Automatic… For the people?

How Scotland can harness the technologies of the Fourth Industrial Revolution to increase economic and social prosperity

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Enlightened automation

Besides, we may observe, in every art or profession, even those which most concern life or action, that a spirit of accuracy, however acquired, carries all of them nearer their perfection, and renders them more subservient to the interests of society.

- David Hume, An Enquiry Concerning Human Understanding[1]

Technological change is constant and is a continuous influence in the evolution of our societies. But there are times in which those changes are particularly rapid and great - an era of industrial revolution.

Since the First Industrial Revolution, the invention, development and availability of machines has transformed what we do, and where and how we do it, across every aspect of daily life and work. Using these, people have produced unprecedented quantities and qualities of goods and services.

Rapid mechanisation for mass production has regularly replaced some groups of workers. However, with sustained growth in prosperity, new roles and jobs have been created, many emphasising higher decision-making, problem-solving and customer-facing abilities, using technologies and their data.

Following previous revolutionary eras which were characterised by the steam engine, electrification and computers, many believe that we are now in the middle of a Fourth Industrial Revolution. What is differentiating this era is the merging of the physical and digital worlds through the acceleration of technological breakthroughs and what McAfee and Brynjolfsson identify as three great trends[2]:

- Rapidly increasing and diversifying capabilities of machines and data-driven decision-making[3]
- Disruption of incumbent business models by asset-light, digital platform-based businesses
- Global digital interconnection enabling collaboration in decentralised online communities

Machines will be able to perform an expanding range of non-routine tasks better than people and substantially reduce the involvement of workers in business processes and customer transactions. The 'standard relationship' between humans and machines will be reversed as machines take many decisions using data and algorithms, with people in some, but not all, cases providing an input or check.

The prospect of such a fundamental transition has generated much analysis and comment about what it will mean for our lives and work. There are different views about whether new roles and jobs will be created at the right volume, time and quality to avoid technological unemployment and inequality.

Following our reports into *Digital Solutions to the Productivity Puzzle*[4] and *Smart Citizens, Smart City Regions - Delivering Digital Public Services in Scotland*[5], SCDI, BT Scotland, ScotlandIS and The RSE decided that the focus of our latest report should be this key issue: "How can Scotland harness the key technologies of the Fourth Industrial Revolution to increase economic and social prosperity?"

As before, we have approached this theme in an inclusive way. The Fraser of Allander Institute has provided a summary of the evidence on key trends in automation and digitalisation which identifies key areas of economic activity in Scotland which are most likely to be exposed to changes. We organised two cross-sectoral roundtables to discuss the impacts on people and places in Scotland. These themes are explored in two sections of the report along with case studies from our speakers. We have also reviewed what inspiration, and lessons, Scotland can draw from earlier industrial revolutions.

The three great trends of this digital revolution are unquestionably major challenges for workers, businesses and policy-makers. This report is concerned with the economy and jobs; however there is a darker side - cybersecurity, fake news, biases in algorithms and so on - which is also vitally important.

However, we believe that, through an enlightened approach, technologies like artificial intelligence, robotics and the Internet of Things can support renewed prosperity and serve the interests of society.

As this report highlights, other countries are developing strategies to be forerunners of using these technologies in the cause of economic and social prosperity. As a relatively small economy, with a range of strengths and opportunities, Scotland can take the lead in preparing its people and places to be agile and efficient adopters and adapters, as well as innovators and producers, in a digital age.

Leadership in the adoption of Industrial Digital Technologies can help Scotland and the UK to leapfrog forwards in productivity growth and international competitiveness. With additive manufacturing and customisation of products reducing cost differences and increasing the benefits of location closer to markets, jobs may be re-shored from low-wage economies. Wearable technologies could help workers improve product quality and reduce waste. This would create new jobs with new skills and higher pay[6].

In public services, the application of technologies could improve outcomes even with demographic and cost pressures. Data science could help professionals to make better decisions[7]. Doctors could use artificial intelligence systems, which review symptoms input, patient and family medical data and history, as well as research and clinical studies, to make diagnoses and recommend treatments[8]. Blockchain technology could increase the security, privacy and interoperability of health data[9].

The message is that change is inexorable. We can seek to shape it in our interests or we can continue to be unsettled by it. As this report maps out, there is much good work on these issues in Scotland and the UK which needs to be joined-up and communicated. How do we better engage all parts of the economy and society? How do we increase confidence in and create greater demand for this future?

We are very grateful to all those who have contributed their thinking to the development of this report. This is the issue of our times and we firmly believe in and encourage an enlightened approach. We look forward to working with all those who agree that Scotland urgently needs to bring a national focus to how our country can harness these technologies for prosperity and the public good.

Executive summary and recommendations

Automation and technological progress have the potential to help boost Scotland's productivity and to generate higher growth even while Scotland's working age population is forecast to fall.

Scotland's track record in research, innovation and skills - including in our universities - provides an opportunity to lead globally, for instance in FinTech, advanced manufacturing or digital technologies. Many of the new manufacturing jobs of the future will rely upon highly skilled workers, innovation and a robust services sector providing ongoing support. Just as technological change is an opportunity with challenges, some of the big challenges that we face come with opportunities. We know that many of the sectors that will be in demand from an older population are less likely to be subject to technological change but are also some of the least productive and lowest paid in our society.

Should technological change further erode the value of labour in the economy, then prospects for earnings, employment and more disadvantaged groups may become more challenging. Labour-saving technologies will displace workers. This is likely to span a much wider part of the skills distribution than before. All things being equal, this could raise unemployment. But not all things will remain equal:

- As goods become cheaper, and of better quality, this will increase real incomes. This will boost demand, which in turn will create new employment opportunities
- At the same time, technological change will automate individual tasks rather than whole jobs. So, many jobs will 'evolve' rather than disappear entirely
- Technological change will also *complement* existing tasks and create new work
- The technology sector is one of the fastest growing in the UK, and it too will create new jobs as entrepreneurs take advantage of new developments in innovation

Estimates of the scale of potential for automation vary between reports. All estimates are subject to a significant degree of uncertainty - and are naturally superficial to a degree - but they help illustrate the magnitude of possible change. **What is clear, from all studies, is that many current jobs will either be replaced or changed fundamentally by automation.**

Automation is most likely to affect jobs which involve administrative, clerical and production roles. This suggests that transport, some aspects of manufacturing and the retail sectors are most likely to be impacted. Occupations in which human interaction is a key element of the job are believed to be less likely subject to technological change - for example, social care roles.

On average, it is estimated that those with basic levels of education are at greater risk from automation. There is a concern that this could further widen income disparities.

Scotland has made strong progress on the 'pipework' of next generation digital infrastructure across the country and its Digital Strategy. However, with reference to the wider and deeper transformation of the Fourth Industrial Revolution, there is a risk that Scotland is developing policies in the dark. While there will always be uncertainty about changes on this scale, at present Scotland lacks any bespoke estimates and mapping. Recommended priorities for immediate research are:

- A more bottom-up approach to understanding what tasks and activities could be impacted by technological change and their distinct impact on Scottish firms and businesses
- The spatial pattern within Scotland and the impacts on a regional basis
- How Scottish firms are adapting their business practices in response to technological change
- The role of 'fair work' in the context of technological change

This report calls for a Fourth Industrial Revolution strategy for Scotland. It welcomes the plans for AI, data and digitalisation in the UK Industrial Strategy and Scotland's latest Programme for Government, as well as innovative initiatives like CivTech. But it concludes that there is a need for a strategy addressing technology, alongside economic and social dimensions, as is being adopted in frontrunner countries.

