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Artificial Intelligence and Automation in the UK

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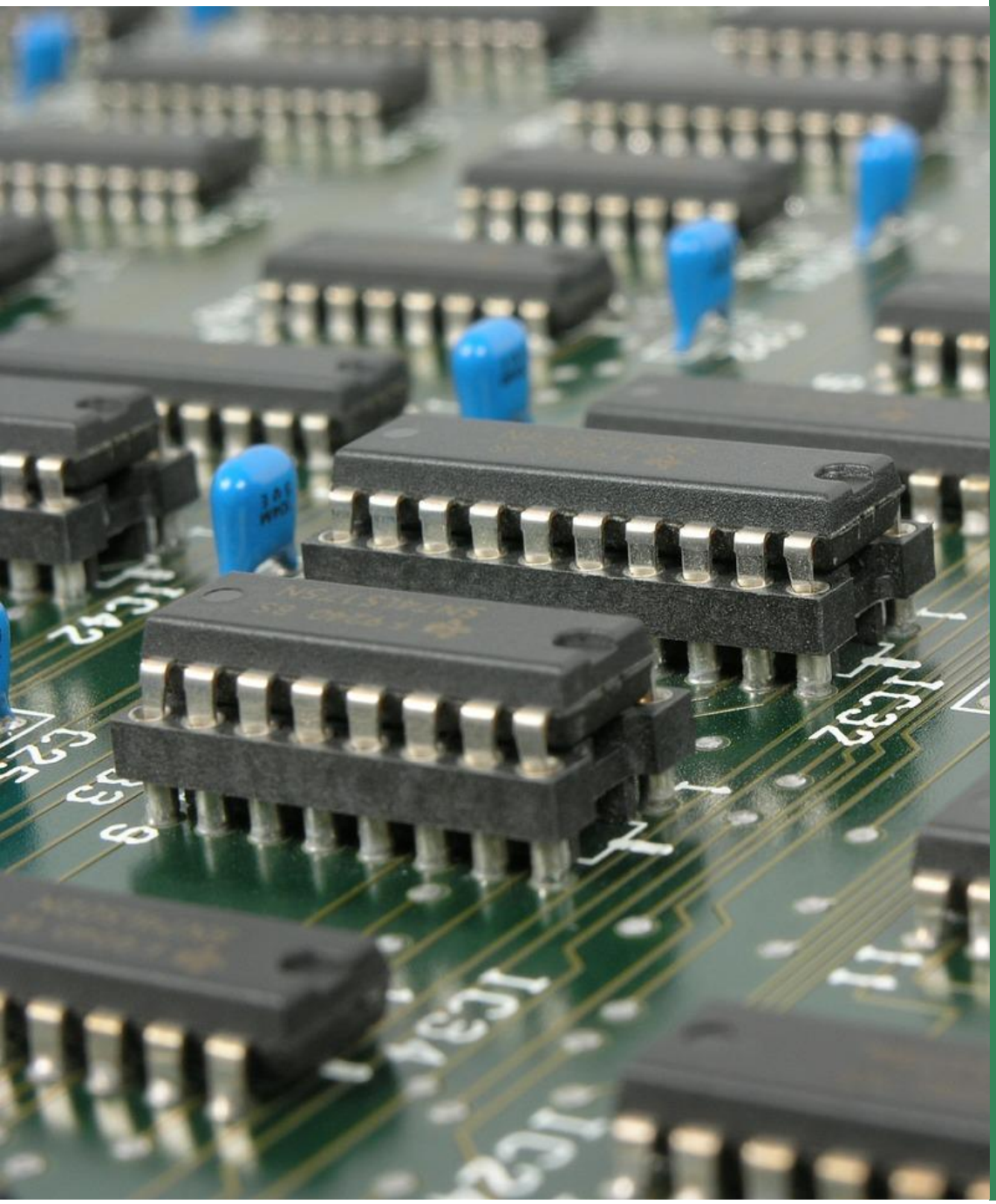

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What is AI?

Artificial intelligence (AI) is widely predicted to have a considerable impact in the coming years and decades on individuals, businesses and the economy. Whilst there is no universal definition of AI, it can be considered as an evolving set of technologies that enable computers to simulate elements of human behaviour such as learning, reasoning and classification, by analysing data to model some aspect of the world and predict and anticipate possible future events.

Uses of AI

AI is already in use today for applications as broad as product recommendation in e-commerce, virtual assistants such as Alexa, identifying documents relevant to a particular legal case, automated writing of newspaper articles or automated trading software. In the future its applications may be even broader, from autonomous vehicles and virtual teaching assistants to utilising data for decision making in Government or healthcare.

Government Policy, Skills and Research

Increasing digital skills and providing funding for research into AI are key issues for the future growth of the industry and for future employment needs. Numerous reports have highlighted skills developments, most recently a review for the Government on growing the AI industry.

The Autumn 2017 Budget and November 2017 Industrial Strategy announced funding for AI and a 'sector deal' for the industry.

How might AI and Automation impact the economy and the workforce?

This briefing covers the impact of AI and automation on the workforce. Debate on AI often leads to discussion of its impact on the economy and individuals – particularly how working lives may change. AI is thought to be an area that will lead to economic and productivity growth as well as the creation of new and different jobs (for example in the Industrial Strategy).

There are a broad range of predictions for how AI and automation may affect the workforce in the coming years and decades, and predictions are difficult to make due to uncertainties in a number of factors such as the rate of technological development and rate of deployment and the variations by country, region and sector. The impact is likely to be significant, however, with the Bank of England reportedly predicting that up to 15 million jobs in the UK could be at risk of automation over the coming 10-20 years (but note this is not a net change – jobs created due to automation are not taken into account, and technological developments often change the type of jobs rather than the total number available). Effects are likely to be felt across a range of sectors and levels of education.

Other Challenges

There are a range of concerns and issues with AI above and beyond those regarding employment, including around the management of data, the verification of different forms of AI and establishing accountability for decisions based on AI.

1. Introduction

Artificial intelligence (AI) refers to a rapidly developing set of technologies widely predicted to have a considerable impact in the coming years and decades on individuals, businesses and the economy. One significant area of predicted impact is employment – with predictions of changing employment and skills demands from employers. AI also has significant potential to bring tangible benefits to the UK economy through new businesses and jobs, whilst also posing a challenge to some existing business models. It is likely that policy decisions and scientific research undertaken now will influence the UK's future role on the global AI stage. The UK is currently considered by many as a world leader in the development of AI,[1] and further research presents opportunities for new businesses and the training of the next generation of researchers and operators of AI. There are also a range of concerns around the development of AI, including around the use of personal data and the transparency of decisions made using AI.

