investment intentions. Leaders' adoption is both broad and deep: using multiple technologies across multiple functions, with deployment at the core of their business. Automakers use AI to develop self-driving vehicles and improve operations, for example, while financial services firms are more likely to use it in customer experience–related functions.
- Early evidence suggests that AI can deliver real value to serious adopters and can be a powerful force for disruption. In our survey, early AI adopters that combine strong digital capability with proactive strategies have higher profit margins and expect the performance gap with other firms to widen in the future. Our case studies in retail, electric utilities, manufacturing, health care, and education highlight AI's potential to improve forecasting and sourcing, optimize and automate operations, develop targeted marketing and pricing, and enhance the user experience.
- AI's dependence on a digital foundation and the fact that it often must be trained on unique data mean that there are no shortcuts for firms. Companies cannot delay advancing their digital journeys, including AI. Early adopters are already creating competitive advantages, and the gap with the laggards looks set to grow. A successful program requires firms to address many elements of a digital and analytics transformation: identify the business case, set up the right data ecosystem, build or buy appropriate AI tools, and adapt workflow processes, capabilities, and culture. In particular, our survey shows that leadership from the top, management and technical capabilities, and seamless data access are key enablers.
- AI promises benefits, but also poses urgent challenges that cut across firms, developers, government, and workers. The workforce needs to be reskilled to exploit AI rather than compete with it; cities and countries serious about establishing themselves as a global hub for AI development will need to join the global competition to attract AI talent and investment; and progress will need to be made on the ethical, legal and regulatory challenges that could otherwise hold back AI.

ARTIFICIAL INTELLIGENCE

The next digital frontier?

The current AI wave is poised to finally break through

Investment in AI is growing at a high rate, but adoption in 2017 remains low

In 2016, companies invested
$26B to $39B
in artificial intelligence

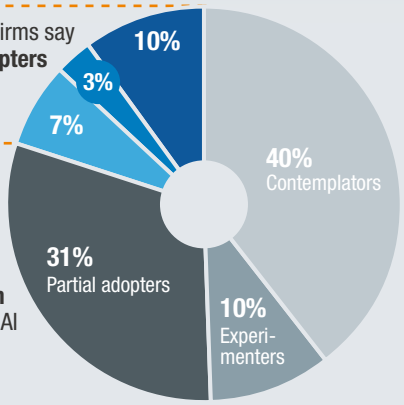
TECH GIANTS
$20B to $30B

STARTUPS
$6B to $9B

3x External investment growth since 2013

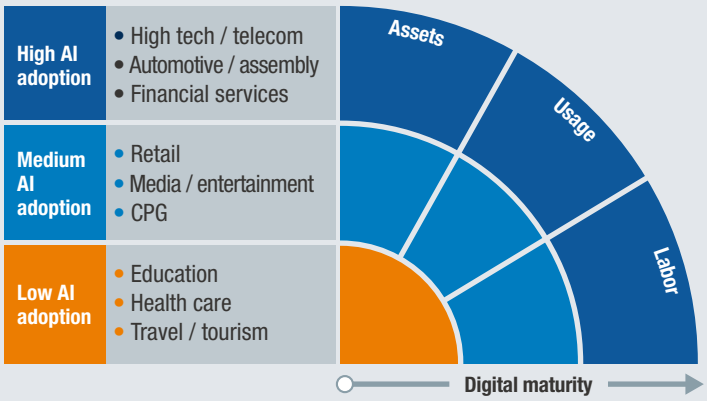
20% of AI-aware firms say they are **adopters**
- 3+ technologies
- 2 technologies
- 1 technology

41% of firms say they are **uncertain about the benefits** of AI



How companies are adopting AI

AI adoption is greatest in sectors that are already **strong digital adopters**



Six characteristics of early AI adopters

- Digitally mature
- Larger businesses
- Adopt AI in core activities
- Adopt multiple technologies
- Focus on growth over savings
- C-level support for AI

Four areas across the value chain where AI can create value

PROJECT: Smarter R&D and forecasting

PRODUCE: Optimized production and maintenance

PROMOTE: Targeted sales and marketing

PROVIDE: Enhanced user experience

Five elements of successful AI transformations

- Use cases / sources of value
- Data ecosystems
- Techniques and tools
- Workflow integration
- Open culture and organization

1. ARTIFICIAL INTELLIGENCE IS GETTING READY FOR BUSINESS, BUT ARE BUSINESSES READY FOR AI?

Claims about the promise and peril of artificial intelligence are abundant, and growing. AI, which enables machines to exhibit human-like cognition, can drive our cars or steal our privacy, stoke corporate productivity or empower corporate spies. It can relieve workers of repetitive or dangerous tasks or strip them of their livelihoods. Twice as many articles mentioned AI in 2016 as in 2015, and nearly four times as many as in 2014.[1] Expectations are high.

AI has been here before. Its history abounds with booms and busts, extravagant promises and frustrating disappointments. Is it different this time? New analysis suggests yes: AI is finally starting to deliver real-life business benefits. The ingredients for a breakthrough are in place. Computer power is growing significantly, algorithms are becoming more sophisticated, and, perhaps most important of all, the world is generating vast quantities of the fuel that powers AI—data. Billions of gigabytes of it every day.

Companies at the digital frontier—online firms and digital natives such as Google and Baidu—are betting vast amounts of money on AI. We estimate between $20 billion and $30 billion in 2016, including significant M&A activity. Private investors are jumping in, too. We estimate that venture capitalists invested $4 billion to $5 billion in AI in 2016, and private equity firms invested $1 billion to $3 billion. That is more than three times as much as in 2013. An additional $1 billion of investment came from grants and seed funding.

For now, though, most of the news is coming from the suppliers of AI technologies. And many new uses are only in the experimental phase. Few products are on the market or are likely to arrive there soon to drive immediate and widespread adoption. As a result, analysts remain divided as to the potential of AI: some have formed a rosy consensus about AI's potential while others remain cautious about its true economic benefit. This lack of agreement is visible in the large variance of current market forecasts, which range from $644 million to $126 billion by 2025.[2] Given the size of investment being poured into AI, the low estimate would indicate that we are witnessing another phase in a boom-and-bust cycle.

Our business experience with AI suggests that this bust scenario is unlikely. In order to provide a more informed view, we decided to perform our own research into how users are adopting AI technologies. Our research offers a snapshot of the current state of the rapidly changing AI industry, looking through the lenses of both suppliers and users to come up with a more robust view of the economic potential of AI and how it will unfold. To begin, we examine the investment landscape, including firms' internal investment in R&D and deployment, large corporate M&A, and funding from venture capital (VC) and private equity (PE) firms. We then look at the demand side, combining use case analyses and our AI adoption and use survey of C-level executives at more than 3,000 companies to understand how companies use AI technologies today, what is driving their adoption of AI, the barriers to further deployment, and the market, financial, and organizational impacts of AI. For further details on sources of our insights, see Box 1, "A multi-lens approach to understanding the AI story."

