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Automation and the Workforce

Automation technologies can reduce costs and raise productivity. However, there is considerable uncertainty over their potential effects on the UK workforce. This note provides an overview of how these technologies are being used; and potential implications for employment, skills, education and inequality in the coming decades.

Overview

- Some types of labour are being replaced or augmented by automation technologies such as robotics and machine learning.
- Few studies have assessed the effects that these technologies may have on jobs.
- There are uncertainties in the pace of technological development, the rate of adoption and other factors.
- Historically, automation has increased productivity, which in turn has led to a net increase in employment. Opinion is divided on whether this will continue.
- Some studies suggest that jobs in sectors such as sales, logistics and administration may be easier to automate than those in health, education, finance and management.
- Workers may need to be more flexible and to respond to changing demands for skills.
- Although evidence is limited, automation may increase inequality; for example, if job losses focus on low-skill roles or the benefits are not felt by employees and consumers.

Background

Robotics and autonomous systems (RAS) are physical and software systems that can perceive their environment, control their actions, reason, and adapt.[1] RAS are making it possible both to automate tasks that could previously only be done by humans, and to assist workers performing tasks that cannot be automated. For example, autonomous robots can perform tasks that historically relied on human vision and dexterity, such as picking delicate fruit.[2,3] Software can also automate 'knowledge work' (cognitive activities involving non-routine problem solving[4]) ranging from answering customer service enquiries[5] to assisting in the diagnosis and treatment of cancer.[6,7]

In 2013, McKinsey predicted that the automation of knowledge work and advanced robotics could be worth \$7-\$11 trillion globally by 2025.[8] KPMG and the Society of Motor Manufacturers and Traders project that the connected and autonomous vehicles sector could be worth up to £51 billion annually to the UK economy by 2030.[9] The Government has committed significant funding (Box 1) to expand the UK's wide-ranging expertise in RAS. This includes machine learning (Box 2), unmanned systems such as autonomous vehicles (Box 3), and robots for use in hazardous environments such as space.[1] However, the UK lags behind in the adoption of some automation technologies, such as industrial robots. The UK has fewer industrial robots than other G7 countries, with an estimated 17,000 in use in 2014, compared to 176,000 in Germany.[10]

Applications for Automation Technology

Software and robotics can replace workers entirely, undertake tasks that would be unsafe or unfeasible for human workers, or enhance workers' productivity.[11,12]

Automation of Knowledge Work

Software using techniques such as machine learning, can perform or support many types of knowledge-based work.

- **Robotic process automation software** can perform routine administration such as data entry and analysis. It can be faster and more accurate than people and can help firms to cut costs, ensure regulatory compliance, and

Box 1. Government Support for RAS in the UK
In 2015, the Robotics and Autonomous Systems Special Interest Group (comprising leading industrialists and academics) published a strategy intended to stimulate innovation and realise the potential economic and social benefits of RAS.[12,13] In response, the 2010-2015 government said it would establish a leadership council to enable the planning and execution of the strategy, but this has yet to be set up.

Funding
More than £100 million of funding from the Research Councils has been committed for RAS projects alongside additional private investment. This includes:
- £35 million investment in research centres across the UK in key areas including marine RAS, transport, healthcare and manufacturing, with a further £14.5 million of private funding[14]
- £18.6 million for four doctoral training centres in RAS, supplemented by £20 million of private investment
- £5.9 million funding for a Centre for Innovative Manufacturing in Intelligent Automation.[1]

Beyond the UK Research Councils, public funding includes:
- £100 million for an Intelligent Mobility Fund to support the research, development and deployment of connected and autonomous vehicles (with up to an additional £100 million in matched funding from industry)[15]
- £19 million to test connected and autonomous vehicles in four cities across the UK
- €3.8 million from the EU Horizon 2020 program for UK RAS in 2014-2015
- £33 million invested by Innovate UK since 2009, including intelligent mobility and unmanned vehicle demonstrator projects.

