Artificial intelligence: scope, players, markets and geography

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Abstract

Purpose – *This paper aims to clarify the notion of artificial intelligence (AI), reviewing the present scope of the phenomenon through its main applications. It aims at describing the various applications while assessing the markets, highlighting some of the leading industrial sectors in the field. Therefore, it identifies pioneering companies and the geographical distribution of AI companies.*

Design/methodology/approach – *The paper builds upon an in-depth investigation of public initiatives focusing mostly on the EU. It is based on desk research, a comprehensive review of the main grey and scientific literature in this field.*

Findings – *The paper notes that there is no real consensus on any definition for this umbrella term, that the definition does fluctuate over time but highlights some of the main changes and advances that took place over the past 60 years. It stresses that, in spite of the hype, on both the business and consumer sides, the demand appears uncertain. The scope of the announced disruptions is not easy to assess, technological innovation associated with AI may be modest or take some time to be fully deployed. However, some companies and regions are leading already in the field.*

Research limitations/implications – *The paper, based on desk research, does not consider any expert opinions. Besides, the scientific literature on the phenomenon is still scarce (but not the technical one in the specific research sectors of AI). Most of the data come from consultancies or government publications which may introduce some bias, although the paper gathered various, often conflicting viewpoints.*

Originality/value – *The paper gives a thorough review of the available literature (consultancies, governments) stressing the limitations of the available research on economic and social aspects. It aims at providing a comprehensive overview of the major trends in the field. It gives a global overview of companies and regions.*

Keywords *Artificial intelligence, Deep learning, AI markets, Applications and trends, Pioneers, Regional distribution of companies*

Paper type *Research paper*

Over the past few years, artificial intelligence (AI) has come to the fore and is now expected to be one of the most pervasive disruptive technologies. However, there is no real consensus on the definition of AI, which has changed over time. This paper first clarifies the phenomenon and then gives an overview of its present scope. It looks at the various applications of AI and assesses the markets, highlighting some of the leading industrial sectors in the field, complemented by the geographical distribution of AI companies. Finally, some of the main issues and challenges for policymakers are addressed.

Over the past sixty years, AI has had both ups, or AI summers, and downs, or "AI winters". Stone *et al.* (2016)[1] note that "the rate of progress in AI has been patchy and unpredictable", but add that there have been significant advances nevertheless. The recent development of AI techniques such as "deep learning" is frequently quoted to illustrate these advances. Two events highlight the powerful evolution of some of the technologies involved in AI. In 2013, the company DeepMind[2] developed deep learning software which, for the first time, surpassed human performance with Atari arcade games. The same

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UK AI start-up achieved global coverage in 2016, when its AI computer programme, AlphaGo Art, won a five-match series of the ancient Chinese board game "Go"[3] against the reigning world champion, the South Korean Se-dol Lee, in Seoul[4].

Whatever the significance of these events, one should first clarify what "AI" refers to, its main definitions, and the scope of the technologies it encompasses. The first section of this article looks at definition and scope, giving an overview of the current main applications. Though consulting firms are expecting the market to grow, at the moment it seems rather small. We assess this market in the second section, based on the available research. Then we look at the main field of applications, some pioneering initiatives and the main players. We identify the leading industrial sectors among those that seem most involved already in AI. The third section deals with the geographical distribution of AI companies, and the role of the EU. We conclude by touching on societal and ethical issues and introduce some of the challenges that policymakers are likely to face if they decide to take one path or another.

The article builds upon an in-depth investigation of public initiatives in Europe. It is based on desk research, including a comprehensive review of the main grey and scientific literature in this field.

1. How can we define artificial intelligence?

AI is an umbrella term for the science of making machines smart. It refers to information systems inspired by biological systems. AI encompasses multiple technologies including machine learning, deep learning, computer vision, natural language processing (NLP), and machine reasoning. Definitions have changed over time and there is no real consensus on any one in particular. As stressed in the 2016 White House (National Science and Technology Council) Report: "There is no single definition of AI that is universally accepted by practitioners". Notions of AI involve multiple viewpoints and sometimes even contradictory ideas. AI began as a science and a set of computational technologies, but even among scientists, there is no established unifying theory or paradigm that guides AI research. However, research on AI focuses primarily on 4 key components of human intelligence: learning, reasoning, problem-solving and perception. It is about understanding the nature of intelligent thought and action using computers as experimental devices (Box 1).

AI is inspired by – but operates quite differently from – the ways people use their nervous systems and bodies to sense, learn, reason and take action. Once a mostly academic area of study, twenty-first century AI enables a constellation of mainstream technologies that are perceived as having a substantial impact on our everyday lives.

Box 1. A short history of artificial intelligence

By the early twentieth century, psychologists were collecting experimental data on human learning and thinking, and by the 1940s, biologists were collecting data on the neurological basis of thought. By 1950, scientists from many disciplines, along with mathematicians, linguists, and philosophers, were using the newly developed digital computers to encode and test new theories. In that year Alan Turing (Turing, 1950) brought a new focus to the disparate work when he boldly stated that machines could think. Before releasing his notorious 1950 paper "Computing Machinery and Intelligence", Turing had already developed the principle of the modern computer in 1936. Turing explored what is meant by "machines" and by "thinking", and in what became known as the Turing Test, to answer to the question "Can machines think": "can a computer communicate well enough to persuade a human that it, too, is human?" Some months after a first artificial neural network was built. The modern

history of AI begins with the development of stored-program electronic computers. This period is often referred to under the term of cybernetics aiming at reproducing the functioning of the human brain, and raising questions about the nature of induction (Minsky, 1963).

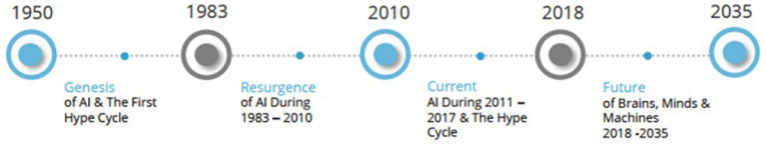
The 1956 Dartmouth Summer Research Project on Artificial Intelligence, organized by John McCarthy, Nathaniel Rochester, Claude Shannon and Marvin Lee Minsky is considered to be the birthplace of the field of AI. McCarthy was to initiate with Minsky[5] what is known now as the MIT Computer Science and Artificial Intelligence Laboratory.

In the 1970s when most public R&D funding dwindled away for almost a decade, videogames emerged, which were also based on man-machine interaction. Playing in research labs began in the 1960s with games like "Spacewar". In the 1970s, the first single-player games with enemy agents were created. This element is seldom mentioned [6], the majority of modern video games feature AI in some shape or form. Today games are using avatars just like virtual assistants or chatbots. Nevertheless, the White House (National Science and Technology Council, 2016) report mentioned the moment when AI first surpassed human performance with Atari games in 2013 as a major milestone.

AI resurfaced, in the 1980s, around the development of "expert systems" (software programs that assess a set of facts using a database of expert knowledge and then offer solutions to problems). For instance, Mycin (created by Buchanan and Shortliffe in 1984) was expert system for medical diagnosis that worked faster than a "real" doctor. In the mid-1980s, neural networks became widely used with the backpropagation algorithm.

Twenty years later, following another "winter", research shifted toward deep learning, applying concepts that emerged in the 1980s but using much more powerful computers (incredibly cheap and powerful computing and memory had become available). The Web became a source of applications and data, and AI made a strong mark on the web (for example, the semantic wVeb and web applications that learn and adapt).

Aggarwal (2018) described two "hype cycles" a first during 1956 and 1982, and another one during 2011 and 2017. He defines a hype cycle as characterized by a boom phase, when researchers, developers and investors become overly optimistic and enormous growth takes place, and a bust phase, when investments are withdrawn, and growth reduces substantially.



Source: Aggarwal (2018a)

Source: Aggarwal (2018), AI Topics, Association for the Advancement of Artificial Intelligence (www.aaai.org) (2017), Buchanan *et al.* (2013), Glinert (2012), McKinsey (2017, p.8), Triclot (2012), Waltz (2006), Wikipedia.

To make matters more complex, AI is not a product, like packaged software, mobile apps or operating systems. It combines software and hardware but there is no specific AI software, just AI solutions which build upon a variety of software. AI systems are designed to accomplish particular tasks, they are not universal. Boundaries between technologies are not clear cut either (see Box 2 for the "hot areas") – for example, there

is frequently an overlap between AI and robotics. Robotics are seen as a sub-segment of AI and are often the first thing that comes to mind, when AI is mentioned. Robots have always been part of the public's perception of intelligent computers; gaining popularity through science-fiction literature and movies featuring robots with human-like characteristics (many myths in antiquity involve human-like artifacts, see Appendix). However, as Buchanan (2005) explains, robotics had initially more to do with mechanical engineering than with intelligent control and the more sophisticated AI technologies[7].

As regards "strong AI", often referred to as artificial general intelligence (AGI), there is some consensus that we may be "a long way from artificial general intelligence" (Brynjolfsson, AI Index 2017), although scientists may disagree on the timeline. In spite of all the advances in AI, experts still consider it is no match for the human brain. D. George[8]: "the current level of AI is like what he calls the 'old brain', similar to the cognitive ability of rats" (quoted by Knowledge@Wharton, 2017). The current consensus of the private-sector expert community is that artificial general intelligence (AGI) will not be achieved for at least decade (White House, NSTC report, 2016a).

Stone *et al.* (2016) put forward a Nils J. Nilsson definition: "Artificial intelligence is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment." As they note, the issue then is to assess what is "appropriate" and what "foresight" consists of. They also list the "hot trends" (Box 2). In a 2018 report, SAP (2018, p. 6) suggests the simplified definition: "Artificial intelligence can be defined as the capability of a machine to imitate intelligent human behaviour". This broad definition does not specify any ingredients but leaves things open. Rao (2017) quotes a Russell and Norvig 1995 definition of AI as "the designing and building of intelligent agents that receive percepts from the environment and take actions that affect that environment". The interaction with the environment (building of inference capabilities) can follow two tracks: conditional instructions (also known as heuristics) or machine learning. Under conditional instructions, an AI bot (see "chatbox" in Box 5) interprets emotions in a conversation by following a program that instructs it to start by checking for emotions that were evident in the recent past. As for machine learning, the machine is taught, using specific examples, to make inferences about the world around it.

Box 2. "Hot" areas[9] of AI research into both fundamental methods and application areas

Large-scale machine learning concerns the design of learning algorithms, as well as scaling up existing algorithms, to work with extremely large data sets.

Deep learning, a class of learning procedures, has facilitated object recognition in images, video labelling and activity recognition, and is making significant inroads into other areas of perception, such as audio, speech and natural language processing. Deep learning requires:

- labelled data for training;
- algorithms for the neural nets; and
- special purpose hardware to run the algorithms.

Reinforcement learning is a framework that shifts the focus of machine learning from pattern recognition to experience-driven sequential decision-making. It has the potential to enable AI applications to take action in the real world. Though it has largely been confined to academia for the past few decades, it is now seeing some practical, real-world successes.

Robotics is currently concerned with how to train a robot to interact with the world around it in generalizable and predictable ways, how to facilitate manipulation of objects in interactive environments, and how to interact with people. Advances in robotics will rely on commensurate advances in the reliability and generality of computer vision and other forms of machine perception.

Computer vision is currently the most prominent form of machine perception. It is the sub-area of AI which has been most transformed by the rise of deep learning. For the first time, computers are able to perform some vision tasks better than people. Much current research is focused on automatic image and video captioning.

Natural Language Processing (NLP), often coupled with automatic speech recognition, is quickly becoming a commodity for widely spoken languages with large data sets. Research is now focusing on developing refined and capable systems that are able to interact with people through dialogue, not just react to stylized requests. Great strides have also been made in machine translation among different languages, with more real-time person-to-person exchanges on the near horizon.

Collaborative systems research investigates models and algorithms to help develop autonomous systems that can work collaboratively with other systems and with humans.

Crowdsourcing and human computation research investigates methods to augment computer systems by making automated calls on human expertise to solve problems that computers alone cannot solve well.

Algorithmic game theory and computational social choice draw attention to the economic and social computing dimensions of AI, such as how systems can handle potentially misaligned incentives, including self-interested human participants or firms and the automated AI-based agents representing them.

Internet of Things (IoT) research is devoted to the idea that a wide array of devices, including appliances, vehicles, buildings and cameras, can be interconnected to collect and share their abundant sensory information to be used for intelligent purposes.

Neuromorphic computing is a set of technologies that seek to mimic biological neural networks to improve the hardware efficiency and robustness of computing systems, often replacing an older emphasis on separate modules for input/output, instruction-processing and memory.

Source: Stone *et al.* (2016, p. 9); Varian (2018, p. 2).

"Don't ask for meaning; ask for the use" Usually attributed to Wittgenstein (Philosophical Investigations)"

According to Castro and New (2016), most AI have at least one of seven functions: monitoring; discovering; predicting; interpreting; interacting with the physical environment; interacting with humans; and interacting with machines. For applications (business mostly), Chitkara *et al.* (2017b, Pwc) identify three main ways in which AI can contribute to a business:

1. Assisted intelligence amplifies the value of existing activity. For example, Google's Gmail sorts incoming emails into "Primary", "Social" and "Promotion" default tabs. Another example in the healthcare field is medical image classification.

2. Augmented intelligence enables organizations and people to do things they could not otherwise do. Assisted intelligence apps often involve computer models of complex realities that allow businesses to test decisions with less risk. One field of application is legal research, browsing through former cases. Another is guided personal budgeting.

3. Autonomous intelligence creates and deploys machines that act on their own, thereby altering the nature of the task, and modifying the business models. For example, learning algorithms are used by Netflix to suggest choices to customers, based not only on the customer's patterns of behaviour but on those of the audience at large. Tencent's messaging and social media platform WeChat, is another example (Box 6).

Chitkara *et al.* anticipate AI applications over the period 2015-2030 in the following areas: arts and communications, health care, management, mobility, personal finance and science and environment. Trajtenberg (2017, p. 2) holds that AI has the potential to become a "General Purpose Technology" (GPT) in the foreseeable future, with impact in various areas. Brynjolfsson *et al.* (2017) also argue that AI will be a GPT, focusing on machine learning.

Table I gives a broader overview of applications, beyond business. It includes the "usual suspects", always seen as promising domains for IT, like health care or education that come up with (almost) every wave of IT innovation. One finds the usual variation on "smart" applications and devices (cars, building, cities [...]) often linked to the Internet of Things and Big Data applications. Nevertheless, Stone *et al.* (2016) point out that the past fifteen years have seen considerable AI advances, albeit uneven in terms of what they call "domains". They give a much more comprehensive account, and add entertainment to the domains they cover. The past fifteen years have seen considerable AI advances, although uneven in each "domain". Without going into details, well-known examples are Google's autonomous vehicles and Tesla's semi-autonomous cars already on city streets, or on-demand transportation (Uber, Lyft [...]). In the domain of entertainment, social media platforms allowing sharing and browsing blogs, videos, photos, rely on techniques that are being developed in natural language processing, information retrieval, image processing,

Table I Artificial intelligence and life in 2030

Infrastructure	Smarter cars
	Self-driving vehicles
	Transportation planning
	Smart grids
	Smarter building
Health care	Electronic health records
	Health-care analytics
	Health-care robots
	Mobile health
	Care for the elderly
Education	Teaching robots
	Intelligent tutoring systems
	Learning analytics
Low-resource communities	Help government agencies
	Planning of food distribution
Service robots	Service robots: deliver packages; clean, enhance security
	Personal assistant robots (with features such as speech recognition)
Public safety and security	Cameras for surveillance
	Drones
	Predictive police applications (such as predicting white-collar crime)

Source: Peter Stone *et al.*, *Artificial Intelligence and Life in 2030* (Stanford, 2016); quoted by B20 Digitalization Taskforce policy paper (2017, p. 32)

crowdsourcing and machine learning. However, as noted by Hall and Pesenti (2017): "No single company's AI activity is representative. The range of business users is mixed and going to become much more mixed".

The fastest-growing category of AI appears to be machine learning[10] (Table II), i.e. the ability of software to improve its own activity by analysing interactions with the world at large (i.e. a computer learns from data sets to perform functions, instead of just executing the specific tasks it was programmed to do). Machine learning has been the key contributor to the AI surge, ranging from search and product recommendation engines, to systems for speech recognition, fraud detection and image understanding (Stone *et al.*, 2016). This technology, which has been around for quite some time, is now deemed to have made a qualitative jump over the past few years through two major waves of progress. One wave leverages deep learning to predict behaviour: for instance, whether a consumer will click on an online ad after the algorithm records some information about him. The second wave is based on remarkable advances in image classification and voice recognition (Brynjolfsson - AI Index, 2017), output no longer being numbers. Figure 1 illustrates a set of AI-enabled vertical applications and indicates the technologies and platforms that enable these applications.

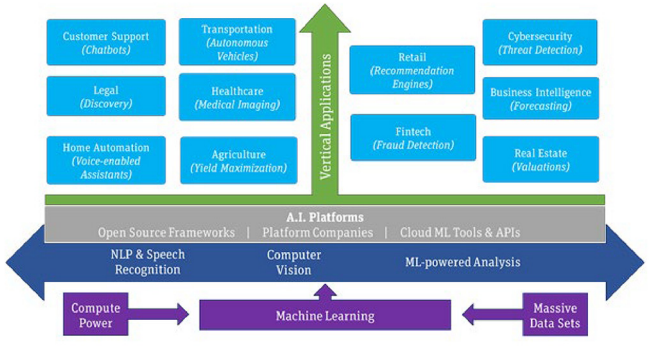
Nevertheless, one may ask whether we are experiencing another summer? or "*Is AI just hype*?" i.e. just pattern recognition with much greater computing power? (see also my introduction about the hype dimension). As stressed by Aggarwal (2018): "The current hype in AI is immensely reminiscent of what took place during the boom phase of the first AI hype cycle between 1956 and 1973".