1 Factiva.

2 Tractica; Transparency Market Research.

AI generally refers to the ability of machines to exhibit human-like intelligence—for example, solving a problem without the use of hand-coded software containing detailed instructions. There are several ways to categorize AI technologies, but it is difficult to draft a list that is mutually exclusive and collectively exhaustive because people often mix and match several technologies to create solutions for individual problems. These creations sometimes are treated as independent technologies, sometimes as subgroups of other technologies, and sometimes as applications. Some frameworks group AI technologies by basic functionality, such as text, speech, or image recognition, and some group them by business applications such as commerce or cybersecurity.[3]

[3] Gil Press, "Top 10 hot artificial intelligence (AI) technologies," Forbes.com, January 23, 2017; "AI100: The artificial intelligence startups redefining industries," CBinsights.com, January 11, 2017.

Box 1. A multi-lens approach to understanding the AI story

For the findings presented in this report, we drew on both primary and secondary research. We used six distinct sources of insight to assess the state of AI and its future potential. See Appendix B for further details.

AI adoption and use survey. We surveyed AI-aware C-level executives at 3,073 companies about how they are using digital technology and AI today, the drivers and barriers to further deployment, and the market, financial, and organizational impacts of AI. Our stratified sample covered 14 sectors of the economy, 10 countries across Europe, North America, and Asia, and companies with workforces ranging from fewer than 10 to more than 10,000. Responses were verified using algorithmic data cleansing techniques.

Use case review. We collated and reviewed over 160 use cases from both public sources and databases assembled for related MGI and Digital McKinsey research. Use cases were individually assessed to determine the extent to which they had achieved commercialization, and were classified according to their primary sector and business function of use.

Investment flows. To measure investment in the development and deployment of new AI technology, products, and services, we conducted an extensive review of publicly available information on both external funding sources (VC, PE, and M&A), as well as R&D and deployment activities internal to large corporations. Our assessment of external investment is based on global deal databases, scrutinizing deals for AI content, and classifying them by type of technology and geography. Internal investment flows are based on an analysis of the top 35 companies investing in AI globally.

Investment hubs. We built a global picture of AI innovation activity, covering 10 countries and over 75 cities, and evaluating their local AI ecosystems. This included mapping AI investment flows from VC, PE, and M&A databases by city, scanning large AI-investing companies' activities by geography, assessing the research outputs of and talent flows from universities, evaluating the broader business environment for entrepreneurs, and interviewing local investors.

Sector case studies. In five sectors, we conducted industry-expert interviews to understand the specific use cases today and promising applications for the future. External interviews were complemented by unique insights from across McKinsey sector practices and functions, including Digital McKinsey and McKinsey Analytics, as well as advanced-analytics firms that McKinsey has acquired or partnered with.

Previous MGI and McKinsey research. This report leverages other recent major research efforts by MGI and McKinsey Analytics, including databases of use cases. In particular, the findings in this report complement and build on the following research: *A future that works: Automation, employment, and productivity* (2017), *The age of analytics: Competing in a data-driven world* (2016), *Digital Europe: Pushing the frontier, capturing the benefits* (2016), and *Digital America: A tale of the haves and have-mores* (2015).

Trying to pin down the term more precisely is fraught for several reasons: AI covers a broad range of technologies and applications, some of which are merely extensions of earlier techniques and others that are wholly new. Also, there is no generally accepted theory of "intelligence," and the definition of machine "intelligence" changes as people become accustomed to previous advances.[4] Tesler's theorem, attributed to the computer scientist Larry Tesler, asserts that "AI is whatever hasn't been done yet."[5]

The AI technologies we consider in this paper are what is called "narrow" AI, which performs one narrow task, as opposed to artificial general intelligence, or AGI, which seeks to be able to perform any intellectual task that a human can do. We focus on narrow AI because it has near-term business potential, while AGI has yet to arrive.[6]

In this report, we focus on the set of AI technology systems that solve business problems. We have categorized these into five technology systems that are key areas of AI development: robotics and autonomous vehicles, computer vision, language, virtual agents, and machine learning, which is based on algorithms that learn from data without relying on rules-based programming in order to draw conclusions or direct an action. Some are related to processing information from the external world, such as computer vision and language (including natural language processing, text analytics, speech recognition, and semantics technology); some are about learning from information, such as machine learning; and others are related to acting on information, such as robotics, autonomous vehicles, and virtual agents, which are computer programs that can converse with humans. Machine learning and a subfield called deep learning are at the heart of many recent advances in artificial intelligence applications and have attracted a lot of attention and a significant share of the financing that has been pouring into the AI universe—almost 60 percent of all investment from outside the industry in 2016.

ARTIFICIAL INTELLIGENCE'S ROLLER-COASTER RIDE TO TODAY

Artificial intelligence, as an idea, first appeared soon after humans developed the electronic digital computing that makes it possible. And, like digital technology, artificial intelligence, or AI, has ridden waves of hype and gloom—with one exception: AI has not yet experienced wide-scale commercial deployment (see Box 2, "Fits and starts: A history of artificial intelligence").

That may be changing. Machines powered by AI can today perform many tasks—such as recognizing complex patterns, synthesizing information, drawing conclusions, and forecasting—that not long ago were assumed to require human cognition. And as AI's capabilities have dramatically expanded, so has its utility in a growing number of fields. At the same time, it is worth remembering that machine learning has limitations. For example, because the systems are trained on specific data sets, they can be susceptible to bias; to avoid this, users must be sure to train them with comprehensive data sets. Nevertheless, we are seeing significant progress.

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4 Marvin Minsky, "Steps toward artificial intelligence," *Proceedings of the IRE*, volume 49, number 1, January 1961; Edward A. Feigenbaum, *The art of artificial intelligence: Themes and case studies of knowledge engineering*, Stanford University Computer Science Department report number STAN-CS-77–621, August 1977; Allen Newell, "Intellectual issues in the history of artificial intelligence," in *The Study of Information: Interdisciplinary messages*, Fritz Machlup and Una Mansfield, eds., John Wiley and Sons, 1983.

5 Douglas R. Hofstadter, *Gödel, Escher, Bach: An eternal golden braid*, Basic Books, 1979. Hofstadter writes that he gave the theorem its name after Tesler expressed the idea to him firsthand. However, Tesler writes in his online CV that he actually said, "Intelligence is whatever machines haven't done yet."

6 William Vorhies, "Artificial general intelligence—the Holy Grail of AI," DataScienceCentral.com, February 23, 2016.

Box 2. Fits and starts: A history of artificial intelligence

The idea of computer-based artificial intelligence dates to 1950, when Alan Turing proposed what has come to be called the Turing test: can a computer communicate well enough to persuade a human that it, too, is human?[1] A few months later, Princeton students built the first artificial neural network, using 300 vacuum tubes and a war-surplus gyropilot.[2]

The term "artificial intelligence" was coined in 1955, to describe the first academic conference on the subject, at Dartmouth College. That same year, researchers at the Carnegie Institute of Technology (now Carnegie Mellon University) produced the first AI program, Logic Theorist.[3] Advances followed often through the 1950s: Marvin Lee Minsky founded the Artificial Intelligence Laboratory at MIT, while others worked on semantic networks for machine translation at Cambridge and self-learning software at IBM.[4]

Funding slumped in the 1970s as research backers, primarily the US government, tired of waiting for practical AI applications and cut appropriations for further work.[5] The field was fallow for the better part of a decade.