The Department for Digital, Culture, Media & Sport (DCMS) holds primary responsibility for AI policy, with the Department for Business, Energy and Industrial Strategy (BEIS) also playing a leading role, although there are implications across Government.[2]

The Industrial Strategy, published by the Government in November 2017, set out "growing the Artificial Intelligence and data driven economy" as one of the four "grand challenges" facing the UK and for the UK to take advantage of. It expects that "Embedding AI across the UK will create thousands of good quality jobs and drive economic growth."[3] The Autumn Budget 2017 announced new funding for AI and the Industrial Strategy announced an 'Artificial Intelligence Sector Deal'.

AI is frequently in the news, usually reflecting either new technologies, the potential for economic development or the dangers it poses to employment.[4] The rapid developments in AI over the past decade have begun to raise a number of important social, economic and ethical issues, as well as highlighting the potential positive impacts of the technology. This section explains what AI is and how it is used. **Section 2** discusses the likely changing skills and education requirements of the public and private sectors, and details government support for the development of AI. **Section 3** discusses the potential impacts of AI on the workforce. In **Section 4**, some of the concerns and issues with AI are introduced – highlighting why these are important considerations and what their potential impacts may be.

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1 "Machine learning: the power and promise of computers that learn by example". The Royal Society. April 2017 and "Why Britain's homegrown AI talent leads the world", *Financial Times*, 5 May 2017

2 PQ 71070 [on Artificial Intelligence] 24 April 2017

3 BEIS, "Industrial Strategy: the Grand Challenges", 27 November 2017

4 See, for example, the Artificial Intelligence and Robotics section of the Financial Times.

1.1 What Is Artificial Intelligence (AI)?

There is no universally accepted definition of AI, with different groups using different definitions. The Government Office for Science defines AI as:

> the analysis of data to model some aspect of the world. Inferences from these models are then used to predict and anticipate possible future events.[5]

A recent Science and Technology Committee report described AI as: "an evolving [set] of technologies that seek to enable computers to simulate elements of human behaviour such as learning, reasoning and classification."[6] It can be categorised into "narrow AI" and "artificial general intelligence":

- "**Narrow AI**" (applied or weak AI) is only good at a particular task, and cannot adapt to other tasks, even if they appear comparable to a human, such as chess and draughts.
- "**Artificial General Intelligence**" (strong or full AI; AGI) would be "capable of attempting more or less any problem a human can."[7] AGI has not currently been developed, and, at present, there is no clear way of developing narrow AI into AGI.

Artificial intelligence is underpinned by **algorithms**, where an algorithm is a set of rules a computer follows to undertake a task.[8] **Machine learning** is a method that can be utilised to achieve narrow AI. Machine learning enables a program to learn specific concepts without them being explicitly programmed into it. This is achieved via gaining experience and learning from examples in training data, to detect patterns and trends.[9] Many recent developments in AI have been made in the area of **artificial neural networks**, in which a large number of computer processors are linked together, akin to neurons and synapses in the human brain. **Robotics**, which is often conflated with AI, refers to machines that are "capable of carrying out a series of [physical] actions on behalf of humans" and may in future increasingly use AI to perform their tasks.[10] Robotics and autonomous systems (RAS), a commonly used terminology, refers to "physical and software systems that can perceive their environment, control their actions, reason, and adapt."[11]

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5 Artificial intelligence: opportunities and implications for the future of decision making. Government Office for Science. November 2016.
6 Robotics and artificial intelligence inquiry. House of Commons Science and Technology Committee. September 2016.
7 An Intelligent Future? Maximising the opportunities and minimising the risks of artificial intelligence in the UK, Future Advocacy, October 2016.
8 Machine learning: the power and promise of computers that learn by example, The Royal Society, April 2017
9 Ibid.
10 Robotics and artificial intelligence, House of Commons Science and Technology Committee, September 2016
11 Automation and the Workforce POSTnote, August 2016

1.2 Current Applications of AI

Narrow AI is in use today in many sectors. Applications of AI in day to day life include helping search engines better handle new queries[12] and product recommendations by online retailers and video streaming sites. Fact checkers are now beginning to utilise AI to check claims made online and in the media.[13] It is also widely used in newer products, like virtual assistants (such as Apple's Siri, Microsoft's Cortana and Amazon's Alexa). In many of these cases, the consumer is not necessarily aware that they are interacting with a form of AI.[14]

Further examples include in journalism, The Washington Post, for example, used AI to update results and write draft reports in its coverage of sport events and elections.[15] It is used in the financial industry to pick investments[16] or spot unusual financial activity.[17] The chatbot[18] 'DoNotPay' has reportedly overturned parking fines, helped vulnerable people apply for emergency housing and helped refugees fill in immigration and asylum applications.[19]

A lot of the high profile development of AI recently has been in the area of gaming. In 2016, Google DeepMind's AlphaGo won a five-match series of the famously complex Chinese board game 'Go' against the reigning world champion, Lee Sedol.[20] It is also used in research, transport infrastructure management and language translation. The European Parliament Thinktank Briefing on 'Artificial Intelligence: Potential Benefits and Ethical Considerations' has an informative summary of current AI applications.[21]

1.3 AI and the UK

A research report commissioned by the UK Government says of the UK industry:[22]

> The UK has AI companies that are seen as some of the world's most innovative, in an ecosystem that includes large corporate users of AI, providers large and small, business customers for AI

12 'AI Is Transforming Google Search. The Rest of The Web Is Next' *Wired Magazine*, April 2016.
13 The State of Automated Factchecking, Full Fact, August 2016.
14 Public views of Machine Learning Findings from public research and engagement conducted on behalf of the Royal Society, Ipsos MORI, April 2017
15 'The Washington Post to use artificial intelligence to cover nearly 500 races on Election Day' *Washington Post*, October 2016.
16 'At BlackRock, Machines Are Rising Over Managers to Pick Stocks' *The New York Times*, March 2017
17 Mastercard Rolls Out Artificial Intelligence Across its Global Network, Mastercard Press Release, November 2016.
18 A chatbot is a computer program which conducts a conversation with a user to achieve a simple task. For example, it may interact with a user by asking questions via a messaging service such as Facebook Messenger.
19 'Chatbot that overturned 160,000 parking fines now helping refugees claim asylum' *The Guardian*, March 2017
20 'AlphaGo seals 4-1 victory over Go grandmaster Lee Sedol' *The Guardian*, March 2016.
21 Artificial Intelligence: Potential Benefits and Ethical Considerations. European Parliament Think Tank. October 2016.
22 'Growing the Artificial Intelligence Industry in the UK', Professor Dame Wendy Hall and Jerome Pesenti, 15 October 2017, see pages 22-23

services, and research experts. Competition for talent and investment is global, so it is useful to see UK activity in that global context.

The report notes that all major global technology companies in the UK are developing and using AI, while reports have estimated that there are more than 200 start-ups and SMEs active in the industry.