A national focus, led by an inclusive Scottish Commission on the Fourth Industrial Revolution

1. Scotland lacks strategic leadership for the Fourth Industrial Revolution. This is not exclusively about government. A national focus is needed on what Scotland wants to do to harness the opportunities afforded by new technologies to generate economic and social value and create national excellence. A Scottish Commission on the Fourth Industrial Revolution, including policy-makers, industry, workers, academics, citizens and young people, should be established to recommend a strategy and actions for government, parliament and delivery partners. This agenda should also be a priority for the new Enterprise and Skills Strategic Board and the implementation of the UK Industrial Strategy in Scotland.

2. Scotland needs to be a digital innovator and an agile adopter and adapter. Significant investment will continue to be needed in blue-skies and applied research, along with actions to more rapidly diffuse and adopt innovations in the economy. Scotland must pursue active participation in the relevant aspects of the Innovation Challenges and sector deals developed under the UK Industrial Strategy. Unlocking long-term opportunities in the Fourth Industrial Revolution economy should be the highest priority for the Scottish National Investment Bank. Excellence in adoption and adaption will also require skills, agile regulation and legislative changes.

Develop regional opportunities and take immediate action to support "at risk" areas

3. Regional opportunities should be a priority for regional agencies (including the new South of Scotland Agency), partnerships and future investment deals. Where this is the case it makes sense to align decision-making and resources. Health and social care challenges offer opportunities to locate more data driven technological research and innovation in post-industrial and rural areas.

4. Regions will, however, face challenges if their labour markets are more highly concentrated and there will be a need to manage risk to avoid deprivation. We should do everything we can to avoid the negative long-term effects of past eras of industrial change. Predictive action should be taken to support people and regions which may be left further behind, aligning economic and skills strategies for sectors and regions which automation may impact most.

Support local communities, businesses and social enterprises to collaborate and innovate

5. Communities should be supported to get the basics right. There are emerging examples of how this can be catalysed at a local level through collaborative 'whole-community' approaches. Experimentation should be encouraged and enabled in the physical and virtual worlds. A virtual tool could be created for communities, local businesses and social enterprises to simulate what new technologies could mean for them and inform A-B testing of ideas.

Redesign education, skills, training, lifelong learning and employment for the new world of work, to equip children from early years onwards and to re-equip the current workforce

6. Fundamental changes are necessary in education and employment. Digital literacy, data analytics and specialist upskilling, for example in AI or additive manufacturing,

are essential. In addition, as more routine and non-routine tasks are automated the demand for high level, non-cognitive skills, social skills - self-management, social intelligence, and innovation[10] - will grow. People will need entrepreneurial mindsets and a lifelong capacity to adapt to changes. Education, skills, industry and social partners need to work together to influence changes:

a. Resources should be increased and linked to system and profession-wide commitments to the development and introduction of new models of teaching and learning which are personalised and flexible around learners, like flipped-classrooms, and to the significant digital upskilling of workforces. Post-school education should provide a range of academic and vocational pathways, including accelerated routes into the labour market which develop higher-level skills including critical-thinking, work-readiness and adaptability. There should be an expansion of undergraduate and post-graduate opportunities in areas like AI and data analytics. There will be a specific need to redress long-term underinvestment in vocational education and training.

b. As a society, we should no longer view education and skills development as a high intensity, short period activity, but rather as an ongoing activity throughout a working life. Individual workers will need to take a stronger interest in developing and adapting their skills and careers. Jobs will need to be re-learned in an AI context and there will need to be support for midcareer transitions. A wide range of policies, such as tax and welfare, should be reviewed to identify what would encourage complementary commitment to and investment in technologies, employment, skills development and lifelong learning, by workers, employers and government. Nordic countries show how flexible labour markets can be combined with higher investment in active labour market policies, including strong support for career transitions and retraining.

Challenge and support businesses, and encourage 'Fair Work' technology partnerships

7. There is a pressing need to gear-up businesses. The Fourth Industrial Revolution will be highly disruptive of markets, offering opportunities, for example, for small businesses and social enterprises with innovative products and services in the global marketplace, or to re-shore production in Scotland through advanced and additive manufacturing, but there will be significant risks for digital laggards, especially if platforms capture much of the value. It could be time to focus public resources on businesses which can demonstrate commitment to increase their digital maturity.

8. Employers should develop their strategies for new technologies in partnership with their workforces. Technologies are more likely to be successfully procured and integrated when leaders, managers and workers discuss them. But there is concern that AI and data are being used in some workplaces, particularly but not only in the Gig Economy, to micromanage workers rather than improve job quality and employee wellbeing. The Fair Work Convention should develop and share best practice on employer-employee partnerships to introduce and utilise technologies and access data, including the potential for better quality of work, job redesign and upskilling, and higher performance and living standards. The Taylor Review of Modern Working Practices identified 'one-sided flexibility' for employers not employees. Action is needed now, but as AI changes the nature work it is likely that further reforms will be needed to employment law.

Take a global lead in developing safe, innovative and ethical data strategy

9. Data is fundamental to the Fourth Industrial Revolution. It is a strength of tech companies in Scotland, supported by Scotland's Innovations Centres and the Edinburgh City Region Investment in Data. Concerns about data protection and personal control are a barrier to unlocking its full potential. Scotland could differentiate itself from countries with a lax approach and take a global lead by developing AI and data, whilst ensuring data privacy and ethical use in society and the workplace. Government and industry, with economic and social partners, should urgently develop a data strategy to protect personal data and unlock the benefits of sharing data for people, organisations and networks.

Develop a 'fit for the Fourth' infrastructure, including digital and smart infrastructure

10. All parts of Scotland will require a 'fit for the Fourth' infrastructure. This means deploying the next generation of digital networks, but also making the technologies of the Fourth Industrial Revolution integral in all infrastructure, and in housing where beneficial. Smart infrastructure, including sensors, the Internet of Things, data, and robotics, can improve the performance of infrastructure, better match supply and demand, and inform the design of new infrastructure.

Keep under review and test longer-term policy options for inclusive growth

11. In the longer-term, wider policies will be required to support economic and social prosperity. Options should be kept under review and piloted. Reduced working hours, with increased job sharing and part of the reduction assigned to on-the-job training, could help to avert technological unemployment and make automation work in the interests of employees, employers and society. A Job Guarantee, offering anyone willing and able to undertake a community job at a socially inclusive minimum wage, and/or a Universal Basic Income, could be options to support displaced workers in transition between employment and retraining due to automation and a changing labour market. The planned Universal Basic Income pilots in Scotland should be designed to help test this potential role in different social contexts.

Promote Scotland's strengths in traditional industries and attractions

12. Scotland should not lose sight of non-digital opportunities. There is a need to continue to develop 'traditional' skills too difficult for machines, and Scotland is well-placed to take advantage of the market for handmade products, authentic places, digital detoxes, and so on.