University researchers' development of "expert systems"—software programs that assess a set of facts using a database of expert knowledge and then offer solutions to problems—revived AI in the 1980s.[6] Around this time, the first computer-controlled autonomous vehicles began to appear.[7] But this burst of interest preceded another AI "winter."

Interest in AI boomed again in the 21st century as advances in fields such as deep learning, underpinned by faster computers and more data, convinced investors and researchers that it was practical—and profitable—to put AI to work.[8]

1 A. M. Turing, "Computing machinery and intelligence," *Mind*, volume 49, number 236, October 1950.
2 Jeremy Bernstein, "A.I.," *The New Yorker*, December 14, 1981.
3 Leo Gugerty, "Newell and Simon's Logic Theorist: Historical background and impact on cognitive modeling," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 50, issue 9, October 2006.
4 "The IBM 700 Series: Computing comes to business," IBM Icons of Progress, March 24, 2011.
5 Michael Negnevitsky, *Artificial intelligence: A guide to intelligent systems*, Addison-Wesley, 2002.
6 Edward A. Feigenbaum, "Expert systems in the 1980s," working paper, 1980.
7 Hans P. Moravec, "The Stanford Cart and the CMU Rover," *Proceedings of the IEEE*, volume 71, issue 7, July 1983; Tom Vanderbilt, "Autonomous cars through the ages," Wired.com, February 6, 2012.
8 Buchanan, Bruce G., "A (very) brief history of artificial intelligence," *AI Magazine*, volume 26, number 4, Winter 2005.

These advances have allowed machine learning to be scaled up since 2000 and used to drive deep learning algorithms, among other things. The advances have been facilitated by the availability of large and diverse data sets, improved algorithms that find patterns in mountains of data, increased R&D financing, and powerful graphics processing units (GPUs), which have brought new levels of mathematical computing power. GPUs, which are specialized integrated circuits originally developed for video games, can process images 40 to 80 times faster than the fastest versions available in 2013. Advances in the speed of GPUs have enabled the training speed of deep learning systems to improve five- or sixfold in each of the last two years. More data—the world creates about 2.2 exabytes, or 2.2 billion gigabytes, of it every day—translates into more insights and higher accuracy because it exposes algorithms to more examples they can use to identify correct and reject incorrect answers. Machine learning systems enabled by these torrents of data have reduced computer error rates in some applications—for example, in image identification—to about the same as the rate for humans.

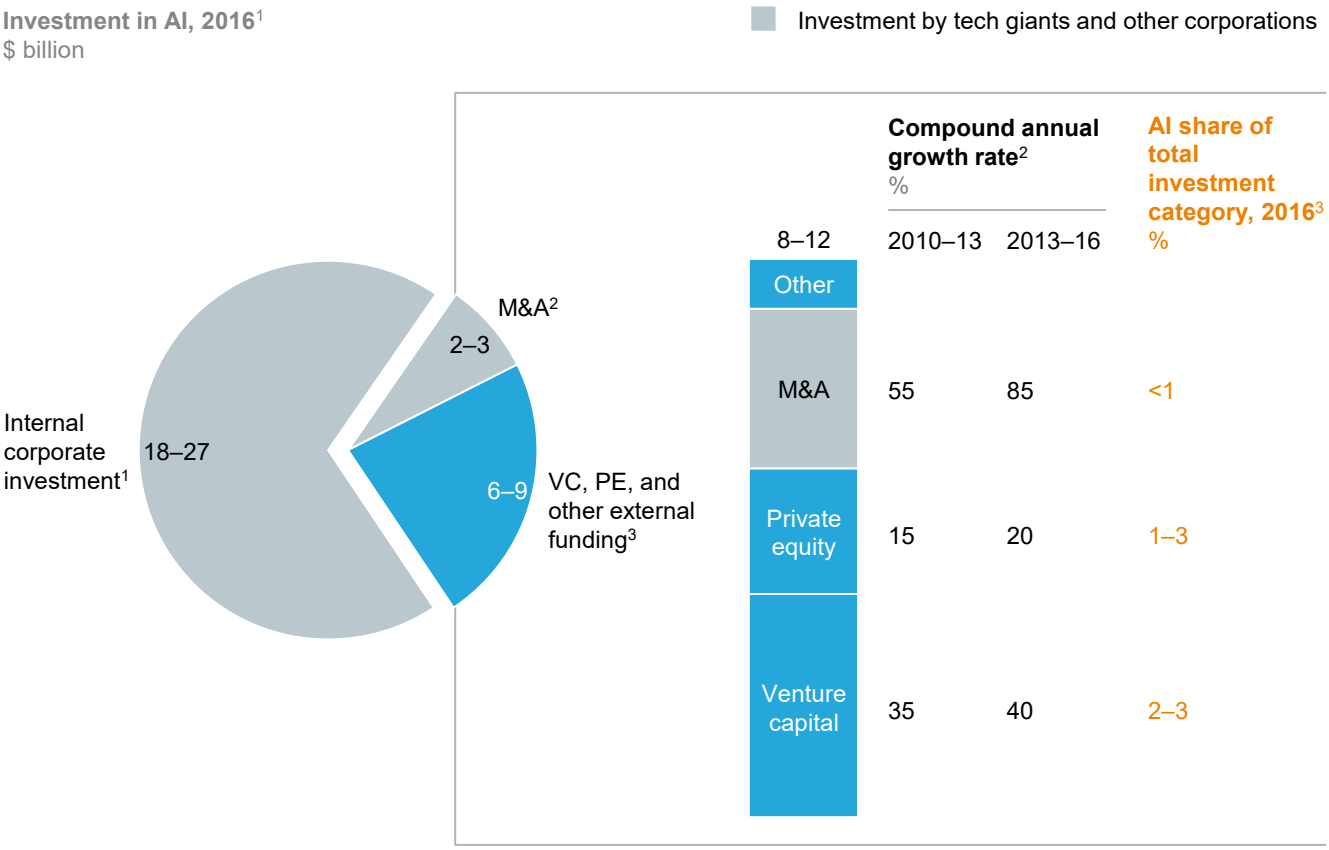
LED BY TECH GIANTS, AI INVESTMENT IS GROWING RAPIDLY, BUT COMMERCIAL ADOPTION IS LAGGING BEHIND

Tech giants and digital native companies such as Amazon, Apple, Baidu, and Google are investing billions of dollars in the various technologies known collectively as artificial intelligence. They see that the inputs needed to enable AI to finally live up to expectations—powerful computer hardware, increasingly sophisticated algorithmic models, and a vast and fast-growing inventory of data—are in place. Indeed, internal investment by large corporations dominates: we estimate that this amounted to $18 billion to $27 billion in

2016; external investment (from VCs, PE firms, M&A, grants, and seed funding) was around $8 billion to $12 billion (Exhibit 1).[7]

Exhibit 1

Technology giants dominate investment in AI



1 Estimate of 2016 spend by corporations to develop and deploy AI-based products. Calculated for top 35 high tech and advanced manufacturing companies investing in AI. Estimate is based on the ratio of AI spend to total revenue calculated for a subset of the 35 companies.
2 VC value is an estimate of VC investment in companies primarily focused on AI. PE value is an estimate of PE investment in AI-related companies. M&A value is an estimate of AI deals done by corporations. "Other" refers to grants and seed fund investments. Includes only disclosed data available in databases, and assumes that all registered deals were completed within the year of transaction. Compound annual growth rate values rounded.
3 M&A and PE deals expressed by volume; VC deals expressed by value.