1.4 Potential Future Applications of AI

- **Health**: Some areas in which AI, and machine learning in particular, are particularly suited include image analysis and mining large datasets for trends. Google DeepMind, for example, are collaborating with the NHS to develop tools to analyse eye scans,[23] whilst others are developing an AI chatbot to diagnose illnesses via a patient's smartphone.[24] These methods have the potential for earlier, faster and more accurate diagnoses and the choice of more effective treatments. A 2016 study by Frost & Sullivan predicted the global healthcare market for AI will reach $6.6 billion by 2021.[25] Other AI applications could include robot-assisted surgery, virtual nursing assistants to alert clinicians when patient care is needed and the improvement of administrative tasks.[26]
- **Transport**: AI is beginning to be rolled out in areas such as traffic management, which could have significant safety, environmental and efficiency benefits.[27] But it could have an even greater impact in autonomous vehicles, as outlined in the recent House of Lords Science and Technology Committee Report 'Connected and Autonomous Vehicles: the future?'.[28] These range from the widely publicised driverless cars and trucks to autonomous agricultural vehicles, aircraft (including drones) and specialist applications such as research vehicles or those for hazardous environments (e.g. nuclear facilities).
- **Education**: Adaptive learning software aims to tailor courses for each student individually, presenting concepts in the order they will find easiest to understand and enabling them to work at their own pace.[29] Along with automated marking and feedback, this has the potential to increase the availability of courses and quality of learning and to assist teachers to focus their attention – acting more like mentors than lecturers.
- **Government**: the potential applications of AI in Government are outlined in the Government Office for Science report 'Artificial

23 Moorfields announces research partnership, Moorfields Eye Hospital, July 2016.
24 'See How Artificial Intelligence Can Improve Medical Diagnosis And Healthcare' Forbes, May 2017
25 From $600 M to $6 Billion, Artificial Intelligence Systems Poised for Dramatic Market Expansion in Healthcare, Frost & Sullivan, January 2016.
26 Artificial Intelligence: Healthcare's New Nervous System, Accenture, April 2017. Automation and the Workforce POSTnote, August 2016.
27 'AI traffic lights to end rush hour jams in Milton Keynes', *The Telegraph*, May 2017
28 Connected and Autonomous Vehicles: the future? House of Lords Science and Technology Committee, March 2017
29 'Artificial intelligence: Education and policy. Re-educating Rita', *The Economist*, June 2016

intelligence: opportunities and implications for the future of decision making':[30]

- Government is already using data science techniques such as machine learning[…] These techniques are providing insights into a range of data, from feedback on digital service delivery to agricultural land use through the analysis [of] satellite images. As their sophistication improves more benefits may be realised. For example:
  - Make existing services – such as health, social care, emergency services – more efficient by anticipating demand and tailoring services more exactly, enabling resources to be deployed to greatest effect.
  - Make it easier for officials to use more data to inform decisions (through quickly accessing relevant information) and to reduce fraud and error.
  - Make decisions more transparent (perhaps through capturing digital records of the process behind them, or by visualising the data that underpins a decision).
  - Help departments better understand the groups they serve, in order to be sure that the right support and opportunity is offered to everyone.

30 Artificial intelligence: opportunities and implications for the future of decision making, Government Office for Science, November 2016

2. Government support: Skills Policy and Research Funding

With AI and automation likely to impact on UK employment and economic growth, digital skills are finding becoming of greater political interest. Furthermore, research – both fundamental and applied, has a clear role to play in developing new technologies and hence new products and businesses in the UK economy. This section looks at skills policy and UK Government support for research into AI.

2.1 Education and Training

The Royal Society,[31] among others, have identified three skill levels that need to be developed to maximise the benefits of AI technologies for society:

- A **basic understanding** of the use of data by people of all ages and backgrounds in order to grasp, at a basic level, how our data is being used
- A pool of **informed users** of the technology
- **Specialists** with advanced skills to develop new technologies

Skills Demands

Several reports have identified the need for digital skills training in the UK, for example:

- The House of Commons Science and Technology Committee, in their Robotics and artificial intelligence report, state:[32]

  > Our witnesses generally agreed that learning new skills, and adapting our education system, would help to ensure that the UK realised the full range of opportunities presented by robotics and AI, while also managing its potential risks.

  They concluded that although we do not know how this 'fourth industrial revolution' will play out:

  > As a nation, we must respond with a readiness to re-skill, and up-skill, on a continuing basis. This requires a commitment by the Government to ensure that our education and training systems are flexible, so that they can adapt as the demands on the workforce change, and are geared up for lifelong learning.

- Prior to their Robotics and Artificial Intelligence inquiry, the House of Commons Science and Technology Committee undertook a digital skills inquiry, publishing their report entitled 'Digital Skills Crisis' in June 2016, finding that:[33]

  > The evidence is clear that the UK faces a digital skills crisis. Although comparative nations are facing similar challenges,

> "As a nation, we must respond with a readiness to re-skill, and up-skill, on a continuing basis.
>
> The evidence is clear that the UK faces a digital skills crisis."
>
> The House of Commons Science and Technology Committee 'Robotics and artificial intelligence' report

[31] Machine learning: the power and promise of computers that learn by example, The Royal Society, April 2017.
[32] Robotics and artificial intelligence, House of Commons Science and Technology Committee, September 2016
[33] Digital skills, House of Commons Science and Technology Committee, June 2016

> only urgent action from industry, schools and universities and from the Government can prevent this skills crisis from damaging our productivity and economic competitiveness.

In February 2014, The UK Commission for Employment and Skills (UKCES) published a report entitled 'The future of work: jobs and skills in 2030'.[34] The report identified 13 trends driving the future of UK jobs and skills, including factors such as demographic change, digitalisation of production, ICT development and big data,[35] and 10 disruptions to the path of 'business-as-usual' which included "AI and robots, penetration of AI and automation into highly skilled occupations". They then identified key areas for consideration by employers, individuals, education providers and policy makers to prepare for tomorrow's world of work. Their recommendations for policymakers had a significant focus on encouraging employers, investors and businesses to support education and training.

A recent OECD report looks at the literacy, numeracy and problem solving skills with computers and considers how computer capabilities might change skill demands in the future. The report was picked up in an article in the *Financial Times* on 31 October 2017 in "Why machines do not have to be the enemy".

The Hall and Pesenti report published in November 2017 provides an overview of skills development for AI and makes recommendations to Government to increase the availability of the skills necessary for the UK to remain competitive in this field (see section 3.3 below).[36]

Government View

The November 2016 Government Office for Science report – "Artificial intelligence: opportunities and implications for the future of decision making" discussed how the skills demands of employers may change.[37] In particular, they predicted increasing demand for highly skilled labour across the EU, stating "almost half of all employment is set to be in managerial, professional or associate professional roles by 2022", whilst cautioning that "having a degree will not necessarily insulate an employee from the effects of automation." They do, however, highlight roles that are likely to grow:

> Jobs that grow in the future are likely to be those that will complement technology (rather than be substituted by it)[…] There is significant evidence that STEM and digital skills will be increasingly in demand.