Table II External investment in AI-focused companies by technology category in 2016

Technology category	*Amount ($bn, estimates*)*
Machine learning multiuse and nonspecific applications	5-7
Computer vision	2.5-3.5
Natural language	0.6-0.9
Autonomous vehicles	0.3-0.5
Smart robotics	0.3-0.5
Virtual agents	0.1-0.2

Notes: *Estimates consist of annual VC investment in AI-focused companies, PE investments in AI-related companies, and M&A by corporations. It includes only disclosed data available in databases and assumes that all registered deals were completed in the year of the transaction.
Source: McKinsey Global Institute (MGI, 2017a, 2017b)

Figure 1 Examples of AI-enabled applications



Source: Garza (2018)

2. Market, sectors and players

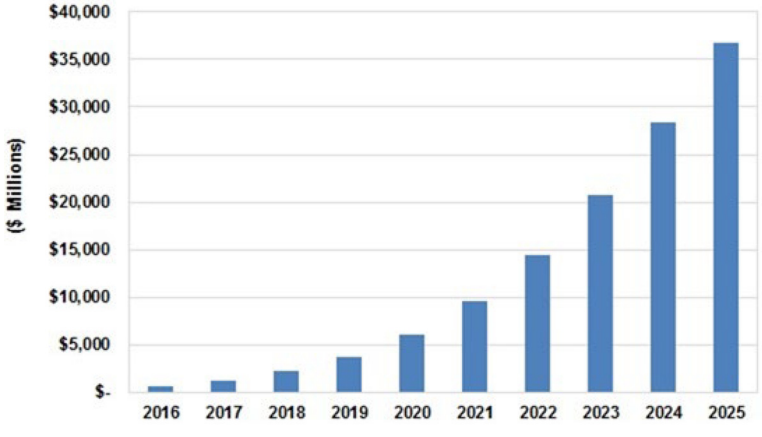
Whatever the definition of AI, these technologies have use cases and applications in almost every industry. They can therefore be expected to significantly change existing business models, while simultaneously creating new ones. Consultancies consider we may be witnessing the early phase of a dramatic increase in AI development and that as a result we should be optimistic about the growth of the market. Some believe that it would not be exaggerated to state that, in the light of current technological and market trends, AI will be absolutely necessary to help people navigate a world of big data, and market shifts that could be too rapid for people to manage. Managing the complexity of the deployment of the Internet of Things is a good example of these challenges. Or, managing data and content, as stressed by A. Bordes[11] "On Facebook, there is so much content, that it is impossible not to use AI"[12] (quoted by Tual, 2018).

In 2020, Statista estimates that market size will be $6.1bn, and IDC estimates spending will be $47bn. The market intelligence firm Tractica (2016) anticipates similar figures for 2020 (Figure 2), and that annual worldwide AI revenue will grow from $643.7m in 2016 to $36.8bn by 2025. Given the caveat about the fuzzy definition and what it really includes, one should remain cautious about these assessments of the market. Nevertheless, whatever the real scope turns out to be, it is clear that most consultancies are expecting significant growth. PricewaterhouseCoopers estimates AI deployment will add $15.7tn to global GDP by 2030 (quoted by Dutt, 2018).

As AI is perceived as a core driver for economic development by most analysts, another approach to calculating potential growth consists of estimating the impact on a range of businesses. McKinsey Global Institute (MGI, 2017a, 2017b) estimated that, by 2025, automating knowledge work with AI will generate between $5.2 and $6.77tn. Advanced robotics which rely on AI will generate between $1.7 and $4.5tn, and autonomous and semi-autonomous vehicles will generate between $0.2 and $1.9tn. By the same token, a report from Accenture (2016) which models[13] the potential impact of AI on economic growth claimed that AI has the potential to double annual economic growth rates in the countries surveyed (Figure 3) in terms of gross value added by 2035.

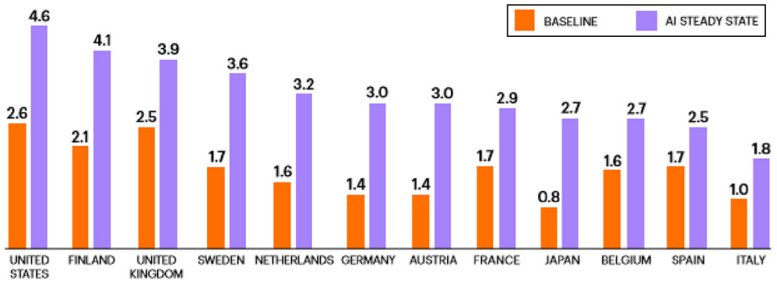
Although there is no direct mechanical relationship between investments and revenues/size of the market, the level of investment is a good indicator, at least of the expectations of the

Figure 2 Artificial Intelligence Global Revenue, 2016-2025 ($m)



Source: Tractica (2016)

Figure 3 The economic impact of AI



Source: Accenture and Frontiers Economics (2016)

companies involved. AI-related financing and M&A activity have reached unprecedented levels worldwide. Financing more than doubled between 2016 and 2017 to over $15bn (GSMA, 2018a, p. 50). A CB Insight report (2017) shows that investment in AI is surging worldwide. The report stresses that over 250 private companies using AI algorithms across different verticals have been acquired since 2012, with 37 acquisitions in the first quarter of 2017 alone. A range of start-ups is gathering funds for various applications. Globally, McKinsey estimated that companies spent in 2016 between $26 and $39bn, with tech giants spending from $20 to $30bn (with 90 per cent of this spent on R&D and deployment, and 10 per cent on AI acquisitions), start-ups invested between $6 and $9bn [McKinsey Global Institute (MGI), 2017a, 2017b]. Box 3 gives an overview of the leading AI companies in 2017, start-ups and large companies. Though rankings are subject to the approach of the ranker, it gives a glimpse of the landscape.

Box 3. The 20 top Artificial Intelligence Companies*

1. *AIBrain*

Based in California, AIBrain is an AI company that builds AI solutions for smartphones and robotics applications. It offers AICoRE, the AI agent, and iRSP, an intelligent robot software platform. This company focuses on developing AI infused with the human skill set of problem solving, learning and memory.

2. *Amazon**

3. *Anki*

Anki is dedicated to bringing consumer robotics into everyday life through its Cozmo and Anki Overdrive products. Cozmo is Anki's flagship robot. Cozmo has been described as one of the most sophisticated consumer robots to date due to its emotional responses, while Overdrive is a car racing game complete with track.

4. *Apple**

5. *Banjo*

Banjo makes use of AI to comb through social media and identify real-time events and situations that are important to its partners. The start-up was developed after the Boston Marathon bombing in 2013 as a way for companies to analyse social media to make better decisions, move faster, and change the way they understand and interact with people all over the world.

6. *CloudMinds*

CloudMinds is developing what it calls cloud intelligence-based systems for robots. CI is different from AI in that it combines machines with humans rather than treating them as separate entities. This allows the robot to be controlled by human beings.

7. *Facebook**

8. *Google**

9. *H2O*

Used by more than 100,000 data scientists at more than 10,000 organizations worldwide, H2O claims to be "the world's leading open source deep learning platform." The company's products include its H2O platform, the Deep Water interface that unites leading open source deep learning tools with H2O, the Sparkling Water framework that combines H2O and Spark, the Steam AI Engine for developers, and Driverless AI, which promises "AI to do AI".

10. *IBM*

IBM has been a leader in the field of AI since the 1950s. Watson – one of the highest profile AI projects – is a supercomputer that reveals insights from unstructured big data through machine learning and natural language processing.

11. *iCarbonX*

iCarbonX is a Chinese biotech start-up which uses AI to provide personalized health analyses and health index predictions. It has formed an alliance with seven technology companies from around the world that specialize in gathering different types of health-care data and will use algorithms to analyse genomic, physiological and behavioural data and provide customized health and medical advice.

12. *Intel*

Intel has acknowledged the importance of AI and hopes to stay ahead of the curve through backing and investing in AI technologies. In addition to numerous acquisitions, Intel has also invested in several AI start-ups, along with Microsoft.

13. *Iris AI*

Iris AI helps researchers sort through scientific work and research to find the relevant information, and as it is used, it learns how to make better searches. Since its launch, 120,000 people have tried the service, some becoming regular users.