SOURCE: Capital IQ; Pitchbook; Dealogic; S&P; McKinsey Global Institute analysis

But for all the recent investment, the scope of AI deployment has been limited so far. That is partly due to the fact that one beneficiary of that investment, internal R&D, is largely focused on improving the firms' own performance. But it is also true that there is only tepid demand for artificial intelligence applications for businesses, partly due to the relatively slow pace of digital and analytics transformation of the economy. Our survey of more than 3,000 businesses around the world found that many business leaders are uncertain about what exactly AI can do for them, where to obtain AI-powered applications, how to integrate them into their companies, and how to assess the return on an investment in the technology.

[7] Internal investment includes research and development, talent acquisition, cooperation with scientific institutions, and joint ventures with other companies done by corporations. External investment includes mergers and acquisitions, private equity funding, venture capital financing, and seed funds and other early-stage investing. The estimates of external investment are based on data available in the Capital IQ, PitchBook, and Dealogic databases. Provided values are estimates of annual investment in AI, assuming that all registered deals were completed within the year of transaction. Internal investment is estimated based on the ratio of AI spend to revenue for the top 35 high tech and advanced manufacturing companies focused on AI technologies.

Most of the investment in AI has consisted of internal spending—R&D and deployment—by large, cash-rich digital native companies. What is the large corporate investment in AI focused on? Bigger companies, such as Apple, Baidu, and Google, are working on suites of technologies internally, but vary in the breadth and focus of their AI investment. Amazon is working on robotics and speech recognition, Salesforce on virtual agents and machine learning. BMW, Tesla, and Toyota are among the manufacturers making sizable commitments in robotics and machine learning for use in driverless cars. Toyota, for example, set aside $1 billion to establish a new research institute devoted to AI for robotics and driverless vehicles.[8] Industrial giants such as ABB, Bosch, GE, and Siemens also are investing internally, often in machine learning and robotics, seeking to develop specific technologies related to their core businesses. IBM has pledged to invest $3 billion to make its Watson cognitive computing service a force in the internet of things.[9] Baidu has invested $1.5 billion in AI research over the last 2½ years. This is in addition to $200 million it committed to a new in-house venture capital fund, Baidu Venture.[10]

At the same time, big tech companies have been actively buying AI startups, not just to acquire technology or clients but to secure qualified talent. The pool of true experts in the field is small, and Alibaba, Amazon, Facebook, Google, and other tech giants have hired many of them. Companies have adopted M&A as a way to sign up top talent, a practice known as "acqui-hiring," for sums that typically work out to $5 million to $10 million per person. The shortage of talent and cost of acquiring it are underlined by a recent report that companies are seeking to fill 10,000 AI-related jobs and have budgeted more than $650 million for salaries.[11]

Overall, corporate M&A is the fastest-growing external source of funding for AI companies, increasing in terms of value at a compound annual growth rate of over 80 percent from 2013 to 2016, based on our estimates. Leading high tech companies and advanced manufacturers have closed more than 100 M&A deals since 2010. Google completed 24 transactions in that time, including eight in computer vision and seven in language processing. Apple, the second-most-active acquirer, has closed nine, split evenly among computer vision, machine learning, and language processing.

Companies are also expanding their search for talent abroad. Facebook, for instance, is opening an AI lab in Paris that will supplement similar facilities in New York and Silicon Valley—and make it easier for the company to recruit top researchers in Europe.[12] Google recently invested $4.5 million in the Montreal Institute for Learning Algorithms, a research lab at the University of Montreal; Intel donated $1.5 million to establish a machine learning and cybersecurity research center at Georgia Tech; and NVIDIA is working with the National Taiwan University to establish an AI laboratory in Taipei. [13]

8 Craig Trudell and Yuki Hagiwara, "Toyota starts $1 billion center to develop cars that don't crash," Bloomberg.com, November 6, 2015.

9 "IBM invests to lead global internet of things market—shows accelerated client adoption," IBM press release, October 3, 2006.

10 Phoenix Kwong, "Baidu launches $200m venture capital unit focused on artificial intelligence," *South China Morning Post*, September 13, 2016.

11 "U.S. companies raising $1 billion or more to fuel artificial intelligence (AI) development: Looking to staff 10,000+ openings, cites new Paysa research," Paysa press release, April 18, 2017.

12 Cade Metz, "Facebook opens a Paris lab as AI research goes global," Wired.com, June 2, 2015.

13 Cade Metz, "Google opens Montreal AI lab to snag scarce global talent," Wired.com, November 12, 2015; "Georgia Tech launches new research on the security of machine-learning systems," Georgia Institute of Technology press release, October 31, 2016; "NVIDIA collaborates with Taipei Tech to establish Embedded GPU Joint Lab," National Taipei University of Technology press release, September 4, 2014.