Beyond STEM skills, they predict skills such as perception, complex manipulation, creativity, social intelligence, adaptability and social skills will be less affected by automation. They also note how technological

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[34] The future of work: jobs and skills in 2030, UK Commission for Employment and Skills, February 2014. UKCES is an executive, non-departmental body sponsored by the Department of Business, Energy and Industrial Strategy.

[35] Big Data Overview POSTnote, July 2014.

[36] 'Growing the Artificial Intelligence Industry in the UK', Professor Dame Wendy Hall and Jerome Pesenti, 15 October 2017, see pages 50-62

[37] 'Artificial intelligence: opportunities and implications for the future of decision making', Government Office for Science, November 2016.

change may lead to people changing jobs more frequently. They conclude that:

> This emphasises the need for reskilling over the course of a career and the need to be pro-active, open to change and resilient. It also means that 'general purpose' skills, like problem solving and mental flexibility, that are transferrable across different domains could be increasingly valuable.

In March 2017, DCMS published the Government's Digital Strategy, which contained "Digital skills and inclusion - giving everyone access to the digital skills they need" as one of the seven strands. Key elements of the strategy include:[38]

- Ensuring adults in England who lack core digital skills will not have to pay to access the basic digital skills training they need.
- Establishing a new Digital Skills Partnership, working together with partners from technology companies, local businesses, local government and other organisations to tackle the digital skills gap.
- Implementing the recommendations of the Shadbolt Review to ensure computer science undergraduates have the real-world, up to date skills needed in the digital economy.[39]
- Helping more young people from a wider range of backgrounds consider a career in tech.
- Pledges from private sector organisations to deliver initiatives to provide digital skills to the public (see box).

The Industrial Strategy, published on 27 November 2017, set out policies to develop digital skills (see page 109).[40]

Other Government developments in this area include:[41]

- £20 million capital funding is available for the establishment of the Institute for Coding to develop specialist graduate level technical IT skills.[42] This will support the new institute for two years from April 2017.
- The Autumn 2017 Budget announced funding of £30 million to test the use of AI and innovative EdTech in online digital skills courses, focusing on priority areas of construction and digital skills.[43]
- The Ada National College for Digital Skills is now open, aiming to teach advanced technical skills to 16-19 year olds, with a focus on apprenticeships and industry involvement.[44] The college aims to use digital skills to drive social mobility and promote diversity, with

38 UK Digital Strategy, DCMS, March 2017.
39 Computer science degree accreditation and graduate employability: Shadbolt review (Independent Report), May 2016.
40 BEIS, Industrial Strategy, Cm 9528, November 2017, p109
41 Government response to the House of Commons Science and Technology Committee Robotics and artificial intelligence report, December 2016
42 Institute of Coding competition, Higher Education Funding Council for England, March 2017.
43 HM Treasury, Autumn Budget 2017, HC 587, November 2017, para 4.22
44 Ada National College for Digital Skills

a target of 2,000 students by 2021 – of which 50% will be women and 50% will be from low-income households.

- In September 2014, a new computing curriculum with a greater emphasis on the computational thinking skills needed by young people to support the future digital economy was launched.[45] This was supported by £4.5m investment over three years to prepare teachers to teach the new curriculum.[46]

Skills Pledges by the Private Sector in the Digital Strategy

- Google has pledged to launch a Summer of Skills programme in coastal towns across the UK, as part of a wider digital skills programme that has already trained over 150,000 people.
- Lloyds Banking Group has pledged to train 2,500,000 individuals, SMEs and charities in digital skills, including internet banking, by 2020.
- Barclays will teach basic coding to 45,000 children and assist up to a million people with general digital skills and cyber awareness.
- BT has pledged to reach a further 500,000 children by the end of the 2017/18 academic year through its Barefoot Computing Project. BT has also pledged to offer 750 work placements to disadvantaged young people to help improve their tech literacy.
- There are also commitments from Accenture, HP, Cisco and IBM.

2.2 Research and Innovation

Research contributes to new technologies and products as well as training and skills. This is illustrated, for example, by the number of academics who have joined technology and AI companies in recent years. This has subsequently caused concerns around a 'brain drain' in academia and an increasing focus on commercial, rather than fundamental, research.[47] Equally it demonstrates the increasing focus on the commercial value of research.

As with other fields, AI research in the UK is funded by numerous organisations, including the Research Councils, EU, and industry. AI is priority area for the Engineering and Physical Sciences Research Council (EPSRC), who created the Alan Turing Institute in 2015, which is the national institute for data science.

The Autumn Budget 2017 highlighted Government investment in technology; including £75 million on AI related developments:[48]

> The government will create a new Centre for Data Ethics and Innovation to enable and ensure safe, ethical and ground-breaking innovation in AI and data-driven technologies. This world-first advisory body will work with government, regulators and industry to lay the foundations for AI adoption, which estimates suggest could benefit households across the UK by up

45 A computing revolution in schools. BBC News. September 2014.
46 Government response to the House of Commons Science and Technology Committee Robotics and artificial intelligence report. December 2016.
47 AI firms lure academics. Nature. April 2016.
48 HM Treasury, Autumn Budget 2017, HC 587, November 2017, para 4.10

> to £2,300 per year by 2030, and increase GDP by 10%. The government will invest over £75 million to take forward key recommendations of the independent review on AI, including exploratory work to facilitate data access through 'data trusts'. The government will create new AI fellowships, and initially fund 450 PhD researchers, to secure the UK's leading position in the global AI market.

It also announced a £21 million investment in 'Tech Nation', to expand the reach of Tech City UK:[49]

> Tech Nation will roll out a dedicated sector programme for leading UK tech specialisms, including AI and FinTech. Regional hubs will be located in: Cambridge, Bristol and Bath, Manchester, Newcastle, Leeds and Sheffield, Reading, Birmingham, Edinburgh and Glasgow, Belfast, and Cardiff.

More broadly, research and development funding by the UK is provided under the National Productivity Investment Fund.

Other recent funding announcements by the Government in this area include:

- £17.3 million in Engineering and Physical Sciences Research Council (EPSRC) grants to support the development of new Robotics and Artificial Intelligence technologies in UK universities.[50] This funding includes £6.5 million capital investment to support further collaboration within the UK Robotics and Autonomous Systems (UK-RAS) Network.[51]
- £93 million over the next 4 years for AI research from the Industrial Strategy Challenge Fund, specifically focused on developments to make industry and public services more productive and develop systems that can be deployed in extreme environments, announced in March 2017.[52] An announcement in November 2017 gave further details of four research hubs benefiting from some of this funding.[53]

The Digital Strategy also highlighted the role of the Digital Catapult Centre as:

> A space for technologists, creatives from business and academia to collaborate and develop their new ideas and showcase their products to the UK and the rest of the world.