14. *Next IT*

Next IT is one of the original companies that pioneered chatbots and has helped companies such as Alaska Airlines and Amtrak to easily interact with customers to answer and solve their problems. Their AI capabilities allow them to help organizations in a variety of industries including health care and insurance.

15. *Salesforce*

Over the past two years, Salesforce has acquired three AI companies and recently announced Salesforce Einstein, their AI service. In addition to Salesforce's own employees, Einstein will be available for customers who can build their own applications.

16. *SoundHound*

SoundHound is known for its music-identification app Hound, but it also has one of the most advanced and accurate platforms for natural language processing for doing all kinds of voice-to-text queries.

17. *Twitter*

Twitter has invested significant funds into AI. A while back Twitter introduced an algorithmic timeline that ranked tweets based on relevance instead of the usual reverse chronological order. The company has also added AI to recommend certain tweets in users' timelines.

18. *ViSenze*

ViSenze's AI technology works by recommending visually similar items to users when shopping online. ViSenze uses machine learning and computer vision algorithms, which process and analyse millions of items of visual content. It uses visual sensing to find a match for an item online and then offers filters for pricing, similarity and availability.

19. *X.ai*

X.ai's intelligent virtual assistant Amy helps users schedule meetings. Through machine learning and natural language processing, Amy schedules the best time and location for meetings based on preferences and schedule.

20. *Zebra Medical Vision*

Zebra Medical Systems is an Israeli company that applies deep learning techniques to the field of radiology. It claims it can predict multiple diseases with better-than-human accuracy by examining a huge library of medical images and a specialized examination technology. In 2016, the company introduced two new software algorithms to help predict, and even prevent, cardiovascular events such as heart attacks.

*for a presentation of the digital giants, see Box 5.

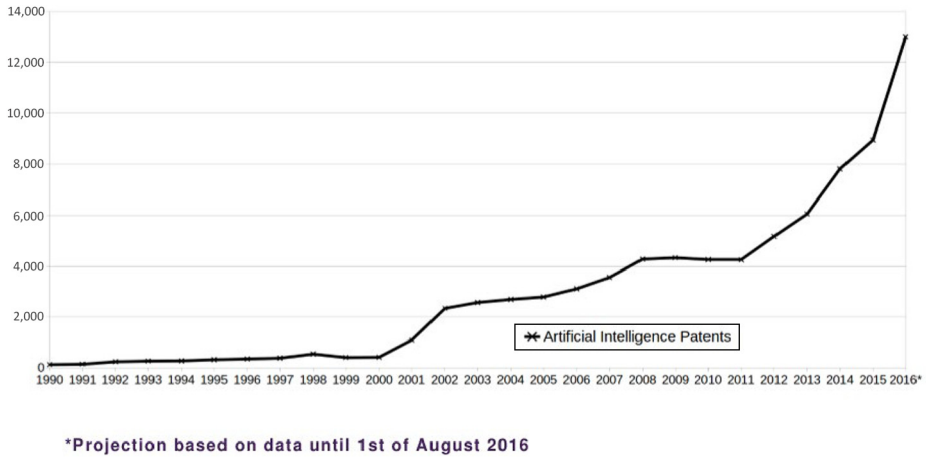
Source: Datamation (2017); Top 20 Artificial Intelligence Companies.

Corporate giants like Google, IBM, Yahoo, Intel, Apple and Salesforce are competing to acquire private AI companies, with Ford, Samsung, GE and Uber[14] emerging as new entrants. Table II shows that 56 per cent of company investment in AI is in machine learning, 28 per cent in computer vision, 7 per cent in natural language, 6 per cent in autonomous vehicles and the rest in virtual assistants (Knowledge@Wharton, 2017). Large, established companies are recruiting deep learning talent. Google is acknowledged as the leading employer of AI talent (Benaich and Hogarth, 2018, p. 61), followed by Microsoft.

Another way to gauge the potential growth of the sector is to take a look at the number of patents in the field of AI. Taking into account the lack of an accepted definition and the blurred borders between key AI technologies, one should be cautious about how patents are tracked. Nevertheless, Figure 5[15], gives a clear indication of the direction of the curve and shows the acceleration since 2011 (Figure 4).

Uptake of AI varies significantly by sector and within sectors. In the industrial sectors that seem most involved in AI already, telecom and tech companies, financial institutions and car manufacturers lead. Figure 5 indicates the sector leading in AI adoption[16]. A number of operators (Telefónica, Vodafone, Deutsche Telekom and Telenor [...]) have already

Figure 4 The global growth of AI patents (1990-2016)



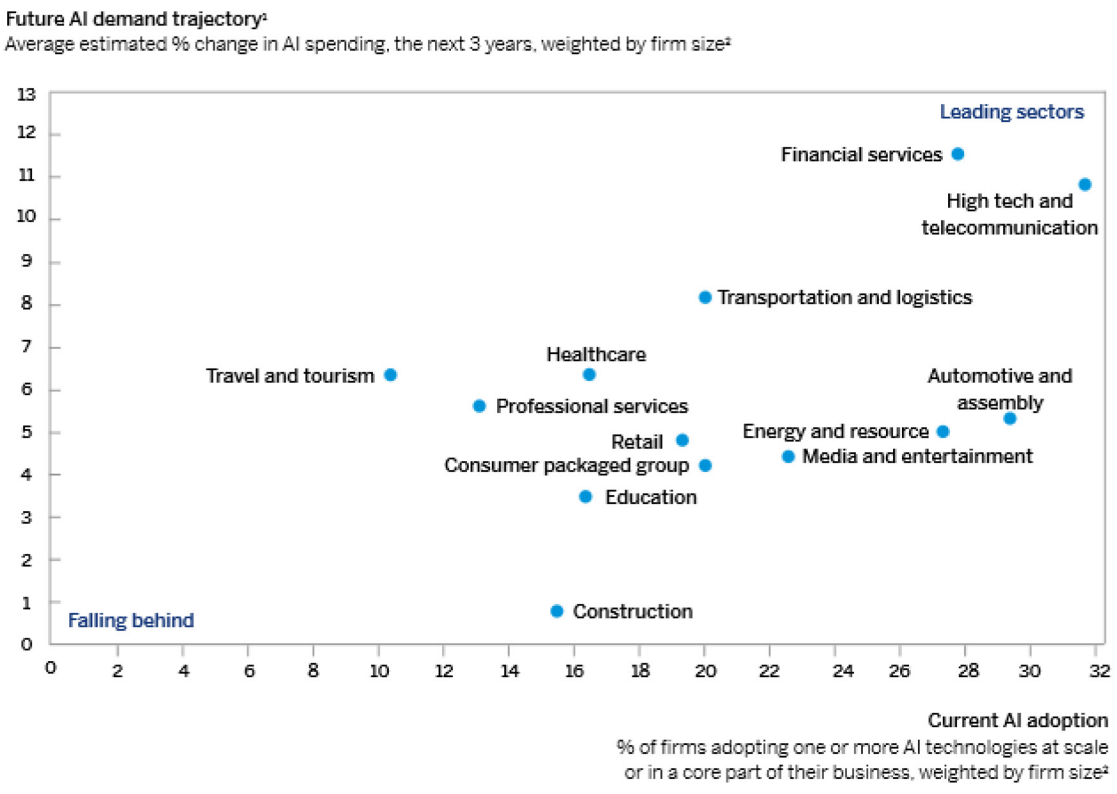
Source: Toivanen (2016)

launched chatbots or digital assistants in various guises, that differ in purpose and complexity (GSMA, 2018a, p. 51).

However, even in the case of leading companies in the telecom sector, as revealed in a late 2017 GSMA' s survey[17], released in February 2018 (GSMA, 2018b, p. 6): "AI, activity is currently confined in terms of rolling it out to the mass market". The reports note that "the complexity and potential investment burden is holding organisations back". When users were asked what uses they have planned for AI, the highest proportion (19.8 per cent) selected improving operational processes from a list that included "personalised and contextualised engagements, sentiments analysis, virtual agents such as chatbots (Box 4), adaptive customer journeys, improving operational processes, network resource allocation optimisation and customer care". A rather cautious and conservative option, for the time being. McKinsey [McKinsey Global Institute (MGI), 2017a, 2017b] acknowledges that many business leaders are uncertain about what exactly AI can do and that adoption remains in its infancy. A McKinsey (MGI, 2018a, p. 12) study reveals that two-third of the opportunities to use AI are in improving the performance of existing analytic uses cases[18]. Atkinson (2018a) points out that "despite the excitement over 'Industry 4.0' technologies, they do not appear to have been adopted on a large scale, as evidenced in part by the fact that most manufacturers appear to be in the very early adoption stages. Likewise, there is considerable excitement about machine learning software systems, but their current capabilities remain relatively limited, notwithstanding some promising early applications".