manage growing workloads.[16] For example, Enfield Council has installed "Amelia" a 'virtual employee' that responds to queries and deals with applications for licenses and permits.[17]
- **E-discovery software** is being used by some law firms to automatically search through documents that may be relevant to a case (a task that would typically be done by paralegals or junior lawyers).[18]
- **Automated report writing** has increased the report output of the Associated Press by a factor of twelve. For example, it uses software to write earnings reports with data extracted from companies' financial statements.[19]
- **Machine translation** of both speech and text is used to provide language translation services, although it is currently less accurate than human translators.[20] The European Commission uses automated translation of texts to help Member States communicate.[21]
- **High frequency trading** uses machine learning to predict the short-term behaviour of markets, allowing automated trading software to perform high-volume trading faster than humans.[22,23]

Automation of Physical Work
Robotics is moving beyond large, inflexible installations (commonly used for tasks such as building cars), towards robots that can be used in a variety of sectors including transport, logistics, agriculture, healthcare, the oil and gas industry and in domestic settings.[24,25,26]
- **Autonomous vehicles** are being developed by many companies including Google, Tesla, Uber, and nearly all car manufacturers.[27,28,29,30] Autonomous lorries and buses are also under development and may eventually replace many transport-sector workers.[31]
- **Automated factories and warehouses** can operate without human intervention. Japanese robot manufacturer FANUC uses production lines that can operate without human assistance for several weeks,[32] and Adidas is planning to open its first automated factory in Germany in 2016.[33] Ocado is trialling warehouses where robots pack and move goods autonomously.[34]
- **Medical robots** are being trialled for tasks such as performing surgery,[35] aiding rehabilitation, and reducing patients' anxiety and distress.[36,37]
- **Collaborative robots** (known as 'cobots') work alongside humans. They assist workers by moving heavy objects or handling repetitive tasks,[38] reducing the risk of injuries.[39] For example, workers at SEW-Eurodrive build power transmission systems with the assistance of robotic arms that help to load machines and pick up components.
- **Some domestic tasks** can be undertaken by autonomous robots. Vacuum cleaners such as the Dyson 360 Eye can find efficient paths around rooms, cleaning an area while avoiding obstacles such as furniture.[40]

Adoption of Automation Technology
The primary drivers of RAS are their potential to cut costs and to increase productivity through higher output, quality and safety.[11,41,42] The pace of adoption of RAS is likely to depend on factors including the cost of technology and labour, awareness of the technology, public perception, and regulation.[43,44]

The falling cost of computing power and greater availability of data (POSTnote 468) have improved the ability of software to perform tasks that traditionally required people.[45] Tools such as IBM's Watson[46] and Google's Tensorflow,[47] have been released under licensing models that make it cheap or free for developers to use machine learning (Box 2). The cost of sensors has also fallen.[48] Industrial robots are becoming cheaper, smaller, more dextrous and easier to install.[49] Conversely, UK labour costs are rising,[50] which might increase the financial incentive to automate.

Public perception can have a major impact on the adoption of technology.[51] For example, the adoption of autonomous vehicles (Box 3) depends on public perception of their safety, which is influenced by accidents such as the recent fatal collision involving a Tesla car on autopilot.[52] The use of machine learning in fields such as medicine may rely on patients trusting that their data will not be misused.[53] Regulation can have both positive and negative effects on the adoption of automation. It could help to build trust in automation technologies but TechUK (the trade association for the UK technology industry) has raised concerns that over-regulation may stifle innovation.[49,51,53,54,55]

Potential Impact on Employment
Historically, technology has not led to long-term unemployment, although it has displaced workers from specific tasks and altered the type of employment available (Box 4). However, it is not clear whether this will continue.[45]

Box 2. Machine Learning
Machine learning (one of a number of fields often collectively referred to as artificial intelligence) has helped to make software better at solving challenging problems such as recognising speech, recognising images of objects and faces, and automatically translating written text from one language to another.

A barrier to automating cognitive activities has been the inability of programming software to accomplish tasks requiring tacit knowledge, for example knowledge of how to recognise a face from many different angles. Machine learning addresses this problem by removing the need for the human programmer to codify this knowledge. The software learns a task by analysing large amounts of data and building a model with which it can process future data, extrapolating its knowledge to unfamiliar situations. IBM's Watson system learns about complex topics from large quantities of unstructured text, such as Wikipedia entries, textbooks and journal articles.[46] Originally taught to play the gameshow Jeopardy!,[56] it is now being used to recommend treatment options for cancer patients.[7]

A 2014 survey of technology experts found that only half believed that technology would continue to create jobs at a similar or faster rate than it displaces them.[57] The available evidence is limited. Two key studies that attempted to quantify the number of jobs that could be automated, are highlighted below. However, neither considered jobs that might be created; for instance, if automation leads to increased demand for existing goods and services, to the creation of new industries, or to the creation of new types of job within existing industries. In addition, predicting the impact of automation over a specific timeframe is difficult because of uncertainties in the rates of technological development and adoption as well as other factors that may affect employment, such as changes to the wider economy.[1]

A 2014 study by Frey and Osborne (published by Deloitte), estimated that 35% of jobs in the UK in 2013 had a greater than 66% chance of being automated in the coming decades.[58] The Bank of England used the same methodology to estimate that up to 15 million UK jobs could be automated over a similar period.[59] However, these figures may be over-estimates, as the studies only considered whether the automation of jobs will be technologically (rather than economically) feasible. Additionally, they assumed that all workers with the same job title performed the same tasks.[43,60]

A 2016 study by Arntz et al. focused on the tasks within jobs.[43] Based on data from 2012, it estimated that for 10% of UK jobs, it would be technically possible to automate more than 70% of their component tasks within the next decade, close to the 9% average for other members of the Organisation for Economic Development (OECD). A further 25% of UK jobs could have at least 50% of their tasks automated over the same period.

Types of Jobs Affected
It is assumed that certain key skills will be difficult or impossible to fully automate in the near future. While views vary, skills commonly highlighted include:[43,61,62]

- social skills – empathy, persuasion and negotiation
- creativity – both artistic and intellectual
- digital skills – programming or maintaining digital systems
- perception – moving and working in unpredictable environments.

Box 3. Autonomous Vehicles
The UK Centre for Connected and Autonomous Vehicles (including vehicles able to communicate with devices and networks such as the internet) was established in 2015 as a joint policy unit between the Department for Transport (DfT) and the former Department for Business, Innovation and Skills. It aims to support the development of connected and autonomous vehicles in the UK (POSTnote 443).[15] A review by the DfT found that UK regulations provide a favourable environment for testing autonomous vehicles,[63,64] and the DfT has published a code of practice which allows for testing to take place anywhere in the UK without need for permits or surety bonds. Trials of autonomous cars are underway in Bristol, Coventry, Milton Keynes and Greenwich.[65] Further tests, including some with platoons of semi-autonomous lorries, are expected to begin soon.

The study by Frey et al. looked at how different sectors might be affected.[58] It suggested that jobs in sectors including sales, transport, logistics, and administration were particularly likely to be affected by automation. Jobs in healthcare, education, and financial and management services were found less likely to be affected. A 2015 follow-up study by Deloitte examined changes in employment between 2001 and 2015.[62] It concluded that technology is likely to have displaced over 800,000 jobs, but created nearly 3.5 million new ones over the same period. The percentage of jobs at “low” (less than 33%) and “medium” (less than 66%) risk of automation increased over this period, while the percentage of “high-risk” jobs fell. On average, new jobs paid £10,000 more per annum than those displaced. However, it is not possible to isolate automation as the sole cause of these changes.

Jobs requiring a greater level of education may also be less likely to be automated. The Arntz et al. study found that, across all OECD countries, fewer than 1% of workers with a Masters degree or PhD were in jobs likely to be automated, compared to over 15% of workers educated only up to secondary school level.[43]

Implications for Skills and Education
Creating RAS technology requires specialist skills. If automation becomes more prevalent, the skills needed by the wider workforce are also likely to change.

Skills for Developing Automation Technology
The development of RAS requires highly skilled workers in disciplines like robotics, computer science and statistics. The UK lacks professionals with STEM (science, technology, engineering and mathematics) skills,[66] which are key for many roles in this field (POSTnote 510). However, four EPSRC-funded Centres for Doctoral Training in RAS have recently opened to equip students with research and entrepreneurial skills.[67] The EPSRC, Innovate UK and companies such as Google Deepmind have said that investment is necessary to build expertise in the UK and to support future research.[54,67,68] Deploying new technologies within existing infrastructure and supply chains

will require workers with a range of technical and non-technical skills.[68]

Skills for Using Automation Technology

It is likely that the wider UK workforce will need to adapt.[69] Economists have suggested focusing training on areas where humans are likely to retain an advantage over RAS technologies.[69] The World Economic Forum (WEF) surveyed employers about how they expected skills requirements to change due to current trends such as increasing use of automation and data analytics. Despite the technological nature of many of these changes, employers predicted that by 2020 social skills (such as persuasion) would remain in higher demand than narrow technical skills such as programming or equipment operation.[70] A 2015 survey by Deloitte found that London businesses anticipated an increased demand for general digital skills, management, creativity and entrepreneurship in the next 10 years.[58]

Education and Training

The UK Commission for Employment and Skills has suggested that continuous learning and adaptation will be an essential part of successful participation in the labour market, due to the increasing rate of technological change.[71] They argue that careers may become more varied, as jobs change rapidly, increasing the need for employees to up-skill or reskill.[66] Several ways to address these challenges have been proposed by industry experts, including:[3,49,72]

- Massively Open Online Courses (MOOCs), that could allow people to take courses outside of work, at low cost, although their effectiveness is debated
- greater employer investment in on-the-job training
- forging links between businesses and educational institutions to address regional skill gaps, by providing targeted training based on business needs.

However, the WEF has raised concerns that rapid changes in skill requirements may reduce incentives for employers to invest in the re-skilling or up-skilling of low skill workers, putting them at risk of redundancy.[70]

Implications for Inequality

Concerns have been raised that automation might lead to an increase in inequality.[3,45,49,59] One scenario is that the majority of the benefits of automation (such as any wealth created) may not be felt by employees (through wage growth) or consumers (through cheaper goods and services). In the past, growth in wages, pensions and other benefits ("compensation") has reflected growth in productivity but this trend has faltered since the 1990s with the former growing more slowly for many workers.[73]

Automation is thought to have primarily affected mid-skill jobs in the recent past (Box 4). However, the studies by Frey et al. and Arntz et al. have predicted that future job losses caused by RAS will primarily affect workers in low-skill roles.[43,62] If demand for low-skill labour decreases, while high-skill workers largely benefit from new job opportunities and higher wages, then the wage gap between high and low-skill workers could drive further inequality.[3] Commentators have discussed potential policy responses to the effects of automation on the labour market, including:

- promoting work sharing (where workers work fewer hours instead of being made redundant)
- tax reforms such as increasing capital, business or consumption taxes while reducing taxes on labour (reducing the cost of employees to businesses)
- providing a universal basic income.[79,80]

Some commentators suggest that automation might encourage the 're-shoring' of manufacturing to the UK,[81] which could inhibit the development of countries with labour-intensive manufacturing, such as those in Southeast Asia.[82]

Box 4. Historical Effect On Jobs

When automation has been deployed in existing industries, productivity gains have reduced the price of goods and services, raising consumers' purchasing power and fuelling demand. This has increased the number of jobs required to meet demand and hence created more employment.[49,59] New technology has also created new types of job and demand for new services. For instance, the growth of computer use and the internet has created roles, such as web designer, which did not exist 20 years ago. Yet automation has also led to permanent job losses, often concentrated in specific jobs or sectors.[74] For example, 41% of the US workforce in 1900 worked in agriculture, but this had fallen to 2% by 2000, mainly as a result of technological change.[75]

Automation is also thought to be one of the main factors contributing to "job polarisation": a growth in the number of low-skill and high-skill jobs, alongside a reduction in the number of mid-skill jobs. This was seen in the UK and other developed countries during the late 20th and early 21st centuries.[76,77] Computers and industrial robots have contributed to this, as they have been used to automate tasks within many routine mid-skill jobs. For example, some book-keeping tasks have been automated, while demand for low-skill data-entry workers and high-skill accountants has grown.[78]

Regional Inequality

There is little research on how the future effects of automation may vary across the UK,[62] but it has been suggested that job losses could differ between regions. For example, if job losses are focused on low-skill workers, then poorer areas that have a higher proportion of low-skill jobs, may experience greater job losses. Regional differences may also be exacerbated if job creation and losses do not occur in the same areas.[83] Deloitte found that between 2001 and 2015, the Midlands, South West, and North West all experienced above average losses in jobs they considered to be at "high-risk" of automation.[62]

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