In 2016, the House of Commons Science and Technology Committee highlighted concerns amongst some about whether the current level of

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49 HM Treasury, Autumn Budget 2017, HC 587, November 2017, para 4.12
50 UK Digital Strategy. DCMS. March 2017.
51 The UK-RAS network aims to provide academic leadership in Robotics and Autonomous Systems (RAS), expand collaboration with industry and integrate and coordinate RCUK RAS activities.
52 Business Secretary announces Industrial Strategy Challenge Fund investments, Industrial Strategy Challenge Fund: joint research and innovation, BEIS, April 2017.
53 Funding for £84 million for artificial intelligence and robotics research and smart energy innovation announced, BEIS, 8 November 2017, para 84

funding for, and investment in, robotics and autonomous systems was sufficient to improve the UK's position in the field.[54]

Internationally, a number of countries have recently started to develop policies focused on promoting and developing AI. These include the US,[55] France[56] and Canada.[57]

2.3 Industrial Strategy and Sector Deal

Prior to the launch of the new Industrial Strategy, the results of the review by Dame Wendy Hall, Professor of Computer Science at the University of Southampton, and Jerome Pesenti, Chief Executive of BenevolentTech were published. The review, commissioned by the Business Secretary and Culture Secretary in March 2017 made 18 recommendations to fulfil a vision for "the UK to become the best place in the world for businesses developing and deploying AI to start, grow and thrive, to realise all the benefits the technology offers."[58] The executive summary provides an overview of the recommendations:

> To continue developing and applying AI, the UK will need to increase ease of access to data in a wider range of sectors. This Review recommends:
>
> - Development of data trusts, to improve trust and ease around sharing data
> - Making more research data machine readable
> - Supporting text and data mining as a standard and essential tool for research.
>
> Skilled experts are needed to develop AI, and they are in short supply. To develop more AI, the UK will need a larger workforce with deep AI expertise, and more development of lower level skills to work with AI. This Review recommends:
>
> - An industry-funded Masters programme in AI
> - Market research to develop conversion courses in AI that meet employers' needs
> - 200 more PhD places in AI at leading UK universities, attracting candidates from diverse backgrounds and from around the world.
> - Credit-bearing AI online courses and continuing professional development leading to MScs
> - Greater diversity in the AI workforce
> - An international AI Fellowship Programme for the UK.
>
> The UK has an exceptional record in key AI research. Growing the UK's AI capability into the future will involve building on this with

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54 Robotics and artificial intelligence, House of Commons Science and Technology Committee, September 2016

55 Preparing for the future of artificial intelligence, Executive Office of the President National Science and Technology Council Committee on Technology, October 2016.

56 Toward a Controlled, Useful and Demystified Artificial Intelligence, The parliamentary office for scientific and technological assessment (OPESCT), April 2017

57 Growing Canada's Advantage in Artificial Intelligence, Department of Finance Canada, March 2017

58 'Growing the Artificial Intelligence Industry in the UK', Professor Dame Wendy Hall and Jerome Pesenti, 15 October 2017

> more research on AI in different application areas, and coordinating research capabilities.
>
> This Review recommends:
>
> - The Alan Turing Institute should become the national institute for artificial intelligence and data science
> - Universities should promote standardisation in transfer of IP
> - Computing capacity for AI research should be coordinated and negotiated.
>
> Increasing uptake of AI means increasing demand as well as supply through a better understanding of what AI can do and where it could be applied. This review recommends:
>
> - An AI Council to promote growth and coordination in the sector
> - Guidance on how to explain decisions and processes enabled by AI
> - Support for export and inward investment
> - Guidance on successfully applying AI to drive improvements in industry
> - A programme to support public sector use of AI
> - Funded challenges around data held by public organisations.

The Industrial Strategy, announced on 27 November 2017, built on these recommendations in announcing a sector deal for AI. It notes:[59]

> AI's extraordinary potential is already well known: by one estimate it could add £232bn to the UK economy by 2030. The UK is a recognised world leader in developing AI: Deepmind, Babylon and Swiftkey – which was backed by Innovate UK – are all globally renowned companies founded here.

And goes on to state:

> The deal will establish an enduring partnership between industry, academia and the government through the UK Artificial Intelligence Council, where all partners will work together to promote the safe, fair application of this technology. The deal contains mutual commitments to encourage the responsible sharing of data to develop new value, and to ensure that the UK produces and retains the best global talent.

It commits to working with industry to create data trusts; on skills it continues to reflect the Hall and Pesenti report:

> To be global leaders in the application of AI, companies must attract the talent they need. We are committed to working together to build and maintain the best AI workforce in Europe, focusing on post graduate level skills and above. We will invest £45m to support additional PhDs in AI and related disciplines, create a prestigious artificial intelligence fellowship programme and work together to develop an industry-funded masters programme.

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59 BEIS, Industrial Strategy, Cm 9528, November 2017, p199-200

Finally, the deal commits to establishing an AI council, a Government Office for Artificial Intelligence, to fund an expansion in Tech City UK and a new 'GovTech' fund.

Further detail on the Industrial Strategy more generally can be found in the Library briefing Industrial Strategy.

3. AI, Automation and the Workforce

There are a broad range of predictions for how artificial intelligence and automation may affect the workforce in the coming years and decades

Debate on AI and automation often leads to discussion of their effects on the economy and individuals – particularly how working lives may change. There are a broad range of predictions for how AI and automation may affect the workforce in the coming years. Predictions are difficult to make due to uncertainties in a number of factors such as the rate of technological development and rate of deployment and the variations by country, region and sector. This section highlights some of the studies and estimates that have been made on employment changes as they are often of Parliamentary interest.

Parliamentary and Press Interest

The potential impact of AI and automation has been widely reported in the press, for example:

- Automation and anxiety: Will smarter machines cause mass unemployment? – The Economist, June 2016
- How Sensors, Robotics And Artificial Intelligence Will Transform Agriculture – Forbes, March 2017
- We are still waiting for the robot revolution – Financial Times, June 2017
- Are robots taking over the world's finance jobs? – The Conversation, June 2017
- What jobs will still be around in 20 years? Read this to prepare your future – The Guardian, June 2017
- UK's wealthiest cities likely to cope best with automation , Financial Times, November 2017
- Range of machines has grown as they learn how to carry out tasks from human masters, Financial Times, November 2017

There has also been parliamentary interest. For example:

- The House of Commons Science and Technology Committee undertook and inquiry into Robotics and Artificial Intelligence in 2016
- A House of Lords ad-hoc Select Committee on Artificial Intelligence has been announced for the 2017-19 session
- Parliamentary questions in both Houses on the impact of AI on the workplace and automation
- An All Party Parliamentary Group on AI was set up in 2016

3.1 Government View

In November 2016, The Government Office for Science published the report – "Artificial intelligence: opportunities and implications for the future of decision making".[60] Acknowledging that new technologies are

[60] Artificial intelligence: opportunities and implications for the future of decision making, Government Office for Science, November 2016

likely to have significant implications for the economy and labour markets, they highlighted the lack of a consensus of their impact:

> There is little consensus about the possible scale of job losses due to automation[…] It could also be that the tasks that constitute particular jobs change considerably[...] However, this only tells half the story and we should expect that new types of job will emerge as other jobs disappear. There are reasons to think that automation may not decrease employment, for instance, because new industries may emerge and grow as productivity gains lead to higher incomes and declining costs.

In the recent Industrial Strategy the Government state that 'embedding AI across the UK will create thousands of good quality jobs and drive economic growth'.[61] The Hall and Pesenti report note, on the overall impact on the UK economy:[62]

> The majority view is that impacts will be positive, large, and widely spread across sectors, with uneven rates of uptake. The fact that AI could be used in most industry sectors over time makes overall numbers hard to reach, and leads to differences between different assessments. There are also various views about the pace of change.
>
> As above, Accenture has estimated that AI could add an additional USD $814 billion to the UK economy by 2035, increasing the annual growth rate of GVA from 2.5 to 3.9 per cent. PWC's recent analysis of UK impacts is summarised below.
>
> These are broad projections, covering the whole economy and over a long period. The persuasive force of these analyses is not so much in the precise numbers, but in the consensus that a very wide range of industry activity is expected to be changed by application of AI.

In February 2014, The UK Commission for Employment and Skills (UKCES) published a report entitled. 'The future of work: jobs and skills in 2030'.[63] The report analysed the trends and disruptors driving the future of UK jobs and skills, which included digitalisation of production, ICT development, the age of big data, AI and robots. From this, they identified four potential future scenarios, which range from business as usual to the emergence of a two tier society or wide scale job losses.

There was one reference to employment in the Department for Business, Innovation and Skills (BIS, now BEIS) submission to the Commons Science and Technology Committee inquiry into Robotics and Artificial Intelligence:

> The Government also recognises the broader impact of RAS [Robotics and Autonomous Systems] on the UK economy,

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61 BEIS, Industrial Strategy, Cm 9528, November 2017, p36

62 'Growing the Artificial Intelligence Industry in the UK', Professor Dame Wendy Hall and Jerome Pesenti, 15 October 2017, see pages 33-4

63 The future of work: jobs and skills in 2030. UK Commission for Employment and Skills. February 2014. UKCES is an executive, non-departmental body sponsored by the Department of Business, Energy and Industrial Strategy that offers guidance on skills and employment issues in the UK.

> including employment as well as the legal and ethical implications of technological developments.[64]

DCMS are the lead Department for AI policy[65] although there are overlaps with BEIS.

3.2 How might automation and AI impact employment in the UK economy

A range of bodies have reported on the effects of automation on employment and the economy, which will be summarised in the following section.

House of Commons Science and Technology Committee

In 2016, the Commons Science and Technology Committee undertook an inquiry into Robotics and Artificial Intelligence, publishing their report in September 2016.[66] On employment, they concluded:

> Advances in robotics and AI hold the potential to reshape, fundamentally, the way we live and work.

> Advances in robotics and AI also hold the potential to reshape, fundamentally, the way we live and work. Improvements in productivity and efficiency, driven by the spread of these technologies, were widely predicted, yet there is no consensus about what this will mean for the UK workforce.
>
> Some expect rising unemployment as labour is substituted for AI-enabled robots and machines. Others foresee a transformation in the type of employment available—with the creation of new jobs compensating for those that were lost—and the prospect of robotics and AI augmenting existing roles, and enabling humans to achieve more than they could on their own.

Research on employment impacts

Work on the US economy, described here, has been the basis for later work on the UK economy. A 2013 study entitled 'The Future of Employment: How Susceptible are Jobs to Computerisation', by Frey and Osborne, co-directors of the Oxford Martin Programme on Technology and Employment at The University of Oxford, found that around 47% of total US employment was at a high risk of being automated in the next decade or two.[67] Workers in transportation and logistics, office and administrative support and production occupations were especially vulnerable.

It should be noted that a high risk of automation will not necessarily result in automation as it will be affected by a range of economic, legal and regulatory factors.

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64 Written evidence submitted by the Department for Business, Innovation and Skills (BIS) to House of Commons Science and Technology Committee Robotics and artificial intelligence inquiry, May 2016

65 PQ 71070 24 April 2017

66 Robotics and artificial intelligence inquiry, House of Commons Science and Technology Committee, September 2016.

67 The Future of Employment: How Susceptible are Jobs to Computerisation, Frey and Osborne, September 2013

The following sections deal with a number of applications of the methodology used by Frey and Osborne.

Research by Deloitte

Using the same methodology in follow up work with Deloitte, Frey and Osborne estimated that 35% of today's jobs in the UK are at high risk of disappearing in the next 20 years due to technology.[68] Providing evidence to the House of Commons Science and Technology Committee Robotics and Artificial intelligence Inquiry representatives of Deloitte explained that these calculations were made purely with technological capability in mind and did not consider factors such as social and political resistance to change or the ease of implementation.[69] The estimate also does not take into account any jobs that may be created as a result of automation. In their other work on AI,[70] Deloitte have found that:[71]

- Across the UK, jobs paying less than £30,000 a year are nearly five times more likely to be replaced by automation than jobs paying over £100,000. In London, [these] lower-paid jobs are eight times more likely to be replaced.
- While technology has potentially contributed to the loss of 800,000 lower-skilled jobs between 2001 and 2015, technology has also helped to create 3.5 million higher-skilled jobs in their place.
- Each of these new jobs was found, on average, to pay nearly £10,000 more per annum than those jobs lost, adding £140 billion to the UK's economy through increased wages.
- Every region of the UK has seen growth in the higher-skilled occupations at low risk of automation, outweighing the loss of jobs in low-skilled, routine occupations at higher risk of automation [in the 2001-2015 period].

In addition, Deloitte found that:[72]

- The sectors with the highest number of existing jobs at high risk of automation are transportation and storage (74% of the workforce in the sector), health and social care (28%), and wholesale and retail (59%) sectors.
- The health and social work sector also has the largest number of jobs with a low likelihood of automation (46% of the workforce in the sector), followed by professional, scientific and technical roles (58%) and education (66%).