To frame it differently, there may be a discrepancy between breakthroughs in AI in the academic research community and commercial applications. Even in the promising field of machine learning, demand is rather uncertain and not only on the business side. On the consumer side, we do not know how willing consumers are to adopt for instance the much-celebrated AI-powered virtual assistants, and if they do, how they use them. For the moment, it is difficult to assume there is the pent-up demand that was experienced by the mobile industry.

Figure 5 The sectors leading in AI adoption (based on a survey of intention to grow investment)



Notes: 1. Based on the midpoint of the range selected by the survey respondent;
2. Results are weighed by firm size
Source: MGI quoted by SAP (2018, p. 9)

Box 4. Chatbots and "conversational" commerce

The rise of voice systems such as Amazon Echo and Alexa, Google Home and Apple's Siri have attracted growing attention to this way of communicating with companies. Chris Messina, the 'inventor' of the hashtag # in tweets and an ex-Uber and ex-Google employee, was the first to use the term 'conversational commerce' in 2015.

Chatbots have gained particular prominence. Facebook's announcement in April 2016 that it would open up its Messenger platform for the commercial use of chatbots was a key catalyst.

A chatbot is a computer program that simulates human conversation or chat through AI. Chatbots allow machines to interact with humans on closed domains via written text, and increasingly voice interactions too, with or without human assistance. This "conversational" user interface follows on from the graphical user interface that most people are familiar with. Using chatbots to allow companies to communicate directly with customers on messaging platforms such as Facebook Messenger, WhatsApp and WeChat has been called "conversational commerce".

Chatbots can work in two different ways:

1. Scripted chatbots deliver simple responses based on a specific command. These are effectively decision trees with only limited AI presence. These chatbots are only as good as their programming and are likely to struggle with more complex questions or situations.
2. Artificially intelligent bots can answer contextual questions by learning from previous interactions, carrying on a pseudo-conversation. These AI bots are built on the twin capabilities of natural language programming and machine learning (or more specifically, the use of neural networks that mimic the human brain).

Source: GSMA Intelligence (2017, p. 10), *Global Mobile Radar January 2017[19]*, www.ecommercewiki.org/topics/119/chatbots-conversational-commerce

Not all organizations are first adopters. As noted by SAP (2018, p. 10), early movers tend to be large businesses that are digitally mature and more focused on AI-enabled growth than just cost savings. This view is shared by Hall and Pesenti (2017, p. 30): "organisations that have good data capability (collection, retention, curation, analysis, protection) have a head-start in becoming AI-ready". It comes as no surprise therefore that most IT companies are already leaders in the field, as they are in the field of Big Data: GAFAM and BATX (Box 5) (De Prato and Simon, 2015). One of the co-founders of Google, Larry Page, worked, for his PhD on a web search research project under the supervision of T. Winograd, a leading scientist on AI, at Stanford University. Here, Larry Page met the other co-founder Sergey Brin. As noted by McKinsey Global Institute (MGI) (2017a, 2017b), "digital native companies made some of the most significant and earliest investment in AI, providing test cases for potential return on investments in AI". Major players have formed the Partnership on AI (PAI) in 2016. The entity today counts 80 members including Amazon, Facebook, Google, IBM, Intel, Microsoft and Sony (see Box 5).

Box 5. The Partnership on AI (PAI)

The "Partnership on Artificial Intelligence to Benefit People and Society" (Partnership on AI) is a multistakeholder organization that brings together academics, researchers, civil society organizations, companies building and using AI technology, and other groups working to better understand AI's impacts. The Partnership was established to study and formulate best practices on AI technologies, to advance the public's understanding of AI and to serve as an open platform for discussion and engagement about AI and its influences on people and society.

The Partnership on AI intends to conduct research, organize discussions, share insights, provide thought leadership, consult with relevant third parties, respond to questions from the public and media and create educational material that advances the understanding of AI technologies including machine perception, learning and automated reasoning.

Source: www.partnershiponai.org/about/#!

Box 6. Digital giants[20] and AI

Alibaba

The company has already launched commercial products which use AI, such as FashionAI. AI is used to boost sales. Shoppers can upload pictures of a product, for example a trendy handbag which they have seen worn in the street and would like to buy to its Taobao e-commerce site. The website will then come up with handbags for sale that come closest to the photo. Alibaba also uses augmented reality/virtual reality to make people see and shop from stores like Costco. On its Youku video site, Alibaba is working on a way to insert virtual 3D objects into people's uploaded videos. Alibaba plans to spend $15bn on R&D into "foundational and disruptive technology", including areas such as big data and AI.

Amazon

In 2014, Amazon, a pioneer of voice user interface, introduced Echo, a line of voice-activated "smart speakers". Alexa, Echo's intelligent voice responder in the Cloud has been endowed with an ever-increasing range of skills, i.e. response modules proposed to users, a move backed by third-party developers. Alexa has been integrated into cars, fridges, watches and purifiers by some 50 leading brands. Amazon's Machine Learning platform provides companies with the ability to predict and find patterns using data.

Apple

Apple is integrating AI seamlessly into its devices. Siri, Apple's virtual assistant introduced in 2011, has evolved over the years from a fairly simple voice assistant to a fully fledged digital assistant. Similar to Amazon's Skills Guide, Apple's provides a neat Siri on-boarding site, a clean and well-lit place where users new and old can try out a range of possibilities. Apple is working on a processor (the chip is known internally as the Apple Neural Engine) devoted specifically to AI-related tasks.

Baidu

China's leading search company, Baidu, has had an AI-focused lab for some time, and it is reaping the rewards of improvements in technologies such as voice recognition and natural language processing, and also better-optimized advertising business. Baidu's 1,300-person AI team achieved impressive results, developing better-than-human speech recognition software a year before Western companies. Baidu has also built up a well-respected machine-learning cloud-infrastructure team. In addition, it already offers a range of AI-powered services (Baidu Brain), and a voice assistant platform (DuerOS). It is also involved in autonomous vehicles and set up a $200m fund to promote autonomous driving in South-East Asia.

Facebook

The company focuses on language problems like question answering, dynamic memory and Turing-test-type matters and has developed image recognition apps such as Facebook Picture Search. Yann LeCun[21], Professor at the university of New York (NYU), was hired to chair FAIR (« Facebook Artificial Intelligence Research »), the company's applied machine learning division in 2012. He was also appointed as chief scientist of the new lab in Paris. Early 2018, the company announced it will invest €10m into its Paris facility. It will also open community skills hubs in Spain, Poland and Italy. Facebook is targeting AI to further improve user engagement through the integration of AI-based solutions in services.

Google

Their main research focus is on machine learning which helps advance Google's language, speech translation, visual processing, ranking and prediction capabilities. Email software like Google's Smart Reply can draft messages to respondents based on previous responses to similar messages. Andrew Ng, co-founder of Coursera and an adjunct professor at Stanford who founded the Google Brain Deep Learning Project, had previously headed Baidu's lab. Google was one of the first company to involve users to improve machine learning. Googleplans to open a new AI research centre in France and open four new Google Hubs around the country offering digital skills training. Google started an Artificial Intelligence Research Centre in China.

Tencent

Tencent's messaging and social media platform WeChat has close to 800 million daily active users, most of them in China. The program, which was designed primarily for use on smartphones, offers relatively sophisticated voice recognition, Chinese-to-English language translation, facial recognition (it also suggests celebrities who look like the person holding the phone) and virtual bot friends that can play guessing games. Tencent opened an AI lab in 2016 with 30 researchers. Tencent has been using chatbots (referred to as "public accounts") for several years, ahead of Facebook. It has increased its focus on AI recently and has set up a research lab in Seattle. It has announced plans to invest $15bn over the next three years in AI-related technologies. The company has already launched AI cloud services for the healthcare and manufacturing industries. In May 2017, Tencent launched its Xiaowei virtual assistant.

Xiaomi

The company considers AI technology is a core part of its strategy. Its AI MAU exceeded 30 million, and its AI speaker has accumulated over 2 billion activations within the first year of its launch. In June 2018, the company announced that its Mobile AI Compute Engine ("MACE"), a prediction framework for a deep learning model optimized for mobile devices, would become a fully open source platform. Using MACE, developers can develop AI applications on mobile devices and enhance the user experience of these applications. At present, application scenarios covered by MACE include scene recognition, image super-resolution, image stylization processing, intelligent speech, intelligent translation, etc.

Source: Compiled by author

3. The global distribution of companies

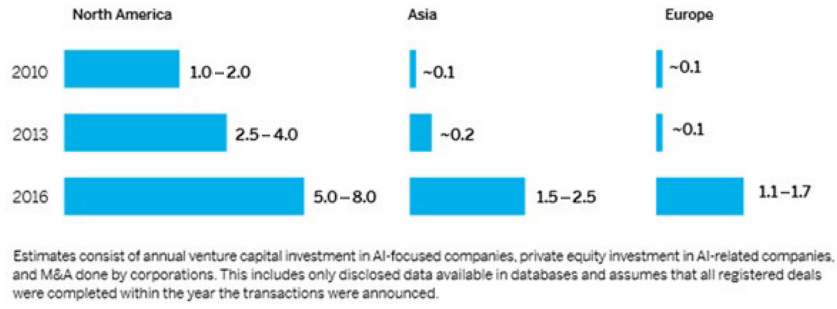
A look at investment from a regional perspective shows that it is dominated by the USA. Figure 6 illustrates the size and growth of investment in AI in Asia, North America and Europe. In Europe, pretty flat investment over the period 2010-2013 gives way to some growth in 2016.

The same pattern appears if one looks at the number of AI companies (Figure 7) and the number of patents in the AI field (Figure 8). The curve is again flat for Europe.

The UK and other EU countries are generally seen as lagging behind the USA and China in terms of scale of AI investment, see VC fundraisings[22] in Table III. This table also reveals the significant gap between the leading countries (USA and China) and the other countries. However, China only overtook the UK in 2014, though VC fundraising appears to have increased strongly in the UK in 2015, The "DeepMind" effect?

Indeed, for now at least, the US appears to be leading the revolution, but China is catching up very quickly as shown by the CB Insights yearly survey of the top 100 AI companies[23].

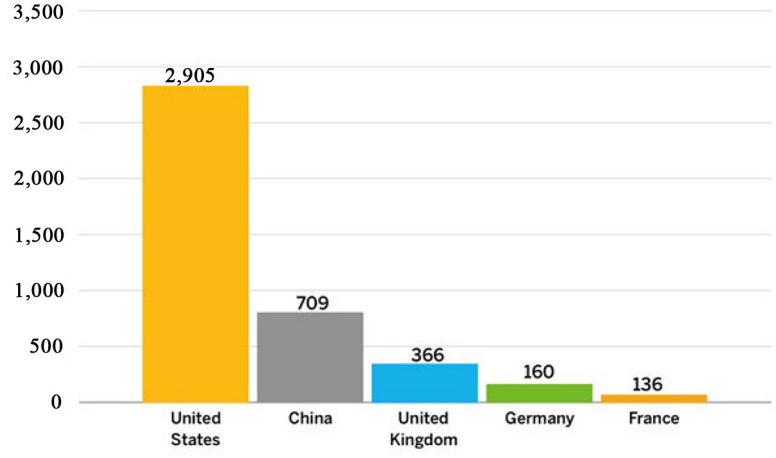
Figure 6 Regional investment in AI (2010-2016)



Estimates consist of annual venture capital investment in AI-focused companies, private equity investment in AI-related companies, and M&A done by corporations. This includes only disclosed data available in databases and assumes that all registered deals were completed within the year the transactions were announced.

Source: McKinsey Global Institute (MGI, 2017a, 2017b)

Figure 7 Number of AI companies (2016)

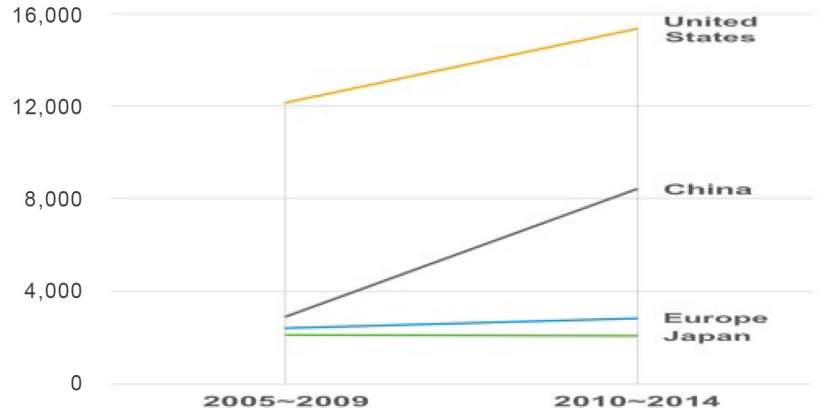


Source: Wuzhen Institute, Global Artificial Intelligence (AI) Development Report, 2017. Quoted by SAP (2018)

The CB Insights, 2017 survey revealed the dominance of US firms by looking at the 2017 sample of start-ups (CB Insights, 2017). Outside the US, companies are scattered. Within the EU, one finds three companies in the UK (one in fintech – Darkrace, two in health care – Babylon Health and Benevolent AI) and one in France (in vision – Chronocam). The 2018 edition of the CB Insights (2018) survey displays a similar pattern with 76 per cent of start-ups coming from the USA. The number of start-ups from China went from 3 in 2017 to 8 in 2018, five of which were already "unicorns".

The last "Global Artificial Intelligence Landscape" report (Asgard-Roland Berger, 2018) confirms that the USA is the clear world market leader for AI (Figure 9). Looking at individual countries, the USA leads the AI ecosystem, with 1,393 start-ups – 40 percent of the total number of AI start-ups worldwide. China comes in second place, with 383 start-ups (11 percent of the total worldwide) and Israel in third place, with 362 start-ups (10 per cent). If Europe is taken as a whole, however, it easily pushes China out of second place, with 769 AI start-ups (22 per cent of the total worldwide). But no individual European Union Member State achieves critical mass.

Figure 8 Number of AI patent applications across regions (2005-2014)



Source: "China AI Patent Submissions Shoot Up", Nikkei Asian Review 2017. Quoted by SAP (2018)

Table III AI value of VC fundraisings among international competitors, 2010-2016 (£m)

Country	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*Total*
USA	112	171	228	399	843	1,503	1,578	4,833
China	6		1	15	55	124	199	401
UK	6	9	24	18	19	67	152	294
Canada	3	17	11	4	2	23	11	71
Germany	3	8	8	0	0	7	9	36
France	3	1		1	1	9	15	31
Total	132	206	272	438	920	1,733	1,964	5,666

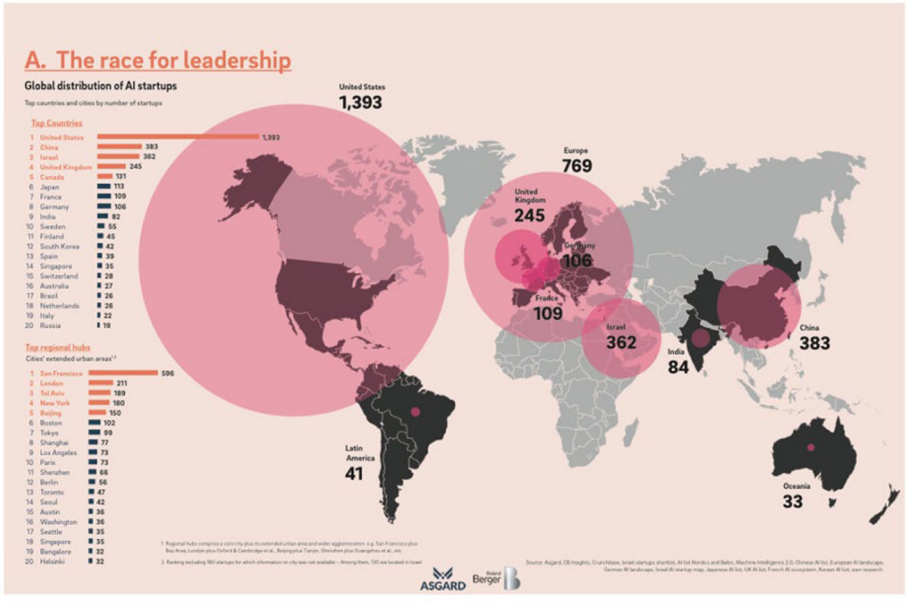
Source: Hall and Pesenti (2017, p. 39)

McKinsey Global Institute (MGI) (2017a, 2017b) concludes that, with the USA and China leading, Europe is falling behind. The SAP report is a bit more optimistic, stressing that when it comes to the B2B market for AI and the intelligent enterprise, Europe may have a much better position. Many European enterprises, both large and small, are world leaders. There are start-up hubs in Paris, London, and Berlin focusing intensively on AI. The report also adds that relevant policies may be required to reap the full benefit of some of these competitive advantages.

The German VC company Asgard (a VC specialized in AI) came up with some figures that back SAP¨s more optimistic views. The company has created a database of over 600 European AI start-ups as of 2017. Their data reveal (Westerheide and Holdhus, 2017) that though, on a global scale, North America has the most AI companies (921), Europe (632) is ahead of Asia (258)[24]. They find that Silicon Valley is the strongest AI hub (with over 400 companies), but that it is followed by London, Paris and then Berlin. Germany hosts the Research Center for AI (DFKI - founded in 1988) which is one of the world's largest AI labs, with nearly 500 researchers.