The pace of change is increasing, but it need not overwhelm us. Fears must be faced, but Scotland can be confident. Being a growing, digital frontrunner economy will make it easier to deal with social challenges. Being inclusive and socially innovative will create a stronger economy, which will make a smaller market like Scotland's more attractive to the new, innovative consumer-facing industries.

Some inspiration, and warnings, from Scottish history

The democratisation of knowledge has historically helped to spread economic and social prosperity.

Scotland's pre-eminence in the First Industrial Revolution can be linked to its high commitment to educating its people. The creation of a network of parish schools following the Reformation, the foundation of Scotland's ancient universities by the end of the 16th century and growth in printing presses, libraries and bookshops in the 18th century, made Scotland "arguably Europe's first modern literate society" able "to contribute their intellectual energies to solving society's problems"[11].

A small society with widespread access to education and reading materials was able not only to produce major figures in the communities of intellectuals, philosophers and scientists of the European Enlightenment, like Hume and Smith, but broadly understand and apply the new, revolutionary ideas[12].

What distinguished Scotland in the early stages of the Industrial Revolution was not so much its inventions, but the rapid way new technologies and business and trade processes were assimilated[13].

These seemingly prosaic achievements - overshadowed by what followed - were the shoulders on which Victorian Scotland stood, pushing back the frontier of technologies. Engineering skills, initially developed in textiles, would become the basis for innovations transferred from sector to sector.

Of all the technologies key to the First Industrial Revolution, perhaps the most iconic was the steam engine, radically improved and commercialised across a range of industries by a Scot, James Watt.

Steam power did not supplant water and wind power for decades, but, critically, Scotland continued to be at the forefront of developments and deployments in the technology across industries. Most famously, from modest beginnings, the Clyde rapidly came to dominate UK and global shipbuilding with its "central early advantage" its pre-eminence in the development of steam engines for ships[14].

Steam power helped further to democratise the culture of improvement, revolutionising the printing industry, with more actions performed automatically or partly mechanically, to enable mass production of affordable books, journals and newspapers. Scotland became home to world-famous printer publishers. There was a 400% increase in printing towns[15]. Traditional industries like paper-making, which remained water powered, experienced complementary innovation and growth.

Scotland led the world in its transformation into an industrial, urbanised economy, as steam power released industries, both old and new, to locate in its rapidly growing cities and towns. Social innovations were introduced, such as New Lanark and the first trade unions, in response to these changes. However, they struggled to keep pace with, and achieve, the scale of economic innovations.

Though preserving many of its strengths in heavy industries, Scotland's economic head start, along with the UK's, would be overhauled in the Second Industrial Revolution of the late 19th and early 20th centuries. Other countries, like Germany, made greater progress in strengthening the relationship between their economies and education systems, introducing new curricula and skills development, opening up access to more in their societies, and investing more in R&D and in the new industries[16].

The Second Industrial Revolution saw electricity replace steam as the main power source in industry. Information was communicated more widely and instantly via telecommunications. However, the productivity benefits again took decades to realise as factory production was rethought and redesigned to take advantage of the potential for individually powered machines and assembly lines.

While the development of the National Grid in Britain made widely available cheap electrical power, labour productivity growth in its manufacturing sector was much slower than in the US. One reason was that British educational and apprenticeship systems were too slowly reformed to prepare young people to be trained on the job to use productively the new technologies advanced by electrification[17].

Poverty and a reliance on lower wages for competitiveness also put Scotland at a disadvantage as the local market for consumer products became key to new, light industries, like electrical goods[18].

The Welfare State and comprehensive education were introduced with the aim of improving social security and economic productivity following World War Two. There were successes in investment and diversification. Scotland's universities started to increase, open access, invest more in research and internationalise. However, Scotland's heavy industries declined and collapsed as markets changed and competitors invested in mechanised production, creating mass structural unemployment[19].

By then, a Third Industrial Revolution was in progress based on computers. Digital technologies exponentially increased the capabilities of machines and the accessibility of specialised technologies and information, initially within closed networks then globally, creating the Knowledge Economy.

Scotland's strategy was to aim for growth in the technologies of the Third Industrial Revolution. The electronics sector attracted to Scotland produced over two-fifths of its manufactured exports by the late 1990s[20]. Service industries also expanded. However, while the labour market grew, many of those made redundant from heavy industry were not re-employed as the skills demands differed.

This Information Age followed the first two industrial revolutions in taking time for the benefits to be evident in productivity growth. As information systems and networks started to be used for more radical reengineering of business processes in the 1990s this accelerated. Scottish productivity grew, albeit like the UK's, following the US's, due to less rapid investment in ICT and business redesign, and development of digital skills, and the lower tech, branch-factory profile of its electronics industry.

After the dot.com crash in 2000, the electronics production sector in Scotland quickly relocated overseas. Despite this, Scotland was in a stronger position than at the time of the decline in heavy industries, due to a more diversified economy, the long-term improvements in higher education, and a relatively successful transition of expertise from electronics into other digital technologies sectors.

In this Fourth Industrial Revolution what, if anything, can we learn from these historic observations?

- Scotland has been generally resilient and adaptable through two centuries of economic change. It has been getting better at industrial and labour market transitions, but there have continued to be negative social and regional impacts - and the pace of change is increasing
- Increasing and democratising knowledge has been a key feature of each industrial revolution. Scotland has progressed with wider access to education and better technologies and networks
- Productivity growth from new 'general purpose technologies', like steam, electricity or information technology, takes time to realise. Early leadership is key, but in smaller markets like Scotland's efficient adoption can be a platform to more cutting-edge innovations. Business models and education and skills must keep pace to unlock productivity
- Inclusive growth and social innovations can create a stronger local market, which can make smaller markets like Scotland's more attractive to innovative consumer-facing industries

The implications of automation for the Scottish economy - Fraser of Allander Institute

Introduction

There has been considerable discussion about the potential impact of technological change on developed economies.

The pace of innovation is arguably at the fastest it has ever been. Technological progress in artificial intelligence and automation is improving the speed at which goods and services can be produced and consumed. And it is also disrupting markets and making some jobs less relevant than in the past.

Whilst it is the case that both the Scottish economy and its labour market will look very different in 2050 than it does today, not all of the changes are likely to be negative.

Indeed, in the light of a shrinking working age population and weak productivity growth, technological change will provide an important new source of growth for many Scottish firms.

One thing that is clear is that technological change will alter employment patterns and many existing work activities. Some types of jobs may decline in number and may be replaced. Others will require a different skills-set.

This short note summarises the literature on technological change from the perspective of the Scottish economy.