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68 Agiletown: the relentless march of technology and London's response, Deloitte, November 2014

69 Robotics and artificial intelligence inquiry. House of Commons Science and Technology Committee, September 2016.

70 'Technology and people: the great job-creating machine' August 2015; 'From brawn to brains: The impact of technology on jobs in the UK' September 2015 and 'Transformers: how machines are changing every sector of the UK economy', January 2016

71 Deloitte Written evidence. Robotics and artificial intelligence inquiry. House of Commons Science and Technology Committee. April 2016.

72 Deloitte Written evidence. Robotics and artificial intelligence inquiry. House of Commons Science and Technology Committee. April 2016.

Research by PwC

PwC have undertaken their own analysis of the potential impact of automation on the UK and other major economies, again based on Frey and Osborne research.[73] PwC conclude:

- 30% of UK jobs could be at high risk of automation by the early 2030s, lower than the US (38%) or Germany (35%), but higher than Japan (21%).
- Risks appear highest in sectors such as transportation and storage (56%), manufacturing (46%) and wholesale and retail (44%), but lower in sectors like health and social work (17%).
- Looking at the risk for individuals, education is a key factor, with the risk of automation lower for higher levels of education in the UK .
- New automation technologies in areas like AI and robotics will both create some totally new jobs in the digital technology area as well as more general productivity gains (that will in turn support the service economy)
- Specifically they find that: "The net impact of automation on total employment is therefore unclear. Average pre-tax incomes should rise due to the productivity gains, but these benefits will probably not be evenly spread across income groups. The pay premium for higher education and non-automatable skills will also probably rise ever higher."

Bank of England

Andrew Haldane, the Chief Economist at the Bank of England, stated in a November 2015 speech that, by conducting research based on Frey and Osborne's model, the Bank predicted that that up to 15 million jobs in the UK could be at risk of automation over the coming 10-20 years.[74]

This estimate was considered by *Full Fact* in December 2016 in Robots and the future of your job. This highlighted that this is a future estimate, rather than a fact, and predicting the future can be hard. It notes that jobs have changed in the past and have been taken over by machines since at least the 19th Century. It concludes that technology changes jobs, but that in the past technological change has not led to mass unemployment in the long run.[75]

OECD

A 2016 OECD report entitled 'The Risk of Automation for Jobs in OECD Countries' used a task-based approach rather than the occupation based approach used by Frey and Osborne.[76] They state that the occupation based approach might:

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73 Consumer spending prospects and the impact of automation on jobs, UK Economic Outlook, PwC, March 2017.

74 Robots threaten 15m UK jobs, says Bank of England's chief economist. The Guardian. November 2015. Labour's Share - speech by Andy Haldane. Given at the Trades Union Congress, London. 12 November 2015. This research does not appear to be published.

75 'Robots and the future of your job', Full Fact, 16 December 2016

76 The Risk of Automation for Jobs in OECD Countries, Arntz, Gregory and Zierahn, OECD, 2016

> Lead to an overestimation of job automatibility, as occupations labelled as high-risk occupations often still contain a substantial share of tasks that are hard to automate.

Using this method, they concluded that only 10% of UK workers were at risk due to job automation. This compared to a range of 6% (South Korea) to 12% (Austria). They attributed this variability to:

> General differences in workplace organisation, differences in previous investments into automation technologies as well as differences in the education of workers across countries.

Other Studies

Future advocacy, a UK think tank and consultancy, published an overview into the impact of AI in 2016. In their report entitled 'An Intelligent Future? Maximising the opportunities and minimising the risks of artificial intelligence in the UK', Future Advocacy split their discussion of AI and employment into the pessimistic and optimistic views. For example, the pessimistic predicts an age of mass unemployment and increasing inequality, whilst the optimistic highlights that new, previously unimaginable jobs, may be created to replace those lost to automation. Overall, they conclude that:

> Ultimately, we should take care not to enter into complacent optimism or pessimism. Our inability to imagine jobs of the future does not mean we are bound to total unemployment. On the other hand, a historical precedent of new jobs offers little by way of assurance that such trends will continue as machines become as good as humans at many physical and intellectual tasks.[77]

They go on to highlight that the impact will be "different on different genders, geographic regions, and age groups", and "improving our understanding of where the impact is likely to be felt is vital if the government is to develop a smart and proactive policy response."

Accenture have investigated the potential impact of AI on global economies, and identified it as the future of growth in their report Why Artificial Intelligence is the Future of Growth.[78] They estimate AI could add in the region of £654 billion ($814 billion) to the UK economy by 2035, with growth rates increasing from 2.5% to 3.9%.

Other research has tried to estimate the time until machines would outperform humans in a range of tasks. A 2017 survey of 352 machine learning researchers worldwide reported that:[79]

> Researchers predict AI will outperform humans in many activities in the next ten years, such as translating languages (by 2024), writing high-school essays (by 2026), driving a truck (by 2027)[…] Researchers believe there is a 50% chance of AI outperforming humans in all tasks in 45 years and of automating all human jobs in 120 years.

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[77] An Intelligent Future? Maximising the opportunities and minimising the risks of artificial intelligence in the UK, Future Advocacy, October 2016
[78] Why Artificial Intelligence is the Future of Growth, Accenture, September 2016
[79] When Will AI Exceed Human Performance? Evidence from AI Experts, Grace, Salvatier, Dafoe, Zhang and Evans, May 2017

The impact of automation on different US cities, relative to their size, has also recently been studied. This work found that, generally, smaller cities (<100,000 residents) have a higher proportion of occupants at risk of job automation than larger cities, due to the range of employment in different sized cities. *New Scientist* magazine highlighted that these findings are also likely to apply in Europe, where cities have a similar range of jobs.[80]

Cities with <100,000 residents have a higher proportion of occupants at risk of job automation than larger cities.