The 2016 Atomico/Slush report[25] is even more optimistic, and considers that Europe[26] is going through a "renaissance" of deep technology capacity and innovation. Since 2011, the number of "deep tech" startups founded in Europe has grown by a factor 3.5. Nearly $2.3bn has been invested in deep tech in Europe since 2015 compared to the $1.7bn that

Figure 9 AI the race for leadership (2018)



Source: Asgard-Roland Berger (2018a)

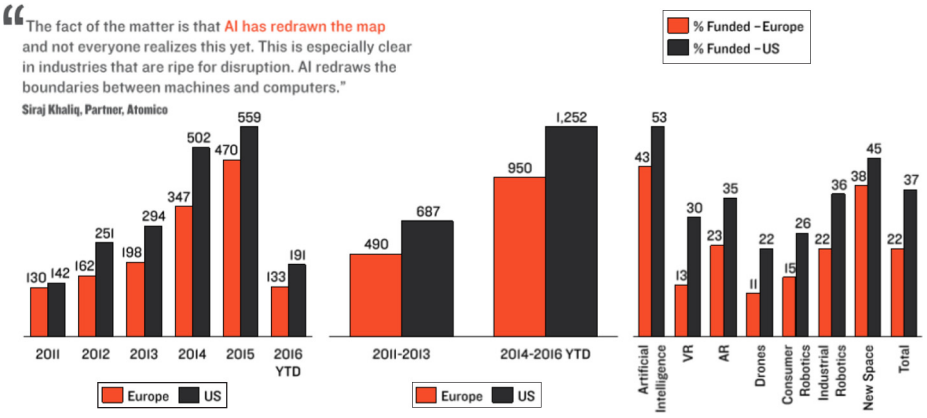
was invested between 2011 and 2014. According to the same report, Europe now has a vibrant deep-tech start-up ecosystem (Atomico/Slush, 2016, p. 70), where AI has contributed "to redrawing the map" (Figure 10). Under "deep tech", the consulting firm lists the following categories:

- *AI*: AI, machine learning, speech recognition, data mining, Big Data, deep learning, NLP, computer vision.
- *Internet of Things*: wearables, smart home and smart city.
- *Virtual reality and Augmented Reality*[27]: virtual reality, augmented reality and 3D technology.
- *Frontier hardware*: drone, robotics, radar, 3D printing, nanosatellites and new spaces.

While acknowledging that Europe is lagging behind in terms of private investments, the 2018 EC Communication on AI (2018, p. 5) stresses that Europe is, nevertheless, home to a world-leading AI research community, as well as innovative entrepreneurs and deep-tech start-ups. Indeed, through an analysis of around 35,000 players in the period 2009-2018[28], a 2018 JRC report shows that "the EU is among the geographical areas with the highest number of players active in AI, just behind the USA and just ahead of China" (Craglia, 2018, p. 31). By the same token, the Atomico/Slush 2018 report also stresses that Europe was a research powerhouse, with a research community larger than USA and China.

Atomico/Slush holds that "Paris is starting to seriously challenge London and Berlin in terms of the number of VC-financed deals and deal volume" (2016). The same report indicates that Paris indeed ranks second, behind London for AI skills[29]. In addition, France ranks third behind China and the US for scientific publication in the field (Ezratty, 2018). The Villani report (2018) claims: "France plays a decisive role in AI research: French researchers have

Figure 10 Europe: a vibrant growing "deep-tech" startup ecosystem (2011-2016*)



Note: *2016 YTD based on nine months to September 2016
Source: Atomico/Slush, (2016, p. 70)

been involved in a major breakthrough in AI and French schools of mathematics and information technology enjoy international acclaim" (Villani[30] Mission Villani sur l'intelligence artificielle, 2018, p. 6). For instance, like the DFKI in Germany, Inria (Institut National de Recherche en Informatique et Automatique) with 2,600 employees (from 102 different countries) is a leading research centre, active in all the AI scientific areas, that runs numerous research projects (INRIA, 2016).

The UK is generally considered as a leader or co-leader in the field of AI, and is still regarded as a centre of expertise in research and application of AI. The pioneering British computer scientist Alan Turing is widely credited with launching and inspiring much of the development of AI (Box 1, Hall and Pesenti, 2017, p. 19). In 2015, the Alan Turing Institute was created as the national institute for data science, building on former research and achievements. Hall & Pesenti state that the UK has produced a number of very innovative AI companies. The UK has a strong history of leadership in machine learning with some of the leading start-ups, like DeepMind. The UK and France published their AI strategies in 2017 and 2018 (Hall and Pesenti, 2017; France Intelligence Artificielle, 2017a, 2017b; Mission Villani sur l'intelligence artificielle, 2018; Simon, 2018a, 2018b).

4. Conclusion

Even though most of the consulting firms we reviewed seem optimistic about future developments of AI, the range of applications, and the growth of the market; they remain cautious about the pace of the potential changes. They note that businesses are either reluctant to invest in these technologies, or they are rather careful in their approach. Fully fledged deployment may therefore take some time. On both business and consumer sides, demand appears uncertain. The scope of the announced disruption is not easy to assess.

Atkinson, broadly optimistic about the potential benefits of AI (see his report for the European Investment Bank, 2018a) expects that technological innovation associated with ICT and AI will be initially modest. However, innovation will be progressive, as improvements to technology will develop relatively slowly, "enabling an uptick in productivity" (Atkinson, 2018b, p. 103). He is clearly sceptical about the idea that the future pace of change will be unprecedented. From another angle, Brynjolfsson *et al.*, 2017, p. 19) claim that "like other general purpose technologies, their full effects won't be realized until waves of complementary innovations are developed and implemented". A view shared by

Tuomi (2018): "The transformative impact of general purpose technologies, like AI, however, becomes visible only gradually, when societies and economies reinvent themselves as users of new technologies".

Education (new skills will be needed) and building a workforce equipped for a new technological age are among the obvious issues, and have been clearly identified as such. The EU may not be lagging behind as much as some of the reports we presented may claim: the EU has been a stronghold for research on AI the beginning of AI. However, knowledge transfer is essential for industrial strategies. Policy makers have acknowledged that this issue is an endemic problem in the EU. For instance in France, to quote the Villani report: "the country's scientific progress does not always translate into concrete industrial and economic applications" and there has been "poor performance in terms knowledge transfer to industry, whether to start-ups or multinationals" (MVFR, 2018, p. 62). This holds for other EU member states and may lead to a brain drain as leading companies, as we have seen, hire the talents they need. Indeed talent and capital will remain a challenge as competition for talent and investment is now global.

Heralds of gloom and the new "technology enthusiasts" may share the belief in the drastic impact of the technologies, whether good or bad[31]. Both envision a not-too-distant future in which AI will displace most human occupations. However as highlighted by Trajenberg, "ever since the dawn of the Industrial Revolution in the late eighteenth century, both the pessimists and the enthusiasts" have almost invariably proven wrong "(quoting Mokyr, 2017, p. 1). Some of the perceived threats or hopes may be misplaced. There are nonetheless challenges, barriers and constraints to be faced by policymakers, who must manage the transition. As Mokyr (2017) pointed out, "*transitions will not be painless and they never were*. One can agree with the French OPECST[32] report which considers that most of the over-mediated threat, linked to advent of super-intelligence for instance, is sheer fantasy. As Atkinson bluntly sums up: "[. . .] there is about as much chance of AGI emerging in the next century as the earth being destroyed by an asteroid" (Atkinson, 2018b, p. 106). The OPECST report stresses: "This is a period of polarized opinions, both excessive anxieties, as well as excessive hopes: the cycles of hopes and disappointments that mark the history of AI invite us to be cautious and to demonstrate realistic expectations of these technologies" (OPECST, 2017). This does not means there are no threats, as noted by a recent report on the malicious use of AI, (and indeed with any general purpose technology): "Across all plausible outcomes, we anticipate that attempts to use AI maliciously will increase alongside the increase in the use of AI across society more generally" (The Malicious Use of AI; 2018, p. 61). However, as noted some three decades ago, by a UK pioneer in the field, Boden (1987), in the first issue of the newly-created journal "Artificial Intelligence and Society", "It is quite clear that various very nasty things could happen, but that obviously applies to every advance in science and technology, and it is not specific to AI".

This paper does not deal with social or legal issues. Instead, it is a more modest attempt to marshal more elements about the phenomenon and to better define its scope. Ethical and societal questions are beyond the scope of this paper. However, this does not mean that the ELSE (Ethical, Legal, Socio-Economic) aspects can be easily ignored, quite the opposite. They may turn into major barriers to the deployment of AI technologies, or usher in the wrong policies. Some dimensions of AI may be more "meaningful" than others from a societal viewpoint (OPECST, 2017; Mission Villani, 2018). Trust and public confidence are still issues, as AI remains subject to constraints of social acceptability. Inclusiveness is also an issue: how can we ensure that the benefits can be evenly distributed across society is a relevant question that this paper does not address. Or how can we help regions and individuals at risk from "technology disruption", as Atkinson puts it. Ethical concerns are legitimate but overestimating their importance, which the French strategy seems to be doing (as does the EC Communication to a lesser extent) [European Commission (EC), 2018, p. 13] is not without risk. The EU may become an "island of ethics" competing with

regions that are "less" concerned, illustrated by China's very dynamic and aggressive strategy of China to achieve industrial leadership[33]. However, there is a growing body of research on the ethics of AI, an array of reports has been released in 2018 with some recommendations to mitigate the tension between an ethical approach and a "business as usual" approach [European Group on Ethics in Science and New Technologies (2018), House of Lords Artificial Intelligence Committee (2018); McKinsey Global Institute, 2018b; AI4People (2018), Microsoft (2018) on health care, PAI (2016)].

Of a range of policy issues, security and privacy already receive a lot of attention and data ownership, data access, differential pricing, returns to scale and algorithmic collusion among others are coming to the fore. Policymakers will face difficult choices when looking for a balance between promoting innovation and the regulation some of their constituents may demand for example, the regulation of robotics pushed by a European Parliament (EP, 2017a, 2017b) report. It is interesting to note that the issue of the regulation of robots and of their "rights" was addressed as early as 2006, by a British Government Office of Science and Innovation report[34]. In addition, encouraging the development of a variety of complementary innovations to fully benefit from AI will require a lot of fine tuning of different policies, the goals of which may conflict with one another.

Notes

1. The Stanford report is part of long-term investigation of the field of Artificial Intelligence, the "One Hundred Year Study on Artificial Intelligence", launched in the fall of 2014.
2. The company was acquired by Google, in 2014, for US$500m.
3. According to legend, the Chinese Emperor Yao 堯 (2356-2255 BC) designed Go for his wayward playboy son, Danzhu 丹朱, to instil in him discipline, concentration and balance.
4. From an anecdotal viewpoint, as the 2016 incident gave Korea a big shock and supposedly triggered the South Korean Government's AI strategy.
5. Minsky was hired as an adviser on Kubricks's "*2001: A Space* Odyssey".
6. The Stone *et al.* (2016) is the only report we reviewed that mentioned AI and games: "*Computer vision and AI planning, for example, drive the video games*".
7. Robots can also use software and algorithms (including artificial intelligence) to interpret the data collected and to control their movement. See UN (2017b), *Next Generation Robotics*.
8. Co-founder of "Vicarious" a start-up that aims to close the gap by developing human-level intelligence in robots.
9. CapGemini (2017) breaks down AI key technologies into nine categories. One can also find another keywords hierarchy in the 2016 Inria White Paper (2016, p. 17).
10. An interesting presentation of machine learning can be found in the Royal Society Report, "Machine learning: the power and promise of computers that learn by example", (2017: pp. 16-30).
11. Director of the Facebook AI lab, FAIR, in Paris.
12. My translation.
13. The model is explained in an Appendix [. . .] but without much detail.
14. Opened a "Geometric Intelligence" Lab in 2016.
15. The author gives some indication of its methodology: 7 million USPTO patents text mined for "artificial intelligence", "learning algorithm", "machine learning", "unsupervised learning", "neural network", "self organizing map", "selforganizing feature map", "kohonen map" in patent full text. All records not classified in IPC main category "H" or "G" removed.
16. One can find similar results in Tata Consultancy Services (2017a, 2017b) "Getting Smarter by the Sector: How 13 Industries Use Artificial Intelligence."
17. Surveying more than 500 respondents about the Internet of Things (IoT), 5G mobile networks, artificial intelligence, augmented and virtual reality, virtualisation and automation.

18. For a more comprehensive overview of use cases see Box 2:"Our AI use cases" p. 7) Mc Kinsey collated and analysed more than 400 use cases across 19 industries and nine business functions for this research.
19. Chapter 6 of the report deals with "robotics": pp. 42-52. See also Chap. 5 « Renewed momentum in the smart home: an early AI battleground" of the Global Mobile Radar January 2016 report: pp.31-38.
20. The digital natives have been hiring the leading scientists in the field: Yann LeCun (Facebook), Andrew Ng (Baidu, Google), Geoffrey Hinton and Fei Fei Li (Google), Vladimir Vapnik and Rob Fergus (Facebook), Nando de Freitas (Google), Zoubin Ghahramani (Uber), Yoshua Bengio (Intel).
21. LeCun is one of the co-founder of the research on deep learning. In 2016 he was appointed as chair of « Informatique et sciences numériques » at the Collège de France. See "L'apprentissage profond: une révolution en intelligence artificielle", www.college-de-france.fr/site/yann-lecun/inaugural-lecture-2016-02-04-18h00.htm
22. VC only, this differs from Figure 6, data includes private equity investment and M&A.
23. Based on submissions (several thousand) from companies the ranking introduces several criteria and uses a data-driven/algorithmic process.
24. As for the methodology, the paper just indicates that the list was based on internal research mainly deriving from the company network and Crunchbase.
25. Based on a survey of 1,550 respondents.
26. Europe not the EU, the report takes a broader geographic view.
27. *Augmented reality* is a view of the real world environment whose elements are supplemented and enhanced by computer-generated sensory input such as sound, video or graphics. *Virtual reality* is an immersive multimedia or computer simulated environment which allows to interact with it. **Source**: Cisco (2017).
28. Of which 16,000 were involved in at least one research or innovation activity, and 19,000 are players engaged solely in industrial activities.
29. The AI skillset is based on any of the following skills: AI, machine learning, computer vision, deep learning, neural networks and natural language processing (NLP). Survey of the cities with the highest amount of LinkedIn members, based on a very specific methodology and restricted to LinkedIn members. Based on this LinkedIn calculated the total number of members holding each of the identified skills in each city.
30. Member of the French Parliament appointed as head of the "mission AI" in 2017, director of the Institut Henri Poincaré (UPMC/CNRS), he was awarded a Field medal in 2010. http://cedricvillani.org/
31. One will find some interesting views around such a debate and particularly on robots, in the 2017 MIT edition of Mary Shelley's Frankenstein. The original 1818 text of Mary Shelley's classic novel, with annotations and essays highlighting its scientific, ethical and cautionary aspects: *Frankenstein Annotated for Scientists, Engineers and Creators of All Kinds* (Guston *et al.*, 2017).
32. It is the French equivalent of the US Office of Technology Assessment (OTA), an office of the United States Congress. It was also used as a model for the European Parliamentary Technology Assessment (EPTA) network created in 1990.
33. For a critical view of "privacy-invading power of algorithmic authoritarianism" see Benaim and Russon Gillman (2018), see also Allen & Kania (2018).
34. Available at: www.gov.uk/government/organisations/government-office-for-science. It also triggered similar debates, see the comments of Sennett (2008: "Sublime tools", pp. 205-209.
35. It triggered sharp criticism from philosophers, like the critique of cognitivism by Hubert Dreyfus, in the 1970s, who in turn influenced some of the research being done.

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Appendix. An archaeology of AI: the quest for mechanical life

The notion of AI can be tracked to antiquity, to Hero of Alexandria (or Heron of Alexandria; 10 AD – c. 70 AD), a mathematician and engineer who wrote:

Pneumatica: a description of machines working on air, steam or water pressure, including the hydraulis or water organ;

Automata: a description of machines which enable wonders in temples by mechanical or pneumatical means (e.g. automatic opening or closing of temple doors, statues that pour wine, etc.).

Centuries later, the eighteenth century was the golden age of "philosophical" toys, the century of automats, linked to the progress of clock-making and a bio-mechanical view of human beings, influenced for instance by Bacon, Descartes or Hobbes (man as an automat in the first chapters of "Leviathan"). Descartes proposed that bodies of animals are nothing more than complex machines. The biological conception of cybernetics in the 1950s was not too far from this notion[35].

In 1748, French philosopher La Mettrie, released "L'Homme Machine". The eighteenth-century mechanic, Jacques de Vaucanson, made 'robots' that were capable of playing musical instruments as melodiously as human beings. The most famous one, "The Digesting Duck", was an automaton in the form of an incontinent duck. Von Kempelen's phony mechanical chess player, "The Turk" (1769) was another notorious toy. The famous scene in Fellini's "Casanova" when Casanova is fascinated (among other things) by a dancing automated woman doll illustrates the climate of this period.

A century later, Count's Dunin Man of Steel, an expanding mannequin of 7,000 pieces, was one of the main attractions of the Great Exhibition of 1851, at the Crystal Palace in London.

Source: AntanPresent, BCU Lausanne (2009), Buchanan (2005), Guillot (2018), Jaffe (2012), Stockman Mania (http://stockman.canalblog.com/archives/2011/01/22/20192447.html), Wikipedia; Wood (2002).

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