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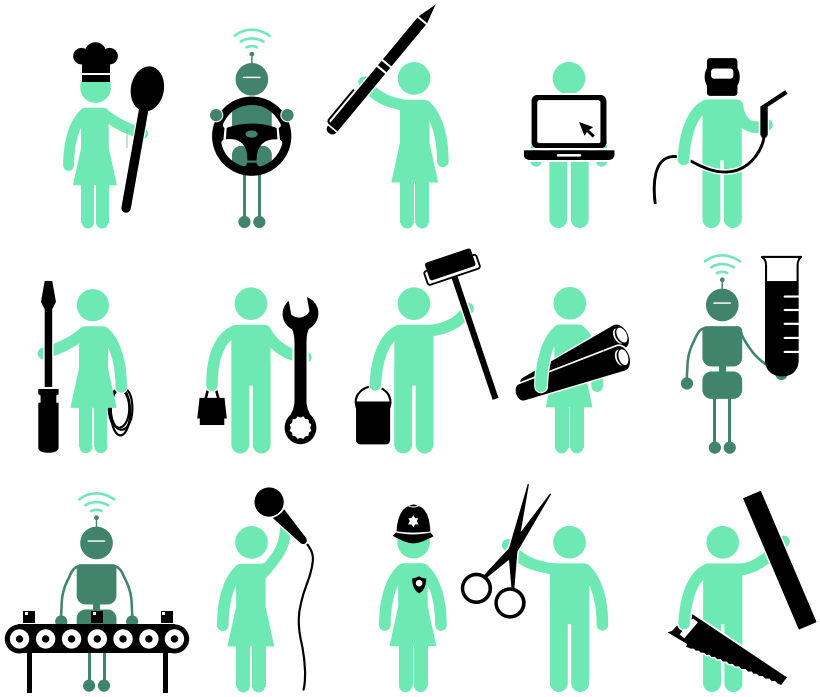

THE IMPACT OF AI IN UK CONSTITUENCIES:

Where will automation hit hardest?

Future Advocacy is a think tank and consultancy working on some of the greatest challenges that humanity faces in the 21st century. We advocate for smart, forward-thinking policies that will allow us to capitalise on the opportunities and mitigate the risks presented by artificial intelligence.

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EXECUTIVE SUMMARY AND RECOMMENDATIONS TO GOVERNMENT

The UK was the crucible of the Industrial Revolution and is one of the crucibles of the Intelligence Revolution. It is home to world-beating artificial intelligence (AI) companies and world-class academic centres of AI research. It is well placed to reap great overall economic benefits from the development of AI, but it is not yet clear how those benefits will be shared.

A number of high profile recent studies have predicted high levels of automation in the UK in the coming years as artificial intelligence and related technologies disrupt the economy. The Industrial Revolution drove automation of repetitive physical work; the Intelligence Revolution is having the same effect on a widening range of intellectual tasks, meaning that more and more jobs can potentially be performed by robots and computers.

There is, however, great disagreement among economists about whether the large amount of work that is automated will be replaced by new (and possibly more fulfilling) alternative work. The history of the Industrial Revolution would suggest that more jobs will be created than are lost. Certainly, in the UK at least, unemployment is currently at record lows (although arguably this is due to an increase in insecure forms of employment). History does not always repeat itself, however: if machines become better than humans at intellectual tasks, what will be left for humans to do? It seems likely that tasks involving creativity, empathy, and high degrees of dexterity will be done by humans for longer. But are these skills that machines will also eventually master?

One thing that almost all economists agree on is that change is coming and that its scale and scope will be unprecedented. Automation will impact different geographies, genders, and socioeconomic classes differently. This report is based on detailed new research into the impact of automation in each parliamentary constituency in England, Scotland and Wales. We have taken the most cutting edge analysis of automation by sector and applied it to constituency level employment data.[1] We have done this in an attempt to encourage a more geographically sophisticated understanding of, and response to, the future of work, and also in an attempt to encourage MPs to pay more attention to this critical issue.

Our findings are startling. The proportion of jobs at high risk of automation by the early 2030s varies from 22% to 39% for different constituencies. **Shadow Chancellor John McDonnell's constituency of Hayes and Harlington is predicted to see the highest rates of automation**, while another Labour MP Ian Murray's Edinburgh South constituency is predicted to have the lowest levels of automation (Table 1, page 4). Most significantly, as the heat map on page 3 shows, the highest levels of future automation are predicted in Britain's former industrial heartlands in the Midlands and the North of England, as well as the industrial centres of Scotland. These are areas which have already suffered from deindustrialisation and many of them are already unemployment hotspots.

This report also includes new opinion poll data from our annual survey of the UK public's attitudes to AI. The poll shows that despite evidence suggesting high levels of automation are coming, the majority of people remain unworried about the impact of automation on their jobs and on jobs in their local area. It seems a deeper public debate about the future of work is urgently required.

1. Berriman, R. and Hawksworth, J. (2017), 'Will robots steal our jobs? The potential impact of automation on the UK and other major economies', in 'UK Economic Outlook March 2017', PwC, available at https://www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf

The story of the 20th century was arguably about the social and political consequences of the differential impacts of the Industrial Revolution on different groups in society. At a very macro level, many have drawn a link between these differential effects and the development of communism, fascism, the welfare state, and various other pivotal events in world history. More recently it is arguably automation (rather than globalisation) that has created the economic and social conditions that led to political shockwaves such as the election of Trump and the vote for Brexit. As artificial intelligence supercharges automation over the next decade, and this hits different groups differently, there will again be profound social and political consequences. Our politicians should surely consider this carefully.

Both automation and the future of work featured in speeches at the recent conferences of the UK's major political parties. But so far no party has anything like an adequate policy response to maximising the opportunities and minimising the risks that lie ahead. We hope that this report demonstrates that **an adequate policy response must take account of how automation will impact different parts of the UK differently.** It must also take account of how automation will impact different genders and socio-economic groups differently. **There will be great political reward for the party that gets this right. Our recommendations for what the UK Government should do are below.**

The UK Government should:

- **Commission and support further detailed research to assess which employees are most at risk of job displacement by automation.** It is essential that we better understand how impacts will differ by employment sector, geography, age group, gender, educational attainment and socio-economic group.

- **Develop smart, targeted strategies to address future job displacement, based on the results of research into the differential impact of automation by sector, region and demographic group in the UK.** The importance of targeting these interventions to those most at risk cannot be overemphasised. Such interventions could include supporting businesses to retrain employees, and providing financial and psychological support to people impacted.

- **Draft a White Paper on adapting the education system to maximise the opportunities and minimise the risks created by AI.** Such a White Paper should not restrict itself to extolling the importance of STEM and coding skills in the future world of work. It must make specific proposals to provide forward-looking and future-proof training in creativity and interpersonal skills, which will be less automatable in the longer term. It must acknowledge how lifelong learning, student-led learning, and the personalisation of education will underpin the resilience and adaptability necessary to thrive in the workplace of the future. Lastly, the White Paper must also support initiatives that encourage underrepresented sectors of society (including women and ethnic minorities) to receive training in AI development and deployment.

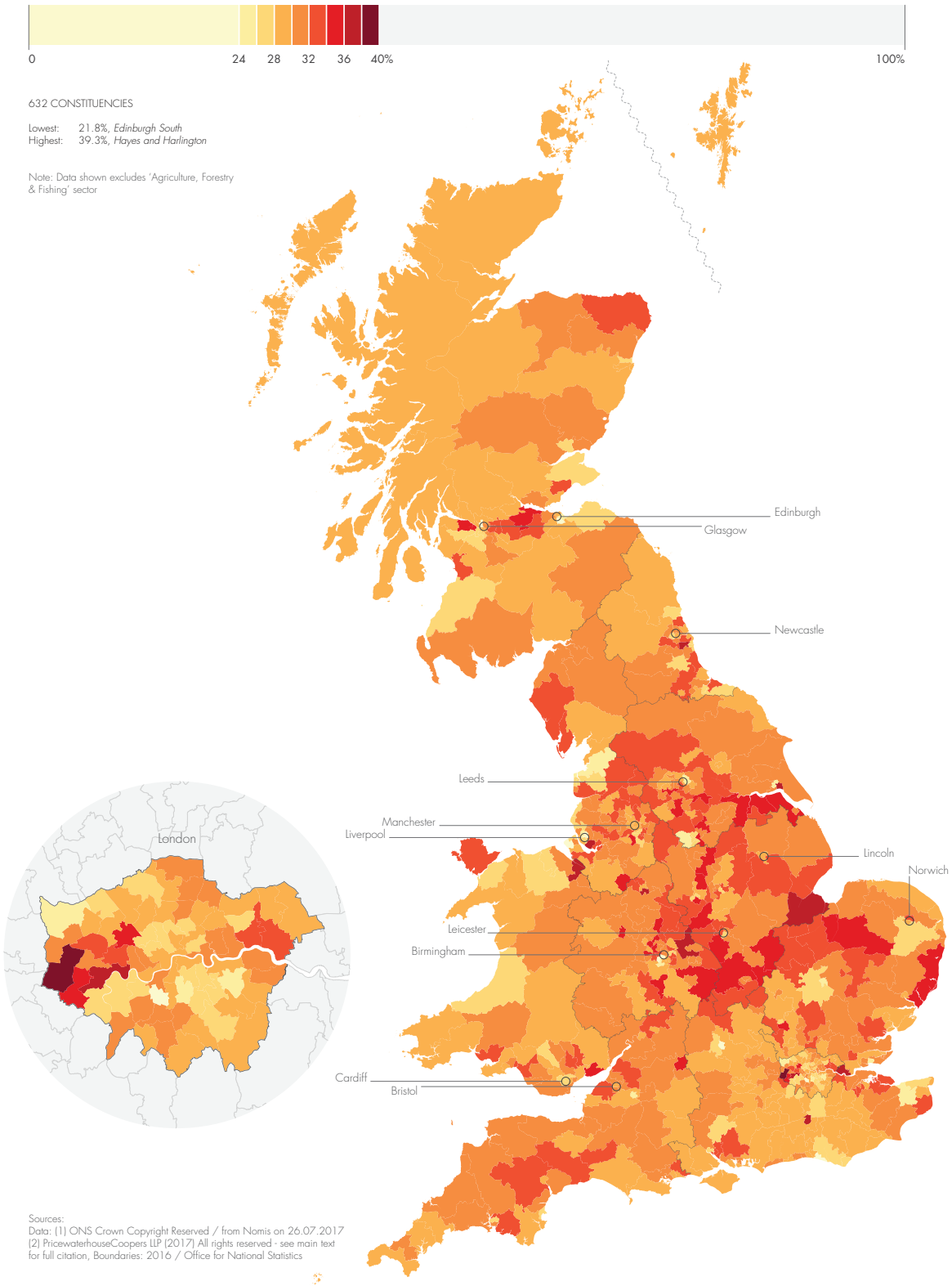
- **Make the AI opportunity a central pillar of the UK's Industrial strategy and of the trade deals that the UK must negotiate post-Brexit.** We look forward to the Hall/Pesenti review on 'Artificial Intelligence in the UK', and to the outcome of the public consultation 'Building our Industrial Strategy' carried out earlier this year by the Department of Business, Energy & Industrial Strategy.

- **Ensure that the migration policy in place following Brexit will still allow UK-based companies and universities to attract the brightest and best AI and robotics talent from all over the world.**

- **Conduct research into alternative income and taxation models that result in fairer distribution of the wealth that these technologies will create.** This could include undertaking well-designed trials of Universal Basic Income along the lines of those currently underway in Finland, Spain, the Netherlands and Canada. The Government's fiscal and welfare policies must be updated to ensure that wealth is not increasingly concentrated in the hands of a few commercial entities who own robots and other automated technologies.

Geographical differences in the impacts of automation

Jobs at potential high risk of automation by parliamentary constituency



▲ **Figure 1:** Heat map showing how the potential impact of automation could vary across Great Britain. Each constituency is colour-coded according to the percentage of current jobs that are at high risk of automation by the early 2030s.

Constituency	Member of Parliament		Rank	Jobs at high risk of automation (%)
Highest proportion of high risk jobs				
Hayes and Harlington	Rt. Hon. John McDonnell (Shadow Chancellor of the Exchequer) (Labour)		1	39.3
Crawley	Henry Smith (Conservative)		2	37.8
North Warwickshire	Craig Tracey (Conservative)		3	37.1
Alyn and Deeside	Mark Tami (Labour)		4	36.8
Brentford and Isleworth	Ruth Cadbury (Labour)		5	36.8
Senior Political Figures				
West Bromwich East	Tom Watson (Shadow Secretary of State for Digital, Culture, Media and Sport) (Labour)		171	31.8
Staffordshire Moorlands	Rt. Hon. Karen Bradley (Secretary of State for Digital, Culture, Media and Sport) (Conservative)		259	31.0
Salford and Eccles	Rebecca Long-Bailey (Shadow Secretary of State for Business, Energy and Industrial Strategy) (Labour)		394	29.7
Tunbridge Wells	Rt. Hon. Greg Clark (Secretary of State for Business, Energy and Industrial Strategy) (Conservative)		426	29.3
Runnymede and Weybridge	Rt. Hon. Philip Hammond (Chancellor of the Exchequer) (Conservative)		454	29.0

Constituency	Member of Parliament		Rank	Jobs at high risk of automation (%)
Ross, Skye and Lochaber	Rt. Hon. Ian Blackford MP (Westminster Leader for Scottish National Party)		459	29.0
Maidenhead	Rt. Hon. Theresa May (Prime Minister) (Conservative)		476	28.8
Twickenham	Rt. Hon. Sir Vince Cable (Leader of the Liberal Democrats)		567	27.2
Islington North	Rt. Hon. Jeremy Corbyn (Labour Leader)		603	26.2
Lowest proportion of high risk jobs				
Wirral West	Margaret Greenwood (Shadow Minister, Work and Pensions) (Labour)		628	22.9
Oxford East	Anneliese Dodds (Shadow Minister, Treasury) (Labour)		629	22.8
Liverpool, West Derby	Stephen Twigg (Labour and Co-operative)		630	22.3
Glasgow North	Patrick Grady (Chief Whip) (Scottish National Party)		631	22.2
Edinburgh South	Ian Murray (Labour)		632	21.8

Table 1: Constituencies of political interest, including the constituencies at highest and lowest risk of job displacement by automation, and those represented by members of the Cabinet or Shadow Cabinet with roles related to the issue of technological unemployment.

SECTION A: INTRODUCTION

Revolutions in the workplace

All around us, the global intelligence revolution marches on. Increases in computing power available for use in artificial intelligence (AI) development, coupled with advances in the ability of algorithms to learn how to solve problems, have led to AI systems becoming better at sorting data, finding patterns, and making predictions.[2,3] Algorithms are undertaking an ever-increasing range of tasks, from filtering email spam, to delivering takeaways, to tackling more sophisticated problems such as providing legal advice or deciding whether you are visited by the police.[4,5,6]

Defining AI is difficult, not least because 'intelligence' itself is so difficult to define. At Future Advocacy, we use an inclusive definition of intelligence as 'problem-solving' and consider 'an intelligent system' to be one which takes the best possible action in a given situation.[7] The term **'artificial intelligence'** comprises machine learning techniques such as deep learning and neural networks, as well as 'symbolic' or 'rule-based' AI, also known as 'good old-fashioned AI'.[8] (see 'Appendix A: Glossary' for full list of definitions used in this report).

However we define AI, automation and robotics, it is clear that progress in these technologies has allowed automation to make greater inroads into the workplace. With such potential for disruption, Future Advocacy makes the case for a world in which the social, ethical and economic opportunities of AI and automation are maximised, while the risks are minimised.[9] Our mission is to work collaboratively towards the policy changes, business practice changes, and individual behavioural changes that will ensure that AI development is beneficial to all of humanity. We hope that this report will contribute to the discussion needed for society to achieve this vision.

Technology - the great job creator?

Concerns about the potential for new technologies to cause job losses have existed since before the Industrial Revolution. The (possibly apocryphal) efforts of Ned Ludd, and the eponymous movement he inspired, to stop the increased use of mechanical knitting machines in the late 18th century are well known.[10] The Luddites may have been surprised to read research by the consultancy Deloitte in 2015, which found that in England and Wales, technology has created more jobs than it has destroyed in the last 144 years. Specifically, automating technologies have freed humans from physically-demanding and repetitive work, such as agriculture and laundry work, and allowed more to engage in jobs involving the care and provision of services to others, largely

2. Mitchell, T. (1997) Machine Learning. London, UK: McGraw-Hill Education.
3. Janakiram, MSV (2017) 'In The Era Of Artificial Intelligence, GPUs Are The New CPUs', Forbes, available at https://www.forbes.com/sites/janakirammsv/2017/08/07/in-the-era-of-artificial-intelligence-gpus-are-the-new-cpus/#6f8728b55d16
4. Legal advice provided by AI algorithms ranged from suggesting strategies for appealing parking tickets to guiding asylum applications. See The Guardian (2017) 'Chatbot that overturned 160,000 parking fines now helping refugees claim asylum', available at https://www.theguardian.com/technology/2017/mar/06/chatbot-donotpay-refugees-claim-asylum-legal-aid
5. Chicago Police Dept have used predictive policing to visit those at a high risk of committing an offence to offer them opportunities to reduce this risk, such as drug/alcohol rehabilitation or counseling. See Saunders, J. et al (2016) 'Predictions put into practice: a quasi-experimental evaluation of Chicago's predictive policing pilot.', Journal of Experimental Criminology, 12(3), 347-371, Stroud, M. (2016) 'Chicago's predictive policing tool just failed a major test.' The Verge, available at https://www.theverge.com/2016/8/19/12552384/chicago-heat-list-tool-failed-rand-test. Areas of the UK, such as Kent, are beginning to use predictive policing. See O'Donoghue, R. (2016) 'Is Kent's Predictive Policing project the future of crime prevention?' KentOnline, available at http://kentonline.co.uk.
6. Waugh, R., (2017) 'Robots are already delivering people's food in London – here's how to summon one', Metro, available at http://metro.co.uk/2017/07/26/robots-are-already-delivering-peoples-food-in-london-heres-how-to-summon-one-6808269/
7. Russell, S. J., and Norvig, P., (1995) Artificial Intelligence: A Modern Approach, Englewood Cliffs, NJ: Prentice Hall.
8. Haugeland, J. (1989) "Artificial Intelligence: The Very Idea", MIT Press; New Ed edition
9. Future Advocacy (2016) 'An Intelligent Future? Maximising the opportunities and minimising the risks of artificial intelligence in the UK', available at https://www.futureadvocacy.com/s/An-intelligent-future-3.pdf
10. Andrews, E. (2015), 'Who were the Luddites?', History.com, available at http://www.history.com/news/ask-history/who-were-the-luddites

requiring increased intellectual, creative and empathetic skills.[11] Importantly, various technologies have also combined to decrease production costs of essentials, meaning consumers have more disposable income to spend on discretionary goods and services, leading to economic growth and further job creation.[12,13]

Even when considering these huge societal and economic shifts, the changes due to the Industrial Revolution could pale in comparison with those being driven by the Intelligence Revolution, predominantly because of the unprecedented speed and scope of change.[14,15,16] As the ability of algorithms to learn and optimise their performance improves, whole new tasks and activities are falling within their remit, including 'cognitive' tasks previously thought to be beyond their reach. Manyika and colleagues at McKinsey have suggested that tasks fitting the description of "specific actions in familiar settings where changes are relatively easy to anticipate" are now susceptible to automation. Such tasks may include data collection (e.g. form-filling) and simple data analysis. Applying this definition, they estimated that for 60% of all occupations, more than 30% of the tasks making them up are technically automatable.[17]

Automating technologies will impact the workplace unequally

There have been many attempts to quantify the number of jobs at risk of displacement by automation in the coming years. Frey and Osborne's 2013 paper, in which they calculated that about 47 percent of total US employment is at risk of computerisation, is rightly regarded by many as seminal in the field.[18] Since then, estimates of the impact of automation on employment have varied, but a number of trends can be seen.

Firstly, it is accepted that it is more accurate to consider jobs as being composed of a combination of tasks, and that the automatability of each of these tasks needs to be considered separately. As outlined by Arntz, Gregory, and Zierahn of the Organisation for Economic Cooperation and Development (OECD), certain jobs may be composed solely of a set of tasks that is completely automatable, meaning that the job as a whole is automatable, but the majority of jobs do not fall into this category.[19]

The second major trend is the growing understanding that the impact of automation on the workplace is highly likely to be unequally distributed. Workers in different employment sectors, age groups, of different

11. Employment in the caring professions, taken to include health and teaching professionals, children's professionals, welfare professionals and care home workers, has risen from 1.1% of total employment in 1871 to 12.2% in 2011.From Stewart, I., De, D., and Cole, A. (2015), Technology and people: The great job-creating machine', Deloitte, available at https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/finance/deloitte-uk-technology-and-people.pdf
12. ibid
13. A McKinsey Global Institute report published earlier this year estimated that automating technologies could continue to raise global productivity by 0.8 to 1.4% annually. From Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P. and Dewhurst, M. (2017) 'A Future that Works: Automation, Employment and Productivity', McKinsey Global Institute, available at https://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works
14. The worldwide increase in internet users (46% of the global population in 2016, up from 16% in 2005) has outstripped global population growth (from 6.5 billion to 7.4 billion over the same time period). Data is being generated at an unprecedented rate - 2.5 quintillion bytes of data are estimated to be generated daily, and more than 90% of the data in the world today has been created in the last 4 years. See Puiu, T., (2017) 'Your smartphone is millions of times more powerful than all of NASA's combined computing in 1969', ZME Science, available at http://www.zmescience.com/research/technology/smartphone-power-compared-to-apollo-432/; 'ICT Facts and Figures 2017', ITU, available at http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx; IBM, 'Bringing big data to enterprise', available at https://www-01.ibm.com/software/data/bigdata/what-is-big-data.html
15. Brynjolfsson, E. and McAfee, A. (2011) 'Race Against The Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy', Digital Frontier Press
16. AI and related technologies are transforming society "ten times faster and at 300 times the scale, or roughly 3000 times the impact" of the Industrial Revolution. This calculation is highly speculative, but it highlights the Intelligence Revolution's huge potential for disruption. From Dobbs, Richard, James Manyika, Jonathan Woetzel, (2015) 'The four global forces breaking all the trends', McKinsey Global Institute
17. Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P. and Dewhurst, M. (2017) 'A Future that Works: Automation, Employment and Productivity', McKinsey Global Institute, available at https://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works
18. Frey, C. B., and Osborne, M. A. (2013) 'The Future of Employment: How susceptible are jobs to computerisation?', JEL Classification: E24, J24, J31, J62, O33, available at http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf
19. Arntz, M., Gregory, T., and Zierahn, U. (2016) 'The risk of automation for jobs in OECD countries: a comparative analysis', OECD Social, Employment and Migration Working Papers No 189, available at http://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7-en?crawler=true

genders and with different levels of educational attainment may be affected differently by automating technologies.[20]

This differential effect is emphasised in the most recent estimate of the impact of automating technologies on the United Kingdom workforce, by the consultancy PricewaterhouseCoopers (PwC) as part of their 'UK Economic Outlook' report of March 2017. By improving on the OECD approach, Berriman and Hawksworth estimate that up to 30% of existing UK jobs are at 'high risk' of automation by the early 2030s, lower than the US (38%) or Germany (35%), but higher than Japan (21%). In keeping with earlier analyses, the risks appear highest in sectors such as transportation and storage (56%), manufacturing (46%) and wholesale and retail (44%).[21,22] The authors also draw attention to the fact that, for individual workers, a key differentiating factor in determining the risk of job displacement is education. For those with just GCSE-level education or lower, the estimated potential risk of automation is as high as 46% in the UK, but this falls to only around 12% for those with undergraduate degrees or higher. Similarly, men may be at higher risk of job displacement by automation than women.[23] The sectors with the highest estimated risk of automation are characterised by relatively high proportions of male employees and of workers with low educational attainment. This indicates how the factors that influence automatability interrelate, making it difficult to attribute risk of automatability to one factor or another.

The calculation of how many jobs will be created by these new technologies is even more difficult to perform. As outlined above, the increase in productivity brought about by automation is likely to be translated into increased wealth. This wealth will most likely be recycled into the economy, increasing demand and driving the creation of new jobs. When this is combined with the number of completely new jobs - that is, job types that do not currently exist - that these technologies may generate, Berriman and Hawksworth argue that the net effect on total human employment is likely to be neutral.[24] This view is shared by the Royal Society for the encouragement of Arts, Manufactures and Commerce (the RSA). In their recent report, they assert that the advance of automation is unlikely to lead to vast job displacement, and indeed that AI and robotics will change the substance of jobs positively, ushering in "a better world of work". This 'better world' is characterised by improved productivity, greater prosperity, and fewer low-skilled, low-paid jobs, with a shift towards 'human-centric' jobs in healthcare, social care and education.[25]

▶ The government must consider the differential geographic impact of automation

The differential impacts of automation on different genders, educational attainment levels, employer types, employment sectors and countries have been addressed by the studies outlined above. **We now present data on the differential impact of automation in the UK, according to geographical location.** By combining the Berriman/Hawksworth calculations on the automatability of different sectors, which represent the best and most up-to-date analysis, with the sectoral mix of jobs in each British Parliamentary constituency, we estimate the number of jobs at high risk of automation in each area by the early 2030s (see Appendix B for a full discussion of the methodology

20. Low-skill jobs have a higher proportion of automatable tasks, meaning that low-qualified workers are likely to bear the brunt impact of automation. Paradoxically, certain low-skilled jobs requiring manual dexterity are resistant to automation - robots currently perform worse than humans at tasks involving fine movements, such as sewing clothes or manipulating small tools. These combined impacts of technology have led to what Andy Haldane, Chief Economist at the Bank of England, has called a 'hollowing out' of the labour market, with high-skilled jobs and some low-skills jobs preserved, and many low- and mid-skilled workers being displaced, resulting in a widening wage gap across the economy. Read more in Arntz, M. at al (2016); The Economist (2017) 'Sewing clothes still needs human hands. But for how much longer?', available at https://www.economist.com/news/science-and-technology/21727058-robot-tailors-are-their-way-sewing-clothes-still-needs-human-hands-how; and Haldane, A., (2015) 'Labour's Share', speech given at Trades Union Congress, London, available at http://www.bankofengland.co.uk/publications/Pages/speeches/2015/864.aspx
21. In the Frey/Osborne, OECD and PwC papers, 'high risk' of automatability is consistently defined as an estimated probability of automation of ≥70%.
22. Berriman, R. and Hawksworth, J. (2017), 'Will robots steal our jobs? The potential impact of automation on the UK and other major economies', in 'UK Economic Outlook March 2017', PwC, available at https://www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf
23. ibid
24. ibid
25. Dellot, B., and Wallace-Stephens, F. (2017) 'The Age of Automation: Artificial intelligence, robotics and the future of low-skilled work', RSA, available at https://www.thersa.org/globalassets/pdfs/reports/rsa_the-age-of-automation-report.pdf

and the limitations of this approach). We thus provide individual Members of the UK House of Commons with an insight into the employment distribution and the potential impacts of automation in their parliamentary constituencies. Furthermore, we present evidence that the impact of automation will be distributed unequally across the United Kingdom. Based on this analysis, we recommend potential interventions that the UK Government should urgently consider to maximise the opportunities of automation and minimise its risks.

SECTION B: RESULTS AND ANALYSIS

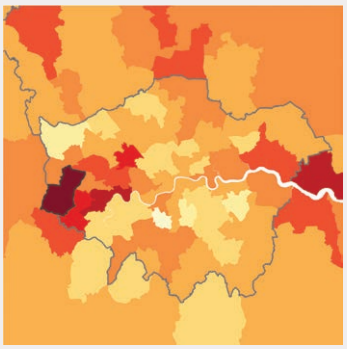
Geographical differences in the impacts of automation

The Berriman/Hawksworth report provided the estimate that up to 30% of UK jobs are at high risk of automation by the 2030s.[26] When focusing on each constituency individually we find that the proportion of these high risk jobs varies from 22% to 39%, indicating a large spread across the United Kingdom (see heat map on page 3, Table 1 on page 4, and full results in Appendix C).

BOX 1: HAYES AND HARLINGTON - THE HIGHEST-RISK CONSTITUENCY?

The MP for this London constituency is Shadow Chancellor John McDonnell.

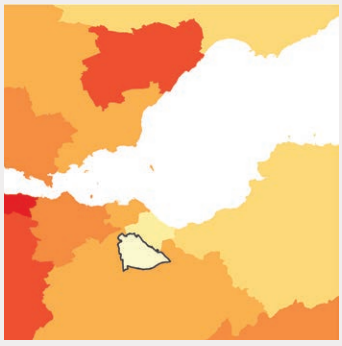
According to the Office of National Statistics' Business Register and Employment Survey 2015 data, there are 92,150 employees in Hayes and Harlington. Our analysis suggests that 36,170 (39.3%) of them are in roles which are at high risk of automation by the early 2030s. It is one of the top two British constituencies that employ people in the 'Transportation and storage' sector (30,000, of which 56% [16,920] are at high risk of job displacement by automation in the early 2030s). Heathrow Airport is found in the southern part of this constituency. As the second busiest airport in the world, Heathrow is a major provider of employment in the area when including its many associated businesses, such as retail, cargo handling, and parking.[27]



BOX 2: EDINBURGH SOUTH - THE LOWEST-RISK CONSTITUENCY?

The MP for this Scottish constituency is Ian Murray (Labour Party).

The constituency covers a southern portion of the city area, and is predominantly suburban. According to the annual 'Edinburgh by Numbers' report released by the City of Edinburgh Council, Edinburgh has a larger proportion of high skilled occupations (40.1%) than other UK cities, including the London region.[28] In fact, the major employment sector in this constituency according to the Business Register and Employment Survey 2015 data is 'Health' (11,000 employees), followed by 'Education' (5,000 employees).



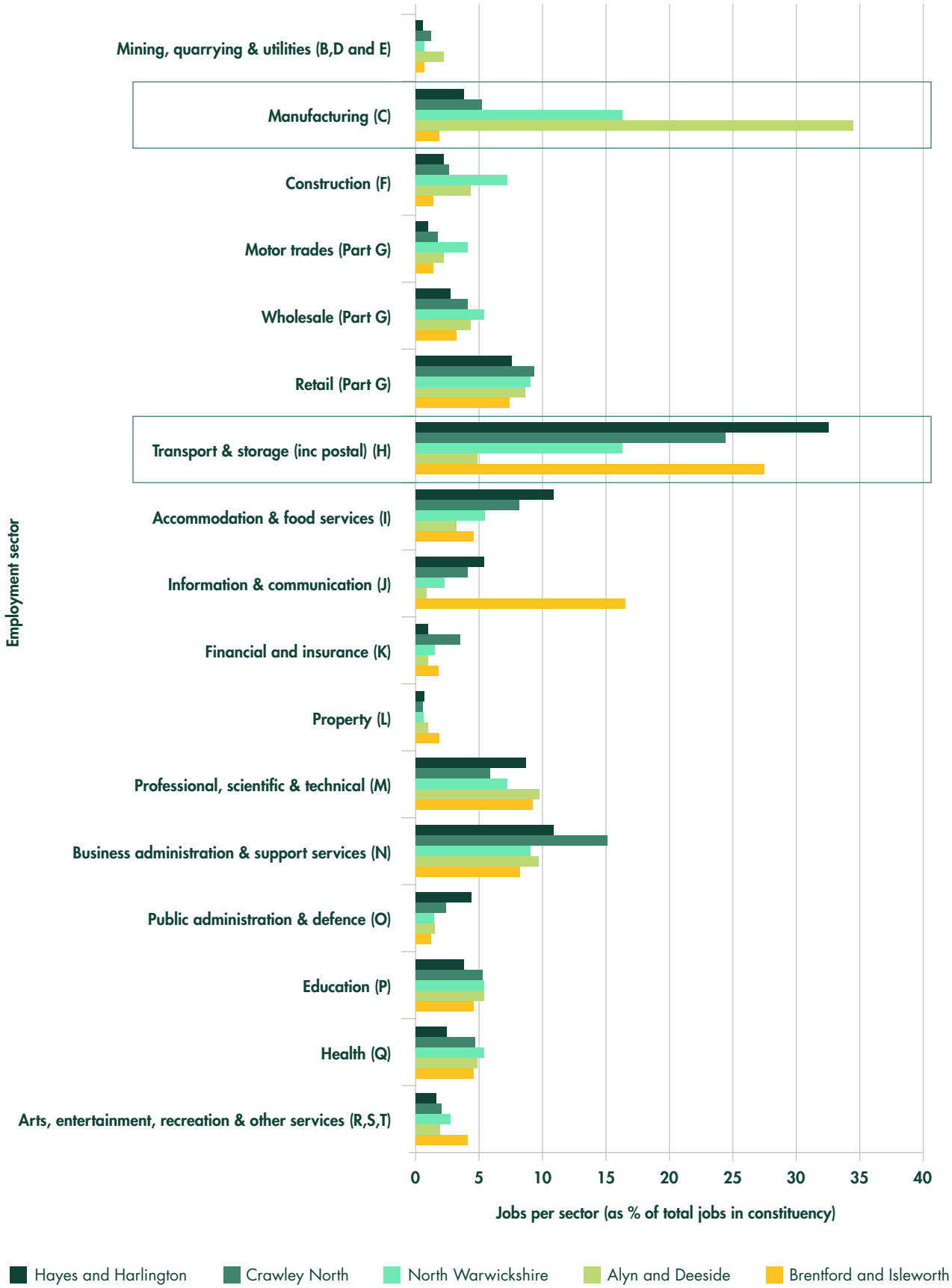
26. Berriman, R. and Hawksworth, J. (2017), 'Will robots steal our jobs? The potential impact of automation on the UK and other major economies', in 'UK Economic Outlook March 2017', PwC, available at https://www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf
27. Smith, O. (2017) 'Which is the world's busiest airport for international passengers?', The Telegraph, available at http://www.telegraph.co.uk/travel/news/busiest-airport-international-passengers/
28. City of Edinburgh Council (2017) 'Edinburgh by Numbers', available at http://www.edinburgh.gov.uk/info/20247/edinburgh_by_numbers/1012/edinburgh_by_numbers

When looking at the sectoral mix alone (see Appendix B for the limitations of this approach), the five constituencies with the greatest proportion of jobs at high risk of automation by the early 2030s are **Hayes and Harlington**, **Crawley**, **North Warwickshire**, **Alyn and Deeside**, and **Brentford and Isleworth** (see Table 1 on page 4). All are characterised by high numbers of jobs in the 'Transport & storage (including postal)' and/or the 'Manufacturing' sectors (Figure 2, page 12).

Hayes and Harlington, Crawley, and **Brentford and Isleworth** all share proximity to a major airport as a common feature: Heathrow Airport in the case of Hayes and Harlington and Brentford and Isleworth, and Gatwick Airport in the case of Crawley. Furthermore, Hayes and Harlington and Brentford and Isleworth are the two constituencies with the most employees in 'Transport and storage' in Great Britain (30,000 employees each). With great strides being made in the automation of road transport and warehousing processes, one can see how this sector may be at risk of this degree of job displacement by the early 2030s. At the end of August, for example, the Government announced the first trials of convoys of semi-automated trucks on UK motorways. These will be conducted by the end of 2018 by the Transport Research Laboratory (TRL), which has been involved in other tests of autonomous vehicles, including passenger shuttles in Greenwich and autonomous delivery pods for online shopping.[29] Automated processes in warehouses, aiding item selection, packaging and distribution, are already in routine use by companies such as Amazon, Ocado and IKEA.[30,31] Fascinatingly, Boeing also announced plans for fully automated, pilotless planes ahead of the Paris Airshow earlier this year, indicating that "the basic building blocks of the technology clearly are available".[32] **Thus, the jobs in transport, warehousing and associated industries that coalesce around Heathrow and Gatwick may be at high risk of displacement by automation by the early 2030s.**[33]

29. Topham G. (2017) 'Semi-automated truck convoys get green light for UK trials', The Guardian, available at https://www.theguardian.com/politics/2017/aug/25/semi-automated-truck-convoy-trials-get-uk-go-ahead-platooning
30. Banker, S. (2016) 'Supply Chain Trends To Follow In 2017', Forbes, available at https://www.forbes.com/sites/stevebanker/2016/12/15/supply-chain-trends-to-follow-in-2017/#5d35abbe1a83
31. Shead, S. (2017) 'Amazon now has 45,000 robots in its warehouses', Business Insider UK, available at http://uk.businessinsider.com/amazons-robot-army-has-grown-by-50-2017-1
32. Scott, A. (2017) 'Boeing studies pilotless planes as it ponders next jetliner', Reuters, available at http://www.reuters.com/article/us-boeing-air-show-autonomous/boeing-studies-pilotless-planes-as-it-ponders-next-jetliner-idUSKBN18Z12M
33. This assertion only takes into consideration the risk of jobs at high risk of automation by sector. As outlined in Appendix B, there are limitations to this approach, not least that the automatability of a particular sector depends on various other factors including its geographical location and the skill mix of its employees.

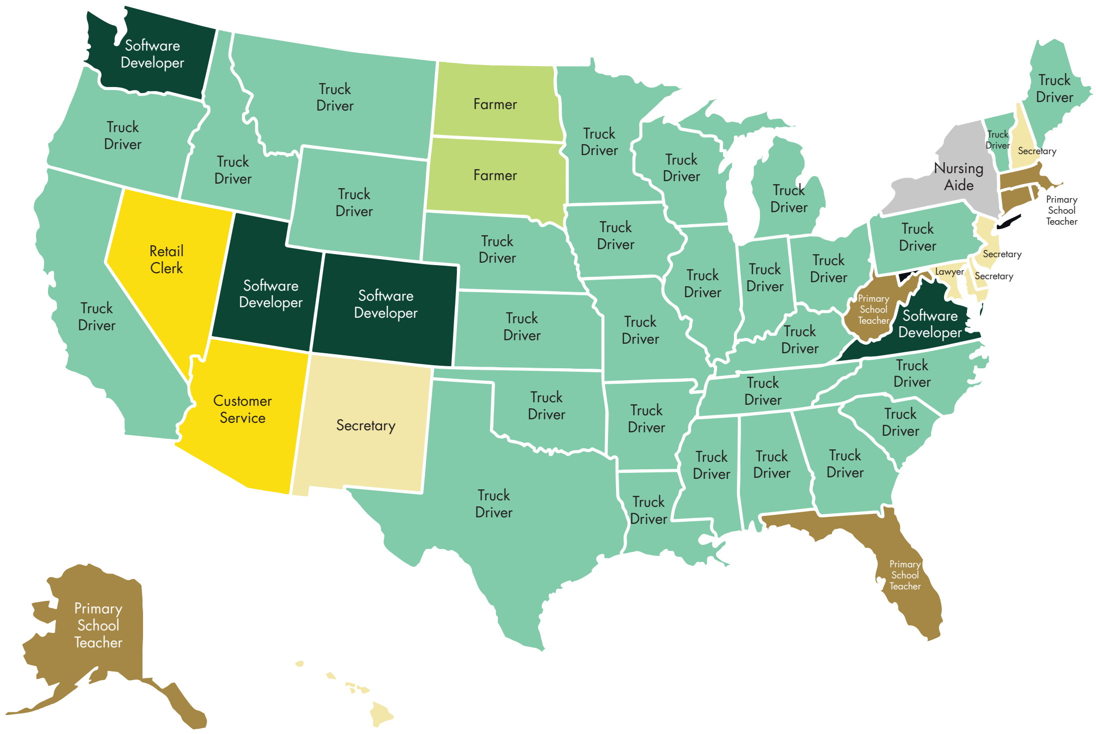
Figure 2: Sectoral mix of jobs in the five constituencies with the highest proportion of jobs at high risk of displacement by automation by the early 2030s.



The **road transport sector** deserves a closer look as it provides an interesting case of the risks and benefits of this form of job displacement. Much has been made of the potential for automating technologies to take over routine, repetitive, or dangerous work. The working conditions that many drivers in the road haulage industry describe - only being paid for driving hours, being away from home for long periods of time, and sleeping in their lorries overnight while on these long journeys - would suggest that certain aspects of this type of work are unattractive.[34]

Indeed, a 2016 House of Commons Transport Select Committee report indicated that large numbers of existing LGV licence holders are actively choosing not to work in this sector, leading to a shortage of up to 60,000 drivers.[35] While it is tempting to think that automation in this sector would be a positive development in some respects, the scale of disruption caused by this automation should not be underestimated, both in the UK and globally. Indeed, 'truck driving' is the foremost employer in 29 out of 50 American states (Figure 3).[36]

▼ **Figure 3:** Most common job type by state in United States in 2014. (Source: NPR)



The employment patterns in the other two of the top five constituencies identified by our analysis also deserve a closer look. **Alyn and Deeside** is characterised by a high proportion of employment in manufacturing (Figure 2, page 12). These employers are predominantly found in the Deeside Enterprise Zone, and include a major Airbus factory, Shotton Paper Mill, a TATA steelworks, and Toyota's highly advanced engine manufacturing plant, as well as companies in the pharmaceutical, construction, food, and sustainable energy sectors.[37]

34. Toynbee, P. (2016) 'A mirror vision of industrial failure – the UK lorry trade', The Guardian, available at https://www.theguardian.com/commentisfree/2016/aug/02/industrial-failure-uk-lorry-trade-truck-driver-squalor-low-pay-no-unions
35. House of Commons Transport Select Committee (2016), 'Skills and workforce planning in the road haulage sector', available at http://www.parliament.uk/business/committees/committees-a-z/commons-select/transport-committee/news-parliament-2015/road-haulage-sector-report-published-16-17/
36. Bui, Q. (2015) 'Map: The Most Common Job In Every State', NPR, available at http://www.npr.org/sections/money/2015/02/05/382664837/map-the-most-common-job-in-every-state
37. The Welsh Government, 'Business Wales: Enterprise Zones Wales', available at https://businesswales.gov.wales/enterprisezones/zones/deeside

North Warwickshire, on the other hand, has a long history of employment associated with the coal mining industry. This industry went through a period of rapid expansion between 1890 and 1913, such that by 1913 miners accounted for 10 per cent of the male working population in the United Kingdom, with 19,000 miners employed in the county of Warwickshire alone.[38] When the coal industry was nationalised in 1947, there were 20 collieries in the whole of Warwickshire, but after a period of decline starting in the 1960s, there are now none, with the last (Daw Mill) closing in 2013.[39] The decline of this industry accounted for 23% of male jobs that were lost in North Warwickshire between 1981 and 2004.[40] In 2015, employment in the 'Mining, quarrying & utilities' sectors accounted for just 0.63% of employment in this area. The main employers now are the 'Transport & storage' and the 'Manufacturing' sectors (9000 employees each).

Taking a regional view of the heat map in Figure 1 (page 3), it is apparent that the regions likely to be hardest hit by automation (because they have the largest proportions of high risk jobs, according to our analysis) are the Midlands and the North of England. The consequences of the historic decline of industries such as manufacturing and coal mining in these regions have been extensively studied, and include high rates of unemployment, high prevalence of illnesses such as depression and drug/alcohol abuse, and depopulation.[41] It is concerning that the areas that have already suffered so much from industrial decline could be hardest hit yet again. Even more worryingly, the speed at which job displacement secondary to automation could potentially occur is worth highlighting. For example, **while it took several decades for the 19,000 mining jobs in the whole of Warwickshire to be lost, our analysis suggests that around 20,500 jobs (or 37.1% of the total number of jobs in 2015) in North Warwickshire could be displaced by the early 2030s (that is, over the next 15 years or so).** The impact on individuals, families, and whole communities will be profound.

Lower risk constituencies - more employment in education and health

The dependence on employment in transport, warehousing and manufacturing in the top 5 constituencies at high risk of job displacement by automation contrasts sharply with the sectoral mix of the constituencies with the lowest proportions of jobs at high risk. These are **Wirral West**, **Oxford East**, **Liverpool West Derby**, **Glasgow North** and **Edinburgh South**. As seen in Figure 4 (page 15), these constituencies have high rates of employment in 'Education' and 'Health', with Edinburgh South displaying greatest employment in these two sectors. Indeed, these constituencies feature household names in the higher education and health sectors, with the majority of University of Oxford colleges found in Oxford East, the University of Glasgow in Glasgow North, and Alder Hey Children's Hospital located on the south side of Liverpool West Derby.

In their recent report on behalf of the RSA, Dellot and Wallace-Stephens make the argument that jobs in the hospitality and leisure, medical and health services, and education sectors are relatively resistant to automation by virtue of their reliance on person-to-person interaction. Skills and attributes such as 'empathising, forming authentic relationships and communicating in open ended dialogue' are currently beyond the reach of algorithms and robotics, meaning that jobs with a high proportion of these tasks are less likely to be displaced by these technologies.[42] Given the differing distribution of these jobs across the United Kingdom, it is unsurprising that different constituencies are likely to be impacted differently by automation.

38. Anney, T. (2013) 'Death on the Warwickshire Coalfield: an examination of the contribution of miners, coalowners and the State to the decline in mining fatalities in the British coal industry in the period of expansion 1840 to 1913.' PhD thesis submitted to University of Wolverhampton, available at http://wlv.openrepository.com/wlv/bitstream/2436/304814/1/Anney_PhD%20thesis.pdf
39. Northern Mine Research Society, 'Warwickshire Coalfield', available at http://www.nmrs.org.uk/mines-map/coal-mining-in-the-british-isles/warwickshire/
40. North Warwickshire Borough Council, 'Economic and Employment issues affecting North Warwickshire', available at https://www.northwarks.gov.uk/download/downloads/id/4684/cd92_economic_and_employment_issues_affecting_north_warwickshire.pdf
41. Comfort, N. (2013) 'The Slow Death of British Industry A Sixty-Year Suicide 1952-2012', Biteback Publishing
42. Dellot, B., and Wallace-Stephens, F. (2017) 'The Age of Automation: Artificial intelligence, robotics and the future of low-skilled work', RSA, available at https://www.thersa.org/globalassets/pdfs/reports/rsa_the-age-of-automation-report.pdf

Figure 4: Sectoral mix of jobs in the five constituencies with the lowest proportion of jobs at high risk of displacement by automation by the early 2030s.

BOX 3: POLITICAL INTEREST IN AI AND AUTOMATION

Along with the attention paid by academic, commercial, third-sector, and other institutions, there has been increasing political interest in both AI and the potential consequences of automation.

- In the last year, there have been 19 mentions of 'artificial intelligence' in the House of Commons, more than in the years 2010 to 2016 combined.[43]
- In October 2016, the House of Commons Science and Technology Select Committee undertook an inquiry on 'Robotics and AI', and in response, the Government announced an extra £2 billion a year in R&D investment in technologies such as robotics and AI.[44]
- In November 2016, a report by Government Office for Science entitled 'Artificial intelligence: opportunities and implications for the future of decision making' suggested that a public debate was needed on how best to understand probabilistic decision-making and how to treat mistakes made through the use of AI.[45]
- In January 2017, the Government launched a consultation on 'Developing a Modern Industrial Strategy' which announced the creation of an Industrial Strategy Challenge Fund focusing on 'Eight Great Technologies', of which 'robotics and AI' is one.[46]
- At the same time, a review on 'Artificial Intelligence in the UK' was announced, led by Dame Wendy Hall, Regius Professor of Computer Science at the University of Southampton, and Jérôme Pesenti, CEO of BenevolentTech, which is expected to report back imminently.
- The Commons Science and Technology Select Committee also announced an inquiry on 'Algorithms in decision-making' with has been re-opened with the new Parliament and is currently receiving evidence.
- Along with the previously-established All-Party Parliamentary Group (APPG) on Data Analytics, two other APPGs have been launched in 2017, one on AI and one on the 4th Industrial Revolution.
- A House of Lords Select Committee on Artificial Intelligence has also been established, and made a call for evidence on the question 'What are the implications of artificial intelligence?' in July 2017.[47]
- In the debate following the Spring Budget of 2017, Rt. Hon. Justine Greening MP, Secretary of State for Education, suggested that the House "should recognise that globalisation and automation are changing the modern workplace. Thirty-five percent of our existing jobs are at a high risk of being replaced in the next 10 to 20 years, not through competition but by technology."
- Jeremy Corbyn made several references to automation in his Leader's speech at the Labour Party conference in September, including the call to "[urgently] face the challenge of automation – robotics that can make so much of contemporary work redundant."

43. Hansard Online, available at https://hansard.parliament.uk/
44. House of Commons Science and Technology Committee (2016), 'Robotics and artificial intelligence inquiry', available at https://www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/inquiries/parliament-2015/robotics-and-artificial-intelligence-inquiry-15-16/
45. Government Office for Science (2016), 'Artificial intelligence: opportunities and implications for the future of decision making', available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/566075/gs-16-19-artificial-intelligence-ai-report.pdf
46. Department for Business, Energy and Industrial Strategy (2017), 'Building our Industrial Strategy', available at https://www.gov.uk/government/news/developing-a-modern-industrial-strategy
47. Lords Select Committee on AI (2017), 'What are the implications of artificial intelligence?', available at http://www.parliament.uk/business/committees/committees-a-z/lords-select/ai-committee/news-parliament-2017/call-for-evidence/

SECTION C: CONCLUSIONS

What should Government be doing to tackle the impacts of automation?

"Prediction is very difficult, especially about the future." Niels Bohr's aphorism can certainly be applied to our understanding of the impact of automating technologies on the workplace and on wider society. Nevertheless, it is not unreasonable to suggest that these technologies have the potential to bring about substantial changes in employment patterns, at unprecedented speed and with unprecedented reach. Moreover, various researchers have identified inequalities in the impact of these technologies, according to gender, educational attainment levels, employer types, and employment sectors. **Our analysis now suggests that the unequal geographical distribution of the impact of automation deserves immediate attention by Government, particularly as it is regions that have previously suffered the effects of industrial decline that are likely to be worst hit.**

Box 3 demonstrates that political interest in AI and in the consequences of automation is increasing. We particularly look forward to the publication of Dame Wendy Hall and Jérôme Pesenti's review on 'Artificial Intelligence in the UK'. In spite of these developments, there is a lack of high-level, joined-up political focus on the social and economic impact of AI. This is in tandem with an absence of public debate and understanding, as revealed by the findings of our annual surveys of public attitudes towards AI (conducted by YouGov). In our most recent online survey, carried out in early October, we asked a representative sample of UK adults age 18+ how worried they are that their job, or those in their local area, "will be replaced by artificial intelligence (e.g. robots, machines) in the near future". The responses to these questions suggest that significant proportions of British adults are unconcerned about the impact of automation. **Only 7% are worried about their own jobs being displaced, while just 28% are concerned about jobs in their local area** (Figure 5, page 18).

Moreover, the tendency of the media to present the issue in a sensationalist way, focusing on Terminator-style artificial general intelligence, may divert attention from the more pressing issue that huge societal change could be brought about by these technologies. Although public faith in politicians is at a low ebb in many countries, ultimately the democratic process is our best hope of ensuring that the social and economic risks of AI are mitigated and the opportunities are maximised. We need politicians to focus more on this issue.

Firstly, it is important that the Government learns the lessons that the recent history of manufacturing, mining and similar industries in the UK have taught us. The decline of these industries in parts of the UK towards the end of the last century may have been inevitable, but it is unarguable that the transition to new job types and different industries in these areas could have been managed better. Better planning may have avoided the collapse in local communities that arguably contributed to many of the issues characterising the political discourse today, including disaffection with politics, the rise of populism and the vote to leave the European Union in 2016.[48,49,50] Mining is a case in point. North Warwickshire, one

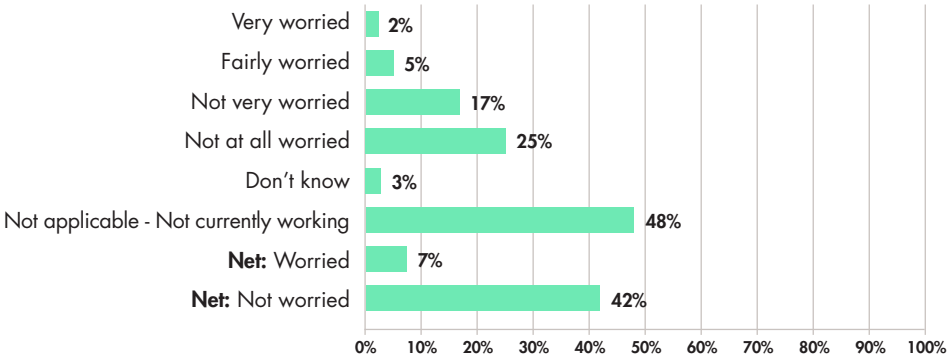
48. Sandle P. (2013) 'In mining ruins left by Thatcher, new economy struggles', Reuters, available at http://uk.reuters.com/article/uk-britain-thatcher-coal/in-mining-ruins-left-by-thatcher-new-economy-struggles-idUKBRE93B07C20130412
49. Seddon, M. (2013) 'The long, slow death of the UK coal industry', The Guardian, available at https://www.theguardian.com/business/2013/apr/11/slow-death-coal-industry
50. Tomlinson, J. (2017) 'Brexit: blame it on the loss of industrial jobs, not on globalisation', LSE Business Review, available at http://blogs.lse.ac.uk/businessreview/2017/04/28/brexit-blame-it-on-the-loss-of-industrial-jobs-not-on-globalisation/

of the constituencies with the highest proportions of high risk jobs, is discussed above as an example of how the collapse in employment in the mining sector, disruptive and shocking as it was, may come to be seen as relatively minor compared to the scale and speed of the changes caused by future automation.

Secondly, it is important to implement policies that recognise the likely unequal distribution of the impact of automation - 'one-size-fits-all' policies will be not be sufficient. This is especially relevant when considering differences in impact across geography as it is when considering differential impacts in different employment sectors, age groups, and genders.

YouGov Poll 2017

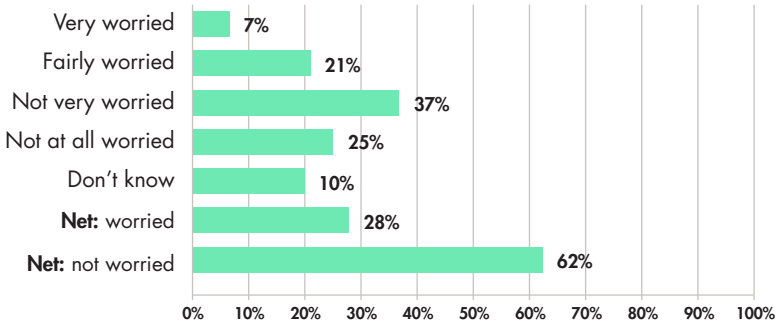
How worried, if at all, are you that your job will be replaced by AI (e.g robots, machines) in the near future?



Total sample size was 2108 adults. Fieldwork was undertaken between 29th September - 2nd October 2017. The survey was carried out online. The figures have been weighted and are representative of all UK adults (aged 18+).

British people tend not to be worried that their jobs will be replaced by Artificial Intelligence, robots, or machines in the near future.

How worried, if at all, are you that jobs in your local area will be replaced by Artificial Intelligence (e.g. robots, machines) in the near future?



Total sample size was 2108 adults. Fieldwork was undertaken between 29th September - 2nd October 2017. The survey was carried out online. The figures have been weighted and are representative of all UK adults (aged 18+).

British people tend not to be worried that jobs in their local area will be replaced by AI in the near future.

▲ **Figure 5:** Results of our survey of public attitudes towards artificial intelligence (conducted by YouGov). A weighted, representative sample of UK adults was asked how worried they are about (a) their jobs and (b) jobs in their local area being replaced AI and other automating technologies.

What are the potential solutions?

One set of solutions concerns education and retraining. Reform of the education system in the case of young people, and retraining programmes in the case of existing workers, will enable both groups to be resilient in the face of change and to find work that is resistant to automation in the years to come. This year's Queen's Speech promised to 'ensure people have the skills they need for the high-skilled, high-wage jobs of the future, including through a major reform of technical education'. This should encompass a drive on STEM skills and coding in schools, but must also encourage creativity, adaptability, caring and interpersonal skills which will provide a crucial comparative advantage for humans over machines over a longer timeframe.[51] Jobs where retraining opportunities may be limited deserve particular attention, and equality of access to retraining programmes regardless of gender, ethnicity, and socioeconomic background must be ensured. These considerations make appreciation of the differential impact of automation on employment all the more important. The Conservative Party's 2017 General Election manifesto commitments to introduce a new right to request leave for training for all employees, and to establish a state-funded 'national retraining scheme' in tandem with this new right, are welcome and we look forward to more detail being published.

In their recent report for the RSA, Dellot and Wallace-Stephens claim that the advance of automation will "almost certainly" change the "substance" of jobs for the better.[52] While fewer people working in routine, unrewarding, low-paid work may be desirable, policymakers need to keep in mind the links between work and various aspects of health and well-being. Unemployment is associated with higher mortality, an effect that is predominantly mediated via adverse health behaviours such as increased smoking and alcohol consumption, and also via suicide. Being unemployed for more than 6 months increases the risk of depression threefold - conversely, the 'sense of purpose' associated with work increases objective measures of well-being.[53,54,55] **Therefore, policymakers thinking about the impacts of automation should ensure that adequate funding and trained staff are available to provide psychological and similar support in those areas identified as being likely to suffer the highest rates of job displacement.**

Another intervention being mooted (most prominently by Bill Gates) to mitigate the potential effects of automation is the introduction of a so-called 'robot tax'. This may constitute a source of funding to support employee retraining programmes, as suggested by the European Parliament earlier this year.[56] Furthermore, 'robot taxes' might provide a solution to the potential problem that reduced employment will lead to reduced income tax and National Insurance revenues. Along with VAT, these two tax types are the largest sources of revenue for the UK Government, together accounting for almost 60% of total tax revenue according to the Institute for Fiscal Studies.[57] There is more work to be done on the practicalities of a 'robot tax' that also fosters innovation. But certainly there is a strong logic to the idea that income taxes unfairly disadvantage human labour and act as an unnecessary further incentive to automation. Universal Basic Income (UBI) is another proposed solution to AI-related job displacement that is gaining traction. Various UBI-like trials across the world have demonstrated societal benefits as a result of relatively small investments.[58,59,60,61] **Ultimately, we support a taxation model that results in fairer distribution of the wealth that these technologies will create, rather than having this wealth concentrated in the hands of a few commercial entities who own robots and other automated technologies.**

51. Autor, D. H., (2015). Why are there still so many jobs? The history and future of workplace automation. The Journal of Economic Perspectives, 29(3), 3-30.
52. Dellot, B., and Wallace-Stephens, F. (2017) 'The Age of Automation: Artificial intelligence, robotics and the future of low-skilled work', RSA, available at https://www.thersa.org/globalassets/pdfs/reports/rsa_the-age-of-automation-report.pdf
53. Morris, J. K. et al (1994) 'Loss of employment and mortality', BMJ, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2540120/
54. Martikainen, P. T. and Valkonen, T. (1996) 'Excess mortality of unemployed men and women during a period of rapidly increasing unemployment', The Lancet, abstract available at http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(96)03291-6/abstract
55. Błaek, M. et al (2015) 'Sense of Purpose in Life and Escape from Self as the Predictors of Quality of Life in Clinical Samples', J Relig Health, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4322214/
56. European Parliament (2017), "Report with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL))", available at http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&mode=XML&reference=A8-2017-0005&language=EN (accessed on 29 March, 2017)
57. Pope, T., and Waters, T. (2016) 'A Survey of the UK Tax System', Institute for Fiscal Studies, available at https://www.ifs.org.uk/bns/bn09.pdf

Lastly, if current trends in automation are to continue, then in the long-term we may well be living in a world with less work that needs to be done by humans. We should start the debate now on what such a world should look like - if humans are not spending most of their time working, what else can they be doing? How do we derive purpose and meaning in a world with less work? These questions do not have simple, straightforward answers, and we call on Government to drive this important debate without delay.

58. Haarmann, C., Haarmann, D., Jauch, H., Shindondola-Mote, H. Nattrass, N., Samson, M. and Standing, G (2008) 'Towards a Basic Income Grant for all! Basic Income Grant Pilot Project Assessment Report', BIG Coalition, Namibia
59. Standing, G. (2017), 'India's Experiment in Basic Income Grants', in 'Global Dialogue: Newsletter for the International Sociological Association', available at http://isa-global-dialogue.net/indias-great-experiment-the-transformative-potential-of-basic-income-grants/
60. 'India flirts with a UBI' (2017) The Economist, available at https://www.economist.com/news/finance-economics/21716025-india-taking-idea-universal-basic-income-seriously-if-not
61. Matthews, D. (2017) 'This Kenyan village is a laboratory for the biggest basic income experiment ever', Vox, available at http://www.vox.com/policy-and-politics/2017/3/6/14007230/kenya-basic-income-givedirectly-experiment-village

APPENDIX A: GLOSSARY

Algorithm: A set or sequence of step-by-step operations that need to be carried out to perform a calculation, to process a set of data, or to test a logical statement.

Artificial intelligence (AI, or machine intelligence): A field of study that combines computer science, engineering and related disciplines to build machines capable of intelligent behaviour, such as solving problems. Note that throughout this brief, we refer only to narrow forms of AI, whose learning is limited to one task or domain of activity only, as opposed to 'broad', 'general', or 'human-level' AI, which most experts agree is still many decades away.[62]

Automation: The use of automatic processes and equipment in manufacturing or other settings.

Autonomous vehicles: Vehicles that are capable of sensing within their environment and navigating terrains without human input.

Deep learning: A branch of machine learning that involves algorithms that analyse data through multiple layers of complex processing. Each layer's output becomes the input to the next layer to carry out pattern analysis and classification and to establish hierarchical relationships for both supervised and unsupervised learning.

Deep neural networks: A kind of deep-learning architecture based on artificial neural networks that uses multiple layers of processing units that loosely mimic human brain structure and can model complex nonlinear relationships.

Machine learning: A type of artificial intelligence that has risen to recent prominence. It refers to the ability of computers to learn without being explicitly programmed. Algorithms use complex statistical methods to recognize patterns in data, learn from these patterns, and subsequently make predictions based on these data. Various techniques allow the algorithm to continuously improve its pattern-finding and predictive abilities.

Neural networks: Artificial neural networks are an architecture of computing used in machine learning. Inspired by the organization and processing mechanisms of biological neural networks, artificial neural networks have been used in speech recognition, image recognition, and other areas involving machine learning.

Robotics: The design, construction, operation, and application of robots.[63]

62. Marcus, G., (2017) 'Artificial general intelligence is stuck. Here's how to move it forward', New York Times, available at https://www.nytimes.com/2017/07/29/opinion/sunday/artificial-intelligence-is-stuck-heres-how-to-move-it-forward.html
63. British Automation & Robot Association, 'Definition of robots', available at http://www.bara.org.uk/definition-of-robots.html

APPENDIX B: METHODOLOGY & LIMITATIONS

We consulted the Office of National Statistics' 'Business Register and Employment Survey' (BRES). This is a survey of businesses in Great Britain (that is - excluding Northern Ireland) that are VAT registered (indicating that they have a turnover of more than £85,000 a year) or are in the Pay-As-You-Earn (PAYE) system (meaning that have employees). In these figures, the number of employees in each employment sector in 2015 is counted for each English, Scottish and Welsh Parliamentary constituency. Note that the term 'employees' also includes working owners, who are typically sole traders, sole proprietors or partners who receive drawings or a share of the profits. BRES therefore includes self-employed workers as long as they are registered for VAT or PAYE schemes. The employment sectors correspond to the Standard Industrial Classification of economic activities (SIC) 2007.[64] The raw data obtained from the ONS is available in Appendix C of this brief.

We then consulted the estimates for the percentage of jobs at high risk of automation in each of these SIC 2007 sectors provided by Berriman and Hawksworth in their ''Will robots steal our jobs? The potential impact of automation on the UK and other major economies" report.[65]

By multiplying the number of 'employees' in each sector by the percentage at high risk of automation, we calculated a figure for the number of employees whose jobs are at high risk of automation, per sector, in each constituency. We then summed the number for each sector, calculating a total number of jobs at high risk of automation by the early 2030s in each constituency. We also expressed this figure as a percentage of total existing jobs in each constituency.

Limitations

This analysis relies on calculations for the number of jobs at high risk of automation **for each employment sector,** published by Berriman and Hawksworth of PwC in March 2017. As they and others have made clear, **sectoral mix is just one of the factors that may influence the number of jobs that are at high risk of automation in a particular area.** Indeed, it may not be the most important factor in some cases.

Berriman and Hawksworth provide the example of Japan. Both Japan and Germany have a relatively similar sectoral mix to the UK, apart from a greater proportion of employment in manufacturing. Despite these similarities, the proportion of jobs calculated to be at high risk of displacement by automation in Japan (21%) is far lower than that in Germany (38%) and the UK (30%). A deeper analysis of the specifics of employment in Japan provides clues as to why this may be, with the majority of sectors being less automatable in Japan than in the UK. Retail, for example, is considered to be 19% less automatable in Japan than in the UK, because a greater proportion of time in Japanese retail jobs is spent on performing management tasks rather than manual ones.[66]

This example illustrates the value of taking a task-based view of the impact of automation on employment, as well as highlighting how the same sector in different employment environments may have vastly different predicted automatability. Our analysis does not address these other factors that may impact on the automatability of a particular sector in a specific region or area, and further research is needed to better identify these factors and to quantify their contribution.

64. Office for National Statistics, 'UK SIC 2007', available at https://www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities/uksic2007
65. Berriman, R. and Hawksworth, J. (2017), 'Will robots steal our jobs? The potential impact of automation on the UK and other major economies', in 'UK Economic Outlook March 2017', PwC, available at https://www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf
66. ibid

There are also a set of limitations related to the BRES data. Although an important source of seasonal and regular employment in some constituencies, agriculture is a very small industry in the United Kingdom (contributing around 0.5% of British national value added in 2015).[67] Indeed, farm agriculture is excluded from BRES - given that this is a survey that relies on self-reporting by local businesses, the data on agricultural employment is considered to be less reliable when this is split up into small areas such as constituencies.[68] In view of these limitations, we have presented no data for employment in 'Section A: Agriculture, Forestry and Fishing'. Furthermore, the BRES excludes self-employed people who are not registered for VAT or PAYE, along with HM Forces and Government Supported trainees.

No data was available from BRES for sectoral employment for the Northern Irish constituencies, as this resource covers Great Britain but not Northern Ireland.[69] Counts in the BRES are rounded to the nearest 5 employees.

Lastly, the mapping between the sectors presented in the PwC report and the BRES survey is imperfect. However, reasonable assumptions can be made, as below:

- 'Property (L)' in the constituency data is mapped to 'Real estate' in the PwC data.
- 'Health (Q)' in the constituency data is mapped to 'Human health and social work' in the PwC data.
- 'Motor trades', 'Wholesale' and 'Retail' are all part of Section G of the SIC classification. The same value for "percentage at potential high risk of job automation" as the risk for 'Wholesale and retail trade' (44%) was applied to all three columns.

67. Development Economics (2017) 'Contributions of UK Agriculture', report on behalf of NFU, available at https://www.nfuonline.com/assets/93419
68. House of Commons Library, personal communication to MF, 13th September 2017
69. The 18 constituencies in Northern Ireland are Belfast East, Belfast North, Belfast South, Belfast West, East Antrim, East Londonderry, Fermanagh and South Tyrone, Foyle, Lagan Valley, Mid Ulster, Newry and Armagh, North Antrim, North Down, South Antrim, South Down, Strangford, Upper Bann, and West Tyrone.

APPENDIX C: RAW DATA AND FULL RESULTS TABLES

The data from the BRES indicates that there were 29,040,190 employees (as per the definitions and limitations above) in the United Kingdom in 2015. The sector employing most people was 'Health', with 3,829,000 employees, whereas the sector with fewest employees (370,100) was 'Mining, quarrying & utilities' . Note that these data exclude 'Agriculture, Forestry and Fishing'.

The UK Parliament constituency with the greatest absolute number of employees in the BRES 2015 was the Cities of London and Westminster (1,140,200), of which the majority are employed in the 'Professional, scientific & technical' (248,000), the 'Financial & insurance' (210,000), and the 'Business administration & support services' (117,000) sectors. On the other hand, the Scottish constituency of Na h-Eileanan An Iar has the fewest employees (10,325) according to BRES 2015 data, most of which (2,250) work in the 'Health' sector.

The full table of proportions of jobs at high risk of automation by employment sector, calculated by PwC's Berriman and Hawksworth, can be found at https://www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf

The raw data from the Business Register and Employment Survey, sourced from Nomis on 26 July 2017 (ONS, Crown Copyright Reserved) can be found at https://futureadvocacy.squarespace.com/s/BRES_RawData_20170726.pdf.

The full results of our analysis can be found at https://futureadvocacy.squarespace.com/s/ResultsHighRiskAutomationSorted_20171009.pdf.

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