[80] 'Automation will have a bigger impact on jobs in smaller cities', *New Scientist*, May 2017, see full article: Small cities face greater impact from automation

4. Wider impacts and Issues with AI

There are a range of other issues with AI that may impact on future public policy including:[81]

- **Verification and validation** - It is important to ensure that AI is operating as intended and that unwanted or unpredictable behaviours are not produced, either by accident or maliciously. For example, the Science and Technology Committee recommended that methods should be developed to "prove, test, measure and validate the reliability, performance, safety and ethical compliance".[82]
- **Transparency** is particularly important for areas where personal data is involved or life changing decisions made – such as in the health sector. The EU's new General Data Protection Regulation is due to come into effect in 2018,[83] which includes an accountability principle that introduces a right to explanation of algorithmic decisions.[84] It has been highlighted, however, that this may be either impossible or extremely difficult.[85] **Privacy and consent** around the access to and use of data are also key issues, as much of AI relies on access to large amounts of accurate data.[86]
- **Programmed bias** –There have already been several cases of algorithmic bias identified.[87] Whilst the causes of these biases are not always clear, they can reflect the biases of training datasets or developers.
- **Accountability and liability** – If something goes wrong, for example an accident involving an autonomous vehicle, who is accountable? It could be, for example, the operator, owner, manufacturer, the AI developer or even the victim.[88]
- **Military uses of AI –**AI has been put to military use, for example for cyber warfare and autonomous vehicles.[89] Lethal Autonomous Weapons Systems (LAWS) may also be developed, which are systems capable of identifying, targeting, and killing without

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81 Also see "AI's rapid advance sparks call for a code for robots", *Financial Times*, 31 August 2017

82 Robotics and artificial intelligence, House of Commons Science and Technology Committee, September 2016.

83 Overview of the General Data Protection Regulation (GDPR), Information Commissioner's Office

84 Robotics and artificial intelligence, House of Commons Science and Technology Committee, September 2016.

85 Study on the human rights dimensions of algorithms, Council of Europe, February 2017

86 DeepMind given 'legally inappropriate' access to NHS data, *Financial Times*, May 2017.

87 AI programs exhibit racial and gender biases, research reveals, *The Guardian*, April 2017. Semantics derived automatically from language corpora contain human-like biases, *Science*, April 2017.

88 Connected and Autonomous Vehicles: the future? House of Lords Science and Technology Committee, March 2017.

89 Automation in Military Operations POSTnote, October 2015.

human intervention, and may need international regulation Concerns have been raised about their development.[90]

- **Super intelligent AI** – Some have speculated (albeit with a low probability) that if artificial general intelligence (AGI) is achieved, it is possible that super intelligent AI could result – as an AI turns its ability towards being smarter and smarter potentially leading to unintended consequences.[91] These could include resource acquisition, improved intellect, self-preservation, and subduing competition in order for the AI to complete its pre-set task.
- There have been suggestions that action might be required to address disruption to Government revenues and workforce displacement, for example, policies such as **taxing robots**[92] and a **universal basic income**[93].
- Algorithms and automated data processing techniques may also have an impact on **human rights** such as the freedom of expression or the rights to a fair trial or privacy. An example is algorithmic predictive policing, in which pre-existing prejudice may be further cemented when predicting future crime patterns.[94]
- **Public awareness** – Public attitudes to AI could play a key role in influencing the rate at which it is adopted.

Public Opinion

Surveys of public opinion give some insight into views of AI. A YouGov survey, undertaken for Future Advocacy, found that 42% of British people thought the government should pay more attention to the opportunities and risks of AI (compared to 8% who thought the government should pay less attention). It also found that British people tend not to be worried that their jobs will be replaced by AI, robots, or machines in the near future.[95] An Ipsos Mori survey for The Royal Society found that most participants were not familiar with 'machine learning' and found it easier to engage with the idea through real-life examples, and that there was a wide range of opinions on the potential risks and benefits of machine learning.[96]

90 "Killer robots 'will cause war on a vast scale'", *The Times*, 22 August 2017
91 An Intelligent Future? Maximising the opportunities and minimising the risks of artificial intelligence in the UK, Future Advocacy, October 2016.
92 'Why robots should be taxed if they take people's jobs', *The Guardian*, March 2017; 'Here's how Bill Gates' plan to tax robots could actually happen', *Business Insider UK*, March 2017; 'Why taxing robots is not a good idea', *The Economist,* February 2017
93 Universal basic income Commons Debate Pack. House of Commons Library. September 2016; 'Universal basic income would fail to cut poverty, says OECD', *The Financial Times*, May 2017; Citizen's income, House of Commons Work and Pensions Committee, April 2017.
94 Study on the human rights dimensions of algorithms, Council of Europe, February 2017
95 An Intelligent Future? Maximising the opportunities and minimising the risks of artificial intelligence in the UK, Future Advocacy, October 2016.
96 Public views of Machine Learning Findings from public research and engagement conducted on behalf of the Royal Society, Ipsos MORI, April 2017

Regulation and Ethics

Overall, the need for leadership in the regulation and ethics of AI has been identified, for example by the House of Commons Science and Technology Committee:[97]

> While it is too soon to set down sector-wide regulations for this nascent field, it is vital that careful scrutiny of the ethical, legal and societal dimensions of artificially intelligent systems begins now. Not only would this help to ensure that the UK remains focused on developing 'socially beneficial' AI systems, it would also represent an important step towards fostering public dialogue about, and trust in, such systems over time.
>
> The UK is world-leading when it comes to considering the implications of AI and is well-placed to provide global intellectual leadership on this matter.

"The UK is world-leading when it comes to considering the implications of AI and is well-placed to provide global intellectual leadership on this matter."

Based on this need, they recommended the establishment of a standing Commission on Artificial Intelligence utilising expertise from a range of fields from academia, industry, NGOs and the public to:

> Examine the social, ethical and legal implications of recent and potential developments in AI. It should focus on establishing principles to govern the development and application of AI techniques, as well as advising the Government of any regulation required on limits to its progression.

This was referred to in the Government response, which highlighted work being undertaken at the time by The Royal Society, The British Academy and The Alan Turing Institute.[98] The Royal Society and British Academy have since published a report Data management and use: Governance in the 21st century which sets out recommended principles for data governance and calls for new body to scrutinise data governance.[99]

[97] Robotics and artificial intelligence, House of Commons Science and Technology Committee, September 2016

[98] Robotics and artificial intelligence: Government response, House of Commons Science and Technology Committee, December 2016

[99] Data management and use: Governance in the 21st century, The Royal Society and British Academy, June 2017

5. House of Lords Select Committee on Artificial Intelligence

For the 2017-19 session a House of Lords Committee on AI has been established. It will consider the economic, ethical and social implications of advances in artificial intelligence, and will report by 31 March 2018.

To date it has published the written evidence it has received and started oral evidence sessions. This paper does not draw on the evidence received to date, but is likely to be updated once the report is published.

Further Reading

- House of Commons Science and Technology Committee Robotics and artificial intelligence inquiry report September 2016 – Contains chapters on Economic and social implications; Ethical and legal issues and Research, funding and innovation, with a large amount of associated written and oral evidence.
- House of Commons Science and Technology Committee, Algorithms in decision-making inquiry
- Artificial intelligence: an overview for policy-makers, Government Office for Science, November 2016.
- A House of Lords ad-hoc Select Committee on Artificial Intelligence has been announced for the 2017-19 session
- Growing the Artificial Intelligence Industry in the UK, Professor Dame Wendy Hall and Jerome Pesenti, October 2017
- Automation and the Workforce POSTnote. August 2016.
- Big Data Overview POSTnote. July 2015.

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