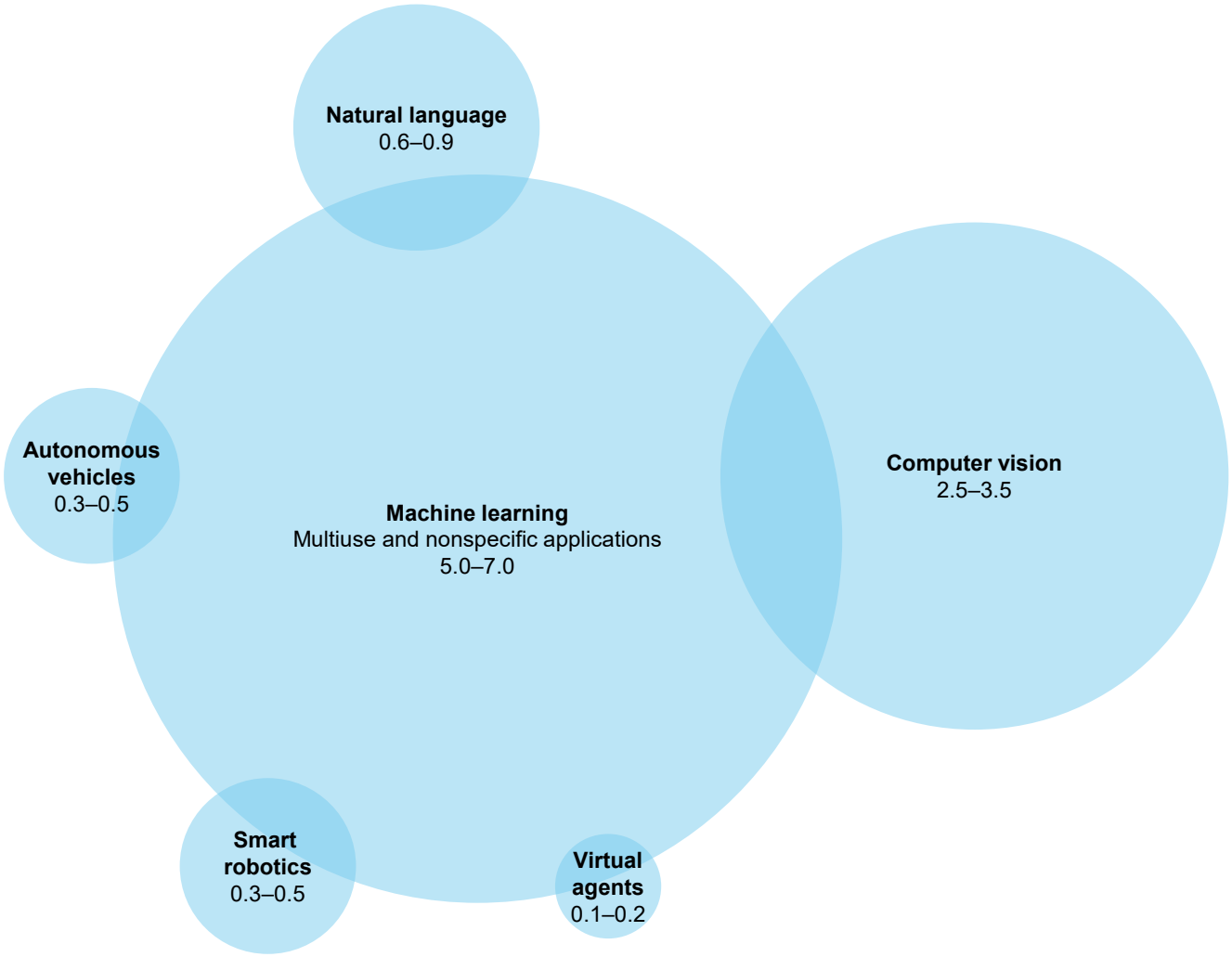
The buzz over AI has grown loud enough to encourage venture capital and private equity firms to step up their investment in AI. Other external investors, such as angel funds and seed incubators, also are active. We estimate total annual external investment was $8 billion to $12 billion in 2016.[14]

Machine learning attracted almost 60 percent of that investment, most likely because it is an enabler for so many other technologies and applications, such as robotics and speech recognition (Exhibit 2). In addition, investors are drawn to machine learning because, as has long been the case, it is quicker and easier to install new code than to rebuild a robot or other machine that runs the software. Corporate M&A in this area is also growing fast, with a compound annual growth rate of around 80 percent from 2013 through 2016.

Exhibit 2

Machine learning received the most investment, although boundaries between technologies are not clear-cut

External investment in AI-focused companies by technology category, 2016[1]
$ billion



1 Estimates consist of annual VC investment in AI-focused companies, PE investment in AI-related companies, and M&A by corporations. Includes only disclosed data available in databases, and assumes that all registered deals were completed within the year of transaction.

SOURCE: Capital IQ; Pitchbook; Dealogic; McKinsey Global Institute analysis

[14] Estimates of external investment in AI vary widely because measurement standards vary. For example, Venture Scanner puts total funding of AI-related startups in 2016 at $2.5 billion, while Goldman Sachs estimates that the venture capital sector alone made $13.7 billion of AI-related investment that year.

Investment in AI is still in the early stages and relatively small compared with the investment in the digital revolution. Artificial intelligence, for example, attracted 2 to 3 percent of all VC funding by value in 2016, while information technology in general soaked up 60 percent. AI also was a small fraction—1 to 3 percent—of all investment by PE firms in 2016.[15] But AI investment is growing fast.

From 2013 through 2016, external investment in AI technologies had a compound annual growth rate of almost 40 percent. That compares with 30 percent from 2010 through 2013. Not only are deals getting bigger and more numerous, but they require fewer participants to complete the financing. This suggests that investors are growing more confident in the sector and may have a better understanding of the technology and its potential.

However, for the most part, investors are still waiting for their investments to pay off. Only 10 percent of startup companies that consider machine learning to be a core business say they generate revenue, according to PitchBook. Of those, only half report more than $50 million in revenue. Moreover, external investment remains highly concentrated geographically, dominated by a few technology hubs in the United States and China, with Europe lagging far behind. We explore these issues further in Chapter 3.

FIRMS AND INDUSTRIES ALREADY ON THE DIGITAL FRONTIER ARE ADOPTING AI, BUT OTHERS ARE HESITANT TO ACT

Investors are pouring billions of dollars into AI companies based on the hope that a market of AI adopters will develop fairly quickly and will be willing to pay for AI infrastructure, platforms, and services. Clearly, Amazon, Google, and other digital natives are investing for their own applications, such as optimizing searches and personalizing marketing. But getting a sense of how much traditional companies in health care, retail, and telecom are spending on AI is not easy. For this reason, we conducted a survey to understand this situation in more depth.

In general, few companies have incorporated AI into their value chains at scale; a majority of companies that had some awareness of AI technologies are still in experimental or pilot phases. In fact, out of the 3,073 respondents, only 20 percent said they had adopted one or more AI-related technology at scale or in a core part of their business.[16] Ten percent reported adopting more than two technologies, and only 9 percent reported adopting machine learning.[17]

Even this may overstate the commercial demand for AI at this point. Our review of more than 160 global use cases across a variety of industries found that only 12 percent had progressed beyond the experimental stage. Commercial considerations can explain why some companies may be reluctant to act. In our survey, poor or uncertain returns were the primary reason for not adopting reported by firms, especially smaller firms. Regulatory concerns, explored further in Chapter 3, also have become much more important.

As with every new wave of technology, we expect to see a pattern of early and late adopters among sectors and firms. We uncover six features of the early pattern of AI adoption, which is broadly in line with the ways companies have been adopting and using the recent cohort of digital technologies. Not coincidentally, the same players who were leaders in that earlier wave of digitization are leading in AI—the next wave.

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[15] It is worth noting that VC funds were focusing on AI technology when choosing investments, while PE funds were investing in AI-related companies.

[16] Survey results throughout this discussion paper are weighted for firm size; "20 percent of firms" indicates firms representing 20 percent of the workforce. See Appendix B for an explanation of the weighting methodology.

[17] The eight technologies are natural language processing, natural language generation, speech recognition, machine learning, decision management, virtual agents, robotics process automation, and computer vision. The five technology systems are robotics and autonomous vehicles, computer vision, language, virtual agents, and machine learning.

The first feature is that early AI adopters are from sectors already investing at scale in related technologies, such as cloud services and big data. Those sectors are also at the frontier of digital assets and usage.[18] This is a crucial finding, as it suggests that there is limited evidence of sectors and firms catching up when it comes to digitization, as each new generation of tech builds on the previous one.

Second, independently of sectors, large companies tend to invest in AI faster at scale. This again is typical of digital adoption, in which, for instance, small and midsized businesses have typically lagged behind in their decision to invest in new technologies.

Third, early adopters are not specializing in one type of technology. They go broader as they adopt multiple AI tools addressing a number of different use cases at the same time.

Fourth, companies investing at scale do it close to their core business.

Fifth, early adopters that adopt at scale tend to be motivated as much by the upside growth potential of AI as they are by cutting costs. AI is not only about process automation, but is also used by companies as part of major product and service innovation. This has been the case for early adopters of digital technologies and suggests that AI-driven innovation will be a new source of productivity and may further expand the growing productivity and income gap between high-performing firms and those left behind.[19]

Finally, strong executive leadership goes hand in hand with stronger AI adoption. Respondents from firms that have successfully deployed an AI technology at scale tended to rate C-suite support nearly twice as high as those from companies that had not adopted any AI technology.

Early-adopting sectors are closer to the digital frontier

Sector-by-sector adoption of AI is highly uneven right now, reflecting many features of digital adoption more broadly. Our survey found that larger companies and industries that adopted digital technologies in the past are more likely to adopt AI. For them, AI is the next wave of digitization.

This pattern in the adoption of technology is not new—we saw similar behavior in firms adopting enterprise social technologies.[20] But this implies that, at least in the near future, AI deployment is likely to accelerate at the digital frontier, expanding the gap between adopters and laggards across companies, industries, and geographic regions.

The leading sectors include some that MGI's Industry Digitization Index found at the digital frontier, namely high tech and telecom and financial services.[21] These are industries with long histories of digital investment. They have been leaders in developing or adopting digital tools, both for their core product offerings and for optimizing their operations. However, even these sectors are far behind in AI adoption when compared with overall digitization (Exhibit 3).

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[18] *Digital Europe: Pushing the frontier, capturing the benefits*, McKinsey Global Institute, June 2016; *Digital America: A tale of the haves and have-mores*, McKinsey Global Institute, December 2015.

[19] Rosina Moreno and Jordi Suriñach, "Innovation adoption and productivity growth: Evidence for Europe," working paper, 2014; Jacques Bughin and Nicolas van Zeebroeck, "The right response to digital disruption," *MIT Sloan Management Review*, April 2017.

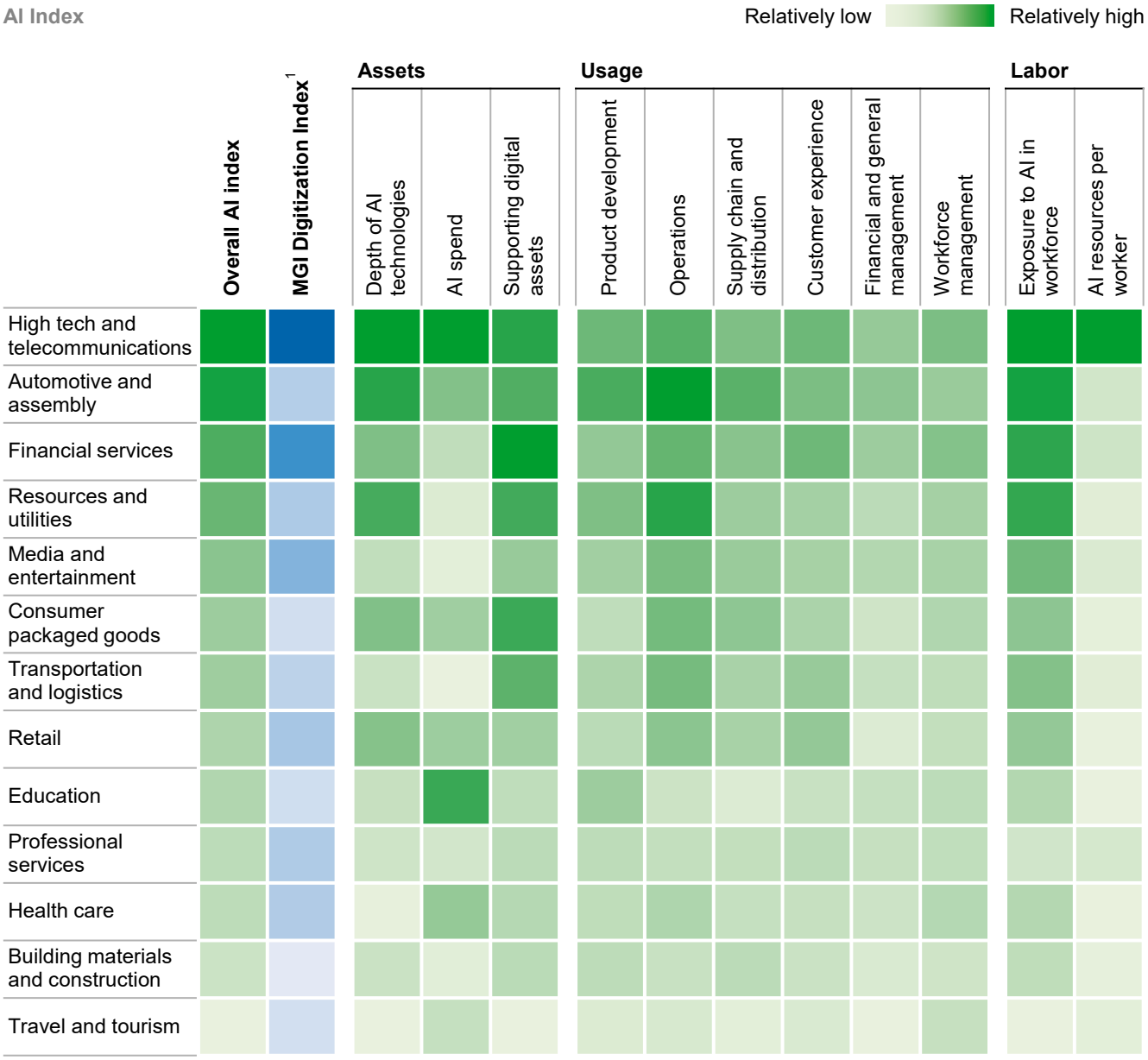
[20] Jacques Bughin and James Manyika, "How businesses are using web 2.0: A McKinsey global survey," *McKinsey Quarterly*, December 2007; Jacques Bughin and James Manyika, "Bubble or paradigm change? Assessing the global diffusion of enterprise 2.0," in Alex Koohang, Johannes Britz, and Keith Harman, eds., *Knowledge management: Research and applications,* Informing Science, 2008.

[21] *Digital America: A tale of the haves and have-mores*, McKinsey Global Institute, December 2015.

Exhibit 3

AI adoption is occurring faster in more digitized sectors and across the value chain

AI Index



1 The MGI Digitization Index is GDP weighted average of Europe and United States. See Appendix B for full list of metrics and explanation of methodology.

SOURCE: McKinsey Global Institute AI adoption and use survey; *Digital Europe: Pushing the frontier, capturing the benefits*, McKinsey Global Institute, June 2016; *Digital America: A tale of the haves and have-mores*, McKinsey Global Institute, December 2015; McKinsey Global Institute analysis

Automotive and assembly is also highly ranked. It was one of the first sectors that implemented advanced robotics at scale for manufacturing, and today is also using AI technologies to develop self-driving cars.

In the middle are less digitized industries, including resources and utilities, personal and professional services, and building materials and construction. A combination of factors may account for this. These sectors have been slow to employ digital tools generally, except for some parts of the professional services industry and large construction companies. They are also industries in which innovation and productivity growth has lagged, potentially in part due to their domestic focus. Some of these sectors have a particularly high number of small firms—an important predictor for AI adoption, as explored below.

Toward the bottom of the pack for now are traditionally less digital fields such as education and health care. Despite ample publicity about cutting-edge AI applications in these industries, the reality is that uptake appears to be low so far. Weaker adoption reflects the particular challenges faced in these sectors. In health care, for example, practitioners and administrators acknowledge the potential for AI to reduce costs but quickly add that they believe that regulatory concerns and customer acceptance will inhibit adoption.

When it comes to adopting AI, the bigger, the bolder

A stylized fact in IT literature is that large firms usually are early adopters of innovative technology, while smaller firms are more reluctant to be first movers.[22] We find the same digital divide when we look at AI: large firms have much higher rates of adoption and awareness. Across all sectors, larger firms—which we define as those with more than 500 employees—are at least 10 percent more likely than smaller firms to have adopted at least one AI technology at scale or in a core part of their business. In sectors with lower rates of AI uptake, the adoption rate of bigger companies was as much as 300 percent that of smaller companies.

Other digitization indicators reflect this fact, as highlighted in MGI's digitization work. Larger firms typically have access to more and better-structured data, and are more likely to have employees with the technical skills needed to understand the business case for AI investment and to successfully engage suppliers. Bigger firms also have an advantage because the kind of fixed-cost investment required for AI tends to generate higher returns when applied to a bigger base of costs and revenue.

Nonetheless, we find success stories among some smaller firms, too. Relative to larger companies, they can benefit from fewer issues with legacy IT systems and lower levels of organizational resistance to change. Smaller firms can also benefit from AI tools provided as a service.

Early AI adopters tend to become serial adopters

We looked at how firms deploy AI across eight different application areas and five technology systems.[23] Our results suggest that early-adopting firms are looking across multiple AI tools when they begin to adopt, rather than focusing on a particular technology. This is consistent with adoption patterns in other digital technologies.[24]

The phenomenon of multitechnology application is persistent at a sector level. Industries with high rates of adopting one technology have higher rates in adopting others. High tech and telecom, for example, report the highest rates of adoption across all five technology groups, while construction is among the lowest among all five.

However, there are anomalies. Education and health care are notable for being slow to adopt AI technology. In frontier sectors—those with a relatively high percentage of early adopters—two-thirds of firms that had already adopted one of the eight AI technologies had adopted at least two others as well. In health care, only one-third had, with language technologies the most likely to be deployed at scale or in a core part of the business.

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[22] Kevin Zhu, Kenneth L. Kraemer, and Sean Xu, "The process of innovation assimilation by firms in different countries: A technology diffusion perspective on e-business," *Management Science*, volume 52, number 10, October 2006; Chris Forman, Avi Goldfarb, and Shane Greenstein, "The geographic dispersion of commercial Internet use," in *Rethinking rights and regulations: Institutional responses to new communication technologies*, Lorrie Faith Cranor and Steven S. Wildman, eds., MIT Press, 2003.

[23] The eight technologies are: natural language processing, natural language generation, speech recognition, machine learning, decision management, virtual agents, robotics process automation, and computer vision. The five technology systems are: robotics and autonomous vehicles, computer vision, language, virtual agents, and machine learning.

[24] Sanjeev Dewan, Dale Ganley, and Kenneth L. Kraemer, "Complementarities in the diffusion of personal computers and the internet: Implications for the global digital divide," *Information Systems Research*, volume 21, number 5, December 2010.

Users are keeping artificial intelligence close to their core

Functionally, AI technologies are finding applications across the value chain, but with some parts of the value chain getting more attention than others. For example, customer service functions such as sales and marketing, as well as operations and product development, all tend to use the most commonly cited AI applications. General and financial management, by contrast, lag well behind. A similar pattern is found in big data. The literature shows that the most frequent big data applications originate in sales and marketing functions.[25]

In general, firms queried in our survey say they tend to adopt AI technologies affecting the part of their value chain closest to the core. Operations are an important area of adoption in the automotive and assembly, and consumer packaged goods sectors, as well as utilities and resources. Operations and customer service are the most important areas for financial services. This is new. Previously, new digital technology tended to remain on the margins, away from the core of the business.

However, in line with trends in technology, we also see sectors going deeper and broader as they increase their degree of AI adoption. Leading sectors are not only more extensively deploying AI in the core parts of their value chain, they are also deploying it in more parts of their value chain.

Early adopters see AI increasing revenue while companies experimenting with AI expect lower costs

As companies become more familiar with AI, their perceptions about its benefits change. The results of survey analysis show that early AI adopters are driven to employ AI technologies in order to grow revenue and market share, and the potential for cost reduction is a secondary idea. Firms that we consider more advanced AI adopters were 27 percent more likely to report using AI to grow their market than companies only experimenting with or partially adopting AI, and 52 percent more likely to report using it to increase their market share. Experimenters, by contrast, were more focused on costs. They were 23 percent more likely than advanced AI adopters to point to labor cost reductions, and 38 percent more likely to mention non-labor cost reductions.

In other words, the more companies use and become familiar with AI, the more potential for growth they see in it. Companies with less experience tend to focus more narrowly on reducing costs. The employment implications are further discussed in Chapter 3.

AI is not only about technical adoption, it is about enterprise acceptance

To be successful, AI adoption requires buy-in by the executive suite to generate the momentum needed to overwhelm organizational inertia.

Successful AI adopters, according to our survey, have strong executive leadership support for the new technology. Representatives of firms that have successfully deployed an AI technology at scale tended to rate C-suite support nearly twice as high as those of companies that had not adopted any AI technology. They added that strong support came not only from the CEO and IT executives—that is, chief information officer, chief digital officer, and chief technology officer—but from all other C-level officers and the board of directors as well.

Successful adopters also adjusted their firm-wide strategy to become proactive toward AI. See more details in Chapter 2.

[25] Jacques Bughin, "Ten big lessons learned from big data analytics," *Applied Marketing Analytics*, volume 2, number 4, 2017.

AI'S NEXT CHALLENGE: GET USERS TO ADAPT AND ADOPT

IT industry analysts concur that the market size for AI technology will experience strong growth over the next three years. Most of the firms we surveyed expected to increase spending on AI in the coming three years, a finding echoed in other recent surveys. For example, 75 percent of the 203 executives queried in an Economist Intelligence Unit survey said AI would be "actively implemented" in their firms within three years (3 percent said it had already happened).

Expectations of how large this growth will be vary widely. Our survey documented relatively modest growth projections—only one-fifth of firms expected to increase expenditure by more than 10 percent. Industry analysts' forecasts of the compound annual growth rate ranged from just under 20 percent to nearly 63 percent, including both adoption by additional companies and increased spending within companies.[26] The actual growth rate may need to be toward the upper end of that range to meet the expectations of investors piling into the industry.

Growth will hinge on the ability of sectors and firms to overcome technical, commercial, and regulatory challenges. Our survey respondents and outside forecasters expect financial services, retail, health care, and advanced manufacturing to be in the AI vanguard. These are the industries where technical feasibility is relatively high (reflected in the case studies on the market today) and the business case for AI is most compelling. They are also the sectors with the highest degree of digital adoption to date—a key foundation for AI (Exhibit 4).

Technical challenges are an important differentiating factor between industries. While big tech and academia are pushing advances in the performance of the underlying technology, engineering solutions need to be worked out for specific use cases, requiring both data and talent. Industries such as financial services, and high tech and telecom have generated and stored large volumes of structured data, but others, including construction and travel, lag far behind.[27]

Commercial drivers also differ between sectors. Industries most likely to lead the adoption of AI technologies at scale are those with complex businesses in terms of both operations and geography, whose performance is driven by forecasting, fast and accurate decision making, or personalized customer connections. In financial services, there are clear benefits from improved accuracy and speed in AI-optimized fraud-detection systems, forecast to be a $3 billion market in 2020. In Chapter 2 (and the supporting appendix) we explore how these commercial drivers play out in other industries. For example, in retail, there are compelling benefits from improved inventory forecasts, automated customer operations, and highly personalized marketing campaigns. Similarly, in health care, AI-powered diagnosis and treatment systems can both save costs and deliver better outcomes for patients.

Even where compelling commercial use cases have been engineered and are demanded by firms, regulatory and social barriers can raise the cost and slow the rate of adoption. Product liability is one such concern; it is especially troublesome for automakers and other manufacturers. Privacy considerations restrict access to data and often require it to be anonymized before it can be used in research. Ethical issues such as trained biases and algorithmic transparency remain unresolved. (For further discussion, see Box 4 in Chapter 3, "An overview of ongoing challenges.") Preferences for a human relationship in settings such as health care and education will need to be navigated. Job security concerns could also limit market growth—there are already serious calls for taxes on robots.

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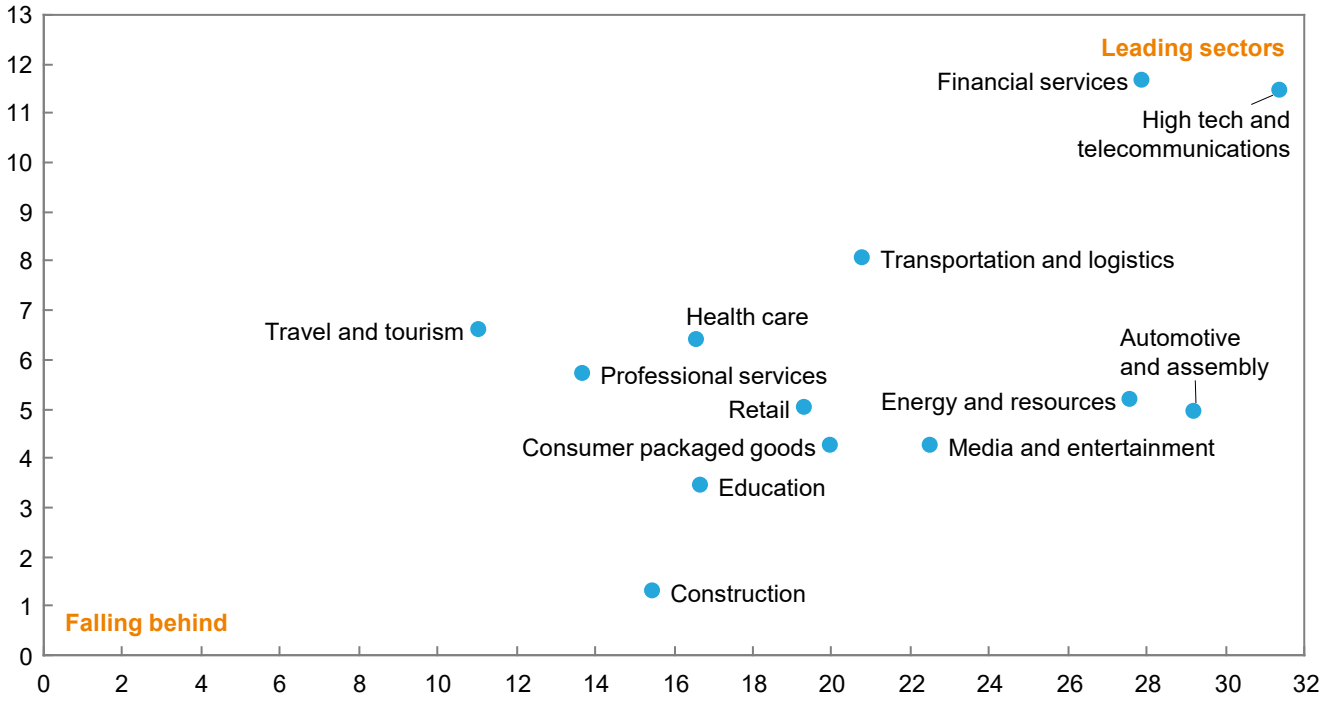
[26] The full range of forecasts: BCC Research, 19.7 percent; Transparency Market Research, 36.1 percent, Tractica, 57.6 percent; IDC, 58 percent; and Markets and Markets, 62.9 percent.

[27] *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.

Exhibit 4

Sectors leading in AI adoption today also intend to grow their investment the most

Future AI demand trajectory[1]
Average estimated % change in AI spending, next 3 years, weighted by firm size[2]



Current AI adoption
% of firms adopting one or more AI technology at scale or in a core part of their business, weighted by firm size[2]

1 Based on the midpoint of the range selected by the survey respondent.
2 Results are weighted by firm size. See Appendix B for an explanation of the weighting methodology.

SOURCE: McKinsey Global Institute AI adoption and use survey; McKinsey Global Institute analysis

These forces will help determine the industries that AI is likely to transform the most. However, if current trends hold, variation of adoption within industries will be even larger than between industries. We expect that large companies with the most digital experience will be the first movers because they can leverage their technical skills, digital expertise, and data resources to develop and smoothly integrate the most appropriate AI solutions.

•••

After decades of false starts, artificial intelligence is on the verge of a breakthrough, with the latest progress propelled by machine learning. Tech giants and digital natives are investing in and deploying the technology at scale, but widespread adoption among less digitally mature sectors and companies is lagging. However, the current mismatch between AI investment and adoption has not stopped people from imagining a future where AI transforms businesses and entire industries. In the next chapter, we explore the four major ways in which AI can create value across the value chain in different sectors.