The economic context[21]

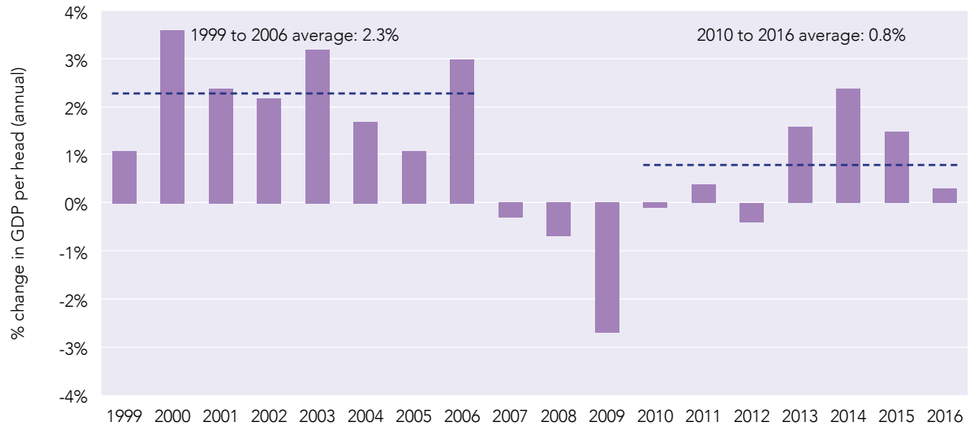
To appreciate the likely impact of technological change on the Scottish economy it is important to consider the current economic climate which sets the important backdrop for how our economy will evolve in the years ahead.

Scotland has a rich and dynamic economy. On most key indicators, such as productivity, household incomes and labour market outcomes, Scotland consistently ranks near the top in the UK on most long-term measures, behind London and the South East, and compares favourably internationally.

A considerable asset is Scotland's skilled workforce which, coupled with key strengths in sectors such as food and drink, energy, financial services, tourism and higher education, gives Scottish businesses a competitive edge.

But Scotland also faces long-term economic challenges. Some of these have become more acute over the last decade. Since the financial crisis, growth has been fragile and more recently, Scotland has been lagging behind the UK. (Chart 1)

Chart 1: Scottish economic growth (%), since 1998



Source: *Scottish Government, Q2 GDP*

Since 2015, the Scottish economy has grown by just 1.1%. This compares with growth in the UK of 4.3%[22].

Against that, Scotland's labour market has held up remarkably well - albeit, employment rates have improved more rapidly in the UK as a whole[23]. (Table 1)

Table 1: UK labour market rates, Sep-Nov 2017

	Employment (16-64)	Unemployment (16+)	Inactivity (16-64)
Scotland	74.9	4.1	21.8
England	75.4	4.3	21.1
Wales	72.8	4.7	23.6
Northern Ireland	68.1	3.9	29.0

Source: *ONS, Labour Force Survey (Dec 17)*

The improvement in headline labour market indicators has been driven, in part, by increased participation in the workforce. Participation of women has picked up strongly and is now close to an all-time high. Youth unemployment is also close to record lows.

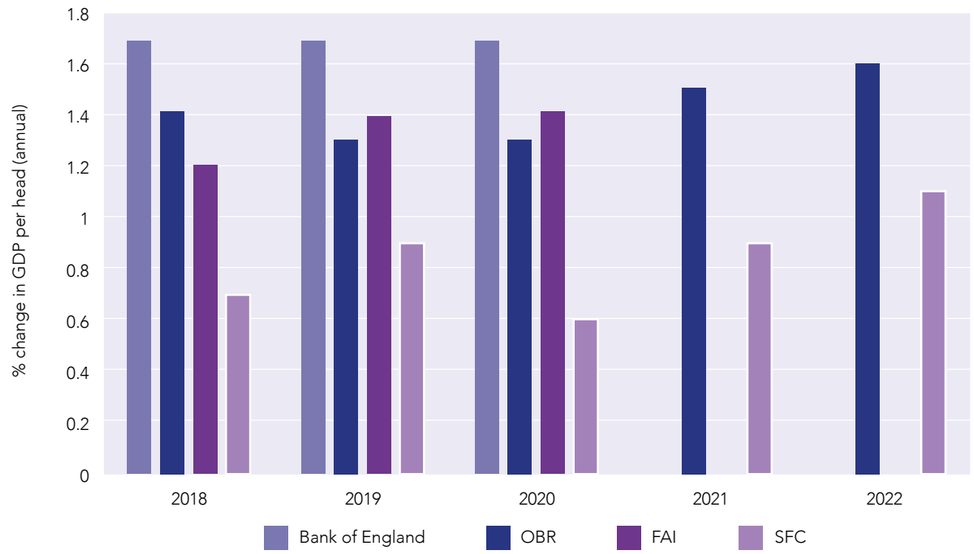
However, this has come at the cost of very weak growth in earnings. Indeed, real earnings have fallen and are not expected to return to their pre-financial crisis levels until the mid-2020s.

Underemployment remains an issue for many and there are people in jobs where their skills are mismatched or over-qualified.

Technological change has also helped to lead to a degree of hollowing out of the labour market.

The Scottish Fiscal Commission (SFC) has forecast very weak growth for Scotland well into the next decade[24]. (Chart 2)

Chart 2: Scottish Fiscal Commission forecasts and comparison forecasts to 2022



Source: *https://www.bankofengland.co.uk/-/media/boe/files/inflation-report/2017/nov.pdf, http://obr.uk/efo/economic-fiscal-outlook-november-2017/, https://www.sbs.strath.ac.uk/economics/fraser/20171212/FEC_Vol_41_No_4.pdf, Scottish Fiscal Commission and other sources (December 2017)*

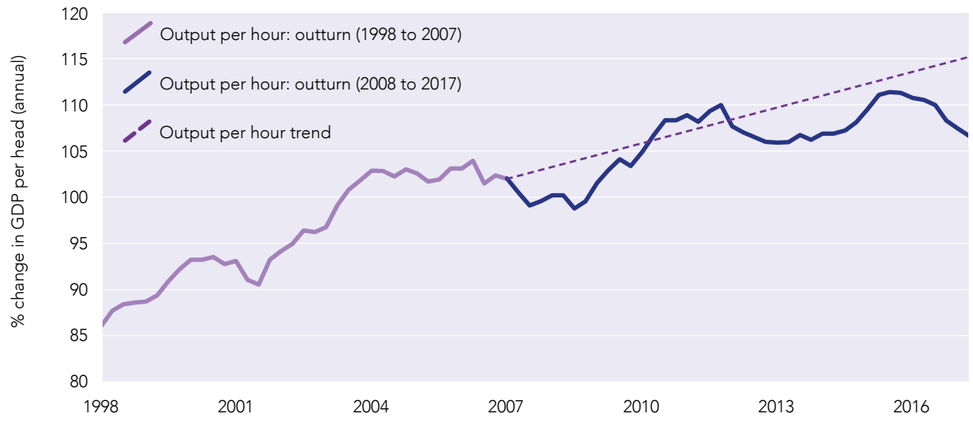
This outlook is driven by a number of factors, but in particular the SFC's growth forecast reflects a weak trajectory for both productivity and Scotland's working age population.

In recent years, Scottish and UK productivity growth has been much lower than prior to the financial crisis[25]. (Chart 3)

Some economists are pessimistic about the long-term outlook, believing that we have entered an era of weak productivity growth[26]. Others argue that we are on the cusp of a productivity boom driven by automation, artificial intelligence and the growth of the digital economy[27].

Whether you are a pessimist or an optimist it is clear that - without significant change - both Scotland and the UK face a considerable long-term productivity challenge.

Chart 3: Scottish productivity since 1988 - trend vs. outturn

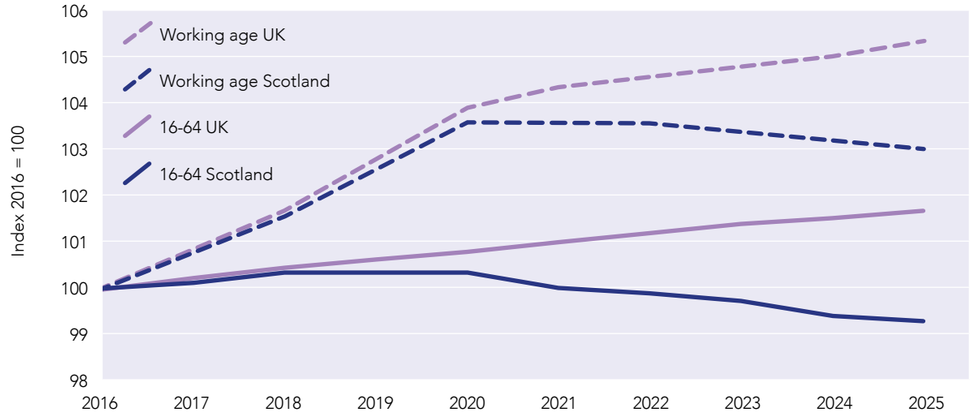


Source: *Scottish Government, Q2 productivity statistics*

Over the longer term, there remains a gap in productivity levels between Scotland and the top performing nations - of around 20% according to the most recent statistics.

The other key reason for the SFC's weak outlook is the trajectory for Scotland's working age population. (Chart 4)

Chart 4: Principal projections for population - Scotland and the UK



Source: *https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea16principalprojectionscotlandsummary, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea16principalprojectionscotlandsummary*

On the one hand, automation and technological progress offer some positive news against such a backdrop: they have the potential to help boost productivity and to generate growth even while Scotland's working population is falling.

Against that however, should technological change further erode the value of labour in the economy, then prospects for earnings, employment and more disadvantaged groups in the labour market may become more challenging.

How might technological change impact on the Scottish economy?

Technological change is already changing the way in which goods and services are produced and consumed. Individuals now have unprecedented levels of information and analysis at their finger-tips, enabling them to compare prices, provide feedback and shift their custom.

Perhaps the mechanism through which technological change may impact on the economy that is discussed most often is whether or not it will have a positive or negative impact on future employment trends. On the one hand, labour-saving technologies will displace workers. All things being equal, this could raise unemployment.

But on the other hand, not all things will remain equal.

As goods become cheaper and of better quality, this will increase real incomes. This will boost demand which in turn will create new employment opportunities. At the same time, technological change will automate individual tasks rather than whole jobs. So, many jobs will 'evolve' rather than disappear entirely.

Technological change will also complement existing tasks and create new work as well - for example, technologies that lead to better diagnosis of illnesses etc.

The technology sector itself is one of the fastest growing in the UK, and it too will create new jobs as entrepreneurs take advantage of new developments in innovation.

Of course which of the various effects dominates will have important implications for the outlook for the Scottish economy. But clearly the story is much more complex than simply 'machines replacing workers'.

One thing that is clear is that whatever the net effect on overall employment rates in the economy, the costs and benefits to individual workers – and sectors of the economy - will vary quite significantly. Indeed, we have already witnessed a substantial hollowing-out of the labour market in recent years and, in many economies, the amount of income that flows to workers has been falling.

What might be the scale of the impact?

As has been well documented, technological change - and in particular automation - will bring both challenges and opportunities to Scotland's economy in the years ahead.

Technological change has been a feature since the industrial revolution. Particular jobs, products and even market-places have been replaced by machines and other forms of automation.

But the technological developments that are taking place today suggest that a wider proportion of jobs could be impacted. For example, the collection and use of big data, advanced information processing, artificial intelligence and 3D printing has the potential for more jobs, including those that involve more complex interactions and judgement, to be impacted.

Automation is therefore likely to span a much wider part of the skill distribution than before.

Estimates of the scale of potential for automation vary.

All jobs are likely to be impacted by technological change in some way or another. But some will be changed more than others, and many current tasks may be replaced completely.

Exploratory research by Frey and Osborne (2013)[28] tried to quantify the potential impact of technological change by assigning probabilities to certain classes of job being automated.

Frey and Osborne used information from machine learning experts to identify the extent to which particular occupations were at 'risk' of automation. They found that 47 per cent of jobs in the US could be seen as having a high potential to be automated.

Similar results are found elsewhere. For example, PwC has estimated that up to 30 per cent of roles within the UK could be subject to greater automation by the 2030s (PwC 2017)[29].

The Bank of England has calculated its own estimates for the UK, matching the Frey and Osborne probabilities to the UK structure of jobs[30]. Taking these estimates, and multiplying them by the numbers currently employed, led them to conclude that up to 15 million jobs could be at risk of automation.

Table 2: Per cent of employment at risk of automation

Risk of automation	US (Frey & Osborne – 2013)	UK (Bank of England)
Low (<33%)	33	37
Medium (33-66%)	10	28
High (>66%)	47	35

Source: *Frey and Osborne (2013) and Bank of England (2015)*

Other researchers, for example Arntz, Gregory and Zierahn (2016) at the OECD, estimate that only around 10% of jobs are under a 'high risk' of automation on average[31]. They base this conclusion on the reasoning that any predictions of job automation should consider the specific tasks that are involved in each job, rather than the classifying occupations.

US economist David Autor from MIT has argued that the replacement of labour activities by machines is likely to be less than many of these studies suggest[32]. He argues that ultimately there will be a mix of automation and on-going demand for workers with a wide skills-set (particularly in areas where workers hold an advantage over machines such as interpersonal interaction, adaptability and problem solving).

A survey for the RSA of UK business leaders found that 15 per cent of private sector jobs in Britain have the potential to be fully automated in the next decade - albeit there was a wide variation amongst respondents[33].

Some estimates for the potential impact of automation on the Scottish economy have been undertaken.

For example, IPPR Scotland (2017) estimate that "just under half of all jobs (46.1 per cent) fit into the 'high potential' category of seeing automation over the coming decades".

This is equivalent to around 1 million jobs. This is broadly in line with what a per capita share - or GVA share - would suggest from the Bank of England study for the UK as a whole.

In the chart below, we apply the shares calculated for jobs at risk at the UK level by PwC (2017) and apply that to Scotland[34]. (Table 3) For the purposes of illustration, we multiply these shares by current jobs in each sector for Scotland.

It should be noted that these estimates are subject to a significant degree of uncertainty - and are naturally superficial to a degree - but they help illustrate the magnitude of possible change.

The timing of any changes is highly uncertain. Talk of widespread replacement of current jobs is wide of the mark. Moreover, some jobs - whilst technically feasibly subject to technological change - might still not be impacted for legal and regulatory reasons.

It should also be remembered that technological change will create new jobs and/or existing jobs may evolve to take advantage of a mix of automation and worker input (as argued by David Autor). The above estimates focus on current jobs, rather than the new jobs created.

Table 3: Employment shares, PwC estimated proportion and total number of employees at potential high risk of automation for industry sectors

	Number employed in Scotland	%	UK % for comparison	Job automation (% jobs at potential high risk)	Jobs at high risk of automation
Agriculture, forestry & fishing	67,000	2.4	1.3	19%	12,529
Mining & quarrying	35,000	1.2	0.2	23%	8,085
Manufacturing	192,000	6.8	7.6	46%	89,088
Electricity & gas	22,000	0.8	0.4	32%	6,996
Water supply etc.	17,000	0.6	0.6	63%	10,642
Construction	180,000	6.4	6.6	24%	42,660
Wholesale & retail	380,000	13.4	14.1	44%	167,200
Transportation & storage	131,000	4.6	5.1	56%	73,884
Accommodation & food	214,000	7.6	6.9	26%	54,570
Information & comms	100,000	3.5	4.1	27%	27,300
Finance & insurance	91,000	3.2	3.2	32%	29,302
Real estate	39,000	1.4	1.6	28%	10,998
Professional, scientific & technical	190,000	6.7	8.7	26%	48,640
Administration	206,000	7.3	8.8	37%	77,044
Public administration	167,000	5.9	4.2	32%	53,607
Education	201,000	7.1	8.3	9%	17,085
Health & Social work	400,000	14.2	12.4	17%	68,000
Arts, entertainment and recreation	108,000	3.8	2.9	22%	24,084
Other services	82,000	2.9	2.7	19%	15,252
Activities of households as employers	4,000	0.2	0.2	8%	324
	2,826,000				**837,290**

Source: *PwC (2017), ONS Workforce Jobs, FAI calculations*

What sectors will be impacted?

Automation is most likely to affect jobs which involve administrative, clerical and production roles. Whilst generalising to sectors is difficult, this suggests that transport, some aspects of manufacturing and the retail sectors are most likely to be impacted. (Table 3)

The RSA reports that the UK has just 33 robot units for every 10,000 employees, compared with 93 in the US and 213 in Japan. Whilst this needs to be viewed within the context of the UK having a smaller manufacturing sector than the other countries, we also know from wider evidence on business investment that the UK lags behind competitors[35].

According to PwC's analysis[36], 44 per cent of wholesale and retail jobs are at high risk of automation. The outlook for retail is important as it is not only a major employer but also has important inclusive growth elements to it (both from a low income and regional growth perspective).

In general, occupations in which human interaction is a key element of the job are believed to be less likely to be subject to technological change. For example, social care roles rely on social and human interaction.

On average it is estimated that those with basic levels of education (the new Scottish National qualification level) are at a greater risk of automation. There is a concern that this could further widen income disparities.

What analysis is now needed?

Much of the research that has been undertaken so far into the potential impacts of technological change on the Scottish economy has taken UK wide analysis and applied it to Scotland's unique industrial structure. This can only take us so far.

A more bottom-up approach to understanding what tasks and activities could be impacted by technological change and their distinct impact on Scottish firms and businesses would be beneficial.

At the same time, much of the analysis thus far has concentrated on the jobs 'at risk' from technological change. But, as highlighted above, many new jobs will be created. Existing jobs will change but remain important. Understanding the opportunities and reforms needed to take advantage of these opportunities is important.

We also know little about the spatial pattern within Scotland and the impacts on a regional basis.

We also know that many businesses are already responding to technological change and adapting their business practices. Research into how firms are evolving their current structures and organisations would be helpful.

The role of 'fair work' in the context of technological change is another area for research, with the prospects for clear policy recommendations.

Emerging strategies for AI and the Fourth Industrial Revolution

Around the world, governments, working in partnerships with industry and civic organisations, are starting to set out their economic and social strategies for the Fourth Industrial Revolution.

Competition between economies will not only be in technological innovation. They will also compete for leadership in the development of regulatory regimes around AI technologies and applications.

AI is one of three technology pillars in the European Industry Strategy[37] and a strategy on robotics and AI is planned for early 2018, including business and societal benefits, and ethical, legal and socio-economic aspects[38]. The EU Commission says that "Europe's challenge will be to help workers gain the right skills. We do not want a situation where there are obvious 'winners' and 'losers' from the digital economy. People who risk losing their job because of digitisation need - and deserve - our help."

In Germany, Industrie 4.0, championed by Chancellor Angela Merkel, is the 10-15 year strategy to advance the adoption of new digital technologies in all parts of German industry, with a strong emphasis on data. This was developed through the 'Rhineland capitalism' approach in which a year-long inquiry involved discussions between policy-makers, industry, academics and social partners[39]. Robots are far more prevalent in its workplaces than in other economies outside Asia, but manufacturing's share of employment remains relatively high[40]. Federal departments are exploring aspects of AI, such as ethics of self-driving cars, the impact on the world of work, and drones[41].

The French Prime Minister Edouard Philippe has commissioned a national AI strategy, to ensure economic benefits but also equality and social justice, to be published in February[42]. Estonia is exploring the use of AI in healthcare, administration, finance, legal, situational awareness in security, and other areas, and has a strong focus on a public discussion on the ethics, liability, integrity and accountability[43] of algorithms, recognising that these will very soon be part of everyone's daily life[44].

China aims to be the world leader in AI by 2030, with the size of its data sets its greatest asset due to more internet users than the US and Europe combined[45]. Its National Plan also explicitly recognises the need for regulatory, legal and ethical principles[46]. Japan's Fourth Industrial Revolution Council has developed a vision for the society and economy for 2030, with specific strategies for the use of new technologies, AI and the Internet of Things in mobility, supply-chains, healthcare and living, to boost productivity and establish new economic, employment and social systems[47]. The UAE recently appointed a Minister of State for AI and published an AI strategy with the vision of being the world's most prepared country, aims across a range of sectors, and themes of innovation, providing all services via AI and full integration of AI into medical and security services, and developing skills[48].

Finland

In May 2017, the Finnish Minister of Economic Affairs appointed a steering group on AI. The group has proposed a vision that Finland should be "brave and ethical forerunners", "AI is actively used by every Finn daily in the future", and that "AI renews work and creates prosperity by growth and productivity"[49]. It has suggested eight key actions for taking Finland towards the age of AI[50]:

1. Enhancement of business competitiveness through the use of AI
2. Effective utilisation of data in all sectors
3. Ensure AI can be adopted more quickly and easily
4. Ensure top-level expertise and attract top experts

5. Make bold decisions and investments
6. Build the world's best public services - healthcare a particularly promising field
7. Establish new models for collaboration
8. Make Finland a frontrunner in the age of AI

In the UK, the recently-published Industrial Strategy[51] aims to support the development of new technologies and position the UK at the forefront of the industries of the future. The first of four Grand Challenges is to put the UK at the forefront of AI and data. This followed an industry-led review of AI for the UK Government on how to grow the industry[52]. AI and data also links to the other three Grand Challenges: clean growth, the future of mobility and an ageing society. The four priorities for AI are:

- Making the UK a global centre for innovation
- Supporting all sectors to boost their productivity through AI and data - with an industry-led AI Council to take a leadership role, supported by a new government office for AI
- Leading the world in safe and ethical use of data and AI - with investment in a new Centre for Data Ethics and Innovation to work with regulators, the industry and government
- Helping people develop the skills needed for jobs of the future

The UK's Behavioural Insights Team's Data Science team tests and trials ideas for using data science in policy. Suggestions in its first report include social workers could use a digital tool, which analyses their notes using natural language processing, to better predict which children are most in need of protection or care and help to manage their caseloads. Inspectorates could bring together their own data, information on local communities, and patient and parent views, to identify which GP practices or schools are priorities, helping to improve community health or close the attainment gap[53].

The Scottish Government's most recent Programme for Government[54] states an intention to make Scotland a country that will lead change in the revolutionary technologies of AI, machine learning, data analytics and low carbon energy, and reap the economic rewards it will bring. The Scottish Government wants to harness this change for the good of all and deliver a step-change in productivity and innovation, by driving the proliferation of digital infrastructure and supporting world-class tech-clusters. It will support manufacturers to develop their own 'Manufacturing 4.0 Improvement Plan'. Digital skills are a high priority, along with preparing the workforce to adapt to the risks to jobs of automation and digitalisation, and seizing their potential to enhance, de-risk and create new work. The Scottish Government has also published an expert report on the collaborative economy[55].

The Scottish Government's CivTech programme provides the opportunity for entrepreneurs to use their digital innovations to create solutions to challenges faced by Scottish public services. The model has proved successful and the UK Government recently announced a similar GovTech programme.

Further links to related strategies, reports and programmes are mapped later in this report.

Scotland is a small part of the global economy and it will be deeply influenced by what happens in other countries and in industry. At present, there is evidence that Scotland and the UK lag behind global frontrunners in AI, partly as it is more prevalent in manufacturing and the share of manufacturing in economic output is higher in many other leading economies than it is in Scotland and the UK.

However, we believe that there are solid reasons for Scotland to be confident about developing a strategy which can have a disproportionately positive impact. We base this on Scotland's strengths and opportunities, its potential to catch-up, and the good examples highlighted in our discussions.

Scotland's universities have a global reputation for AI. The expertise at the Edinburgh Centre for Robotics and Edinburgh University's Artificial Intelligence Applications Institute is being expanded, and Scotland has particular sectoral strengths such as autonomous underwater inspection vehicles in the oil and gas sector provided by companies such as SeeByte and Forum Energy Technologies. A key opportunity for Scotland's tech sector is to collaborate further with research institutions to develop AI products and solutions for all parts of the economy, including for smaller companies.

Data underpins all AI and automation. Data (management, analytics, generation through sensors, and so on) is already a strength of Scotland's tech companies, supported by the Innovation Centres, CENSIS, and The Data Lab. Data intensive businesses in Scotland - such as SAS, Skyscanner, Nucleus Financial, Amazon Development Centre - are using AI to provide more sophisticated products and customer solutions, and growth in this market offers major opportunity for Scottish companies.

Concerns about data protection and personal control are a barrier to unlocking its full potential and Scotland could benefit from taking a global lead by developing AI whilst ensuring data privacy. Scotland's well-developed cyber security sector would be instrumental in this. The global demand for cyber security innovation will only escalate which will support the growth of this sector in Scotland.

Scotland is also developing its expertise in financial technologies and mobility underpinned by digital technologies. Its heritage as a world leader in financial services combined with its innovative tech sector facilitates the growth of its FinTech ecosystem. Launched last year, MaaS Scotland is the largest Mobility as a Service network in Europe, positioning Scotland, based on its capacity in ICT, energy and transport, to play an active role in the global development of personalised mobility solutions[56].

Scotland already leads the UK in developing new applications for health and social care. Given Scotland's demographic, public health and rural and remote area service delivery challenges, there will be a strong demand for innovation, from wearables which monitor health statistics to more diagnostic telecare technology, to the provision of personalised care in homes and communities.

The potential overall benefits are game-changing. Accenture has suggested that AI could be a "new factor in production", catalysing a broad structural transformation. AI would drive growth by creating a new virtual workforce, complementing and enhancing the skills and ability of existing workforces and physical capital, and more rapidly diffusing innovations. For the UK, Accenture forecasts a 25% increase in labour productivity with AI, compared to expected baseline productivity levels in 2035[57]. McKinsey finds that digitally-enabled automation and AI have the potential to bring an uplift in digital front-runner country GDP growth of about €550 billion, or about 1.2% per year from 2016-2030[58].

For Scotland and the UK, the dominance of the services sector in the economy will make realising the benefits of AI in it especially important. Adoption of AI is being deepened within frontier parts of the sector like e-commerce and expanded across other human services through, for example, the automation of administrative tasks or the use of chatbots to interact with customers. This can increase workers' productivity, reduce costs, improve decision-making, and personalise services to users[59].

There is also the potential to revitalise manufacturing. With additive manufacturing and customisation of products reducing cost differences and increasing the benefits of a location closer to markets, production and jobs may be re-shored from low-wage economies[60], especially if the Scottish market is prosperous and attractive for sales. The creation of the new National Manufacturing Institute for Scotland by the Scottish Government, University of Strathclyde and partners, could help to raise Scotland's game in the adoption of Industrial Digital Technologies to reindustrialise the economy. There are also opportunities in primary production, including food and oil and gas. For instance, as the industry faces workforce shortages and environmental challenges, 'precision agriculture' technologies, including robotics and data, can increase production and reduce use of water, fertiliser and pesticides.

Leadership in business is a theme to which all those who participated in this work returned - its importance cannot be overstated. UK business leaders are reported to feel less ready

to implement new organisational models, the augmented workforce and robotics, cognitive computing, and AI than those in other European countries and China[61]. The ideal would be for everyone in Scotland to be on the digital journey, but there is some frustration that after many years of offering support for development there are still too many disengaged businesses[62]. Local partnerships of public services, businesses and the third sector can help to encourage laggards through peer-learning, but it could be time to focus resources on those which are willing to keep pace with the latest technologies and to introduce more conditionality into government support for businesses - for example for trade visits - on having a digital strategy.

This report calls for a Fourth Industrial Revolution strategy for Scotland. It welcomes the plans for AI, data and digitalisation in the UK Industrial Strategy and Scotland's latest Programme for Government, as well as innovative initiatives like CivTech. But it concludes that there is a need for a technology strategy, inclusive of economic and social dimensions, as is being adopted in frontrunner countries.

Recommendations

- Scotland lacks strategic leadership for the Fourth Industrial Revolution. This is not exclusively about government. A national focus is needed on what Scotland wants to do to harness the opportunities afforded by new technologies to generate economic and social value and create national excellence. A Scottish Commission on the Fourth Industrial Revolution, including policy-makers, industry, workers, academics, citizens and young people, should be established to recommend a strategy and actions for government, parliament, and delivery partners. This agenda should also be a priority for the new Enterprise and Skills Strategic Board and the implementation of the UK Industrial Strategy in Scotland.

- Scotland needs to be a digital innovator and an agile adopter and adapter. Significant investment will continue to be needed in blue-skies and applied research, along with actions to more rapidly diffuse and adopt innovations in the economy. Scotland must pursue active participation in the relevant aspects of the Innovation Challenges and sector deals developed under the UK Industrial Strategy. Unlocking long-term opportunities in the Fourth Industrial Revolution economy should be the highest priority for the Scottish National Investment Bank. Excellence in adoption and adaption will also require skills, agile regulation and legislative changes.

- There is a pressing need to gear-up businesses. The Fourth Industrial Revolution will be highly disruptive of markets, offering opportunities, for example, for small businesses and social enterprises with innovative products and services in the global marketplace, or to re-shore production in Scotland through advanced and additive manufacturing, but there will be significant risks for digital laggards, especially if platforms capture much of the value. It could be time to focus public resources on businesses which can demonstrate commitment to increase their digital maturity.

- Data is fundamental to the Fourth Industrial Revolution. It is a strength of tech companies in Scotland, supported by Scotland's Innovations Centres and the Edinburgh City Region Investment in Data. Concerns about data protection and personal control are a barrier to unlocking its full potential. Scotland could differentiate itself from countries with a lax approach and take a global lead by developing AI and data, whilst ensuring data privacy and ethical use in society and the workplace. Government and industry, with economic and social partners, should urgently develop a data strategy to protect personal data and unlock the benefits of sharing data for people, organisations and networks.

- Scotland should not lose sight of non-digital opportunities. There is a need to continue to develop 'traditional' skills too difficult for machines, and Scotland is well-placed to take advantage of the market for handmade products, authentic places, digital detoxes, and so on.

Digital people

As this report has highlighted, the democratisation of knowledge has historically helped to spread economic and social prosperity. The expansion of education and the printing revolution accelerated the Enlightenment and the First Industrial Revolution, with Scotland at the forefront of them all.

Technological advances have overwhelmingly been positive for society. Populations have grown, productivity and wages have increased, hours worked have fallen and living standards are far higher.

However, workforce transitions due to technological changes can create lower employment and wages in some occupations. This can foment social inequality, discontent and disruption.

Technological advances from the Third Industrial Revolution have been a key factor in the growth of the service economy and the long-term decline in the manufacturing workforce, which is now more highly-skilled but offers far fewer opportunities, especially for people in formerly industrial communities. Technologies have also been a key driver of the decline of labour's share of national income and rising inequality[63]. Many new, highly-skilled jobs have been created, including in the tech sector. More people have the opportunity to work flexibly, whether in employment or self-employment. However, there is also high concern about whether the Gig Economy - short-term work by independent contractors often arranged on digital platforms - is increasing exploitation.

Research by IPPR[64] and IPPR Scotland[65] on the labour market confirms a polarised picture:

- High employment and low unemployment
- Significant increases in the qualification level of the working age population
- Weak productivity… with comparatively low levels of demand for, investment in and utilisation of skills
- Skills mismatch between the demand for and supply of entry-level mid-skills workers
- Low pay and in-work poverty… with especially low productivity in low-wage sectors
- A chronic progression gap from low-skilled jobs… with an even lower proportion in Scotland
- Lack of high-quality vocational training
- Regional skills imbalances

There has been a long-term underinvestment by the private and public sectors in workforce training and this has been falling further. Scotland invests heavily in education and skills, but the focus has been more on young people and less on vocational training for those in work and the labour market. With nearly 80 per cent of the existing workforce still of working age by 2030[66], this is a concern. Scotland and the UK are not alone in many of these challenges, but they are greater and more urgent because of other long-term challenges for the labour market like demographic change and Brexit.

The Fourth Industrial Revolution can be viewed as a new revolutionary democratisation of knowledge. While an estimated 130 million books have been published in human history, the portion of the web visible to modern search engines had grown to 45 billion pages by 2015[67]. Knowledge which was until relatively recently available only in large academic libraries, can now be accessed and shared by people around the world at any time via a mobile phone. Decentralised networks can collaborate to add to the sum of human knowledge. Now, with the advances in AI, a new source of intelligence, with incredible potential, is available.

However, a significant minority in society are not online because they do not have the skills or cannot afford access. They do not benefit from the positives of the digital economy, such as online deals, social networks and knowledge, and are more likely to be affected by job displacement and any poor employment

practices. Technological change risks magnifying their economic and social exclusion.

The Fraser of Allander's analysis provides an overview of the evidence, but we also need to look more closely at the workplace. What are the opportunities which could be harnessed and risks to avoid?

Automation and digitalisation in the workplace… perceptions of positives and concerns

What is happening?

- Computers have long substituted for humans in routine tasks.
- Computers are now substituting for human in an increasing range of non-routine tasks:

  1. Cognitive domains e.g. medical, legal, financial judgements
  2. Manual domains e.g. robots, cars

For example, the new Forth Valley Royal Hospital[68] and Queen Elizabeth Royal Hospital[69] were both designed for the use of robots in certain tasks, such as the movement of medical supplies, linen, food and waste around the hospital, and the dispensing of medicines from the pharmacy.

Positives

Improving the quality of work

- There will be fewer tedious, physically tiring and hazardous elements of work for people.
- Technologies enable humans to focus on the tasks that add most value and help them to be more productive in their jobs. Examples include use of collaborative robots (cobots) to work on low-value add activities and AI to provide additional information quicker.
- New tools for workers and employers to understand and improve performance. New platforms for communication and collaboration across the workforce.
- More flexibility and control for people over their working lives, for example in making decisions about when, where and how they want to work to better fit with their lifestyles or other commitments including caring, or to help to maximise their earnings.

Better service for users and customers

- Robots/AI can do repetitive tasks without the errors that humans inevitably make.
- New technologies such as wearable technologies and sensors can make gathering and interpreting data much easier, freeing-up staff to engage with users or customers.
- Blockchain could provide real-time, accurate, confidential information in public services[70].

Inclusive and sustainable growth

- Faster productivity growth due to higher labour productivity and to new products, services and opportunities, increasing economic prosperity and creating new jobs.
- Growing demand for digital skills across the economy in almost 90% of new jobs.
- Replacement of jobs lost with other jobs e.g. retail jobs with delivery and warehouse jobs - although these jobs may themselves become increasingly vulnerable to automation.
- AI can improve recruitment processes and make them fairer.
- A wider range of workers, such as older or disabled workers, can be more productive.
- Greener, more resource-efficient production[71].
- Reshoring of production, creating demand for additive manufacturing skills.
- Personalisation of services and customisation of goods, with lower costs to consumers, improving the living standards of all who can access them, including workers.

Concerns

- Technological unemployment.
- Job insecurity as more people find their skills obsolete at ever younger ages.
- Deskilling of occupations, reducing pay.
- Ever more limited job opportunities for those lacking digital skills.
- Roles become solely a complement to the machines/automated system.
- Flexibility operating one-way i.e. precarious work, lower pay, fewer rights and protections.
- AI could be used to intensify command and control forms of leadership and management. It may micromanage workforce performance and behaviours, such as time-keeping, but not workforce wellbeing, such as working hours, engendering negativity in workplaces.
- Further decline of labour's share of national income and further polarisation between high and low skilled workers as lower-skilled jobs are automated at a faster rate and high-skill workers are better able to adapt to change, aggravating social inequalities[72].
- Exacerbation of gender, regional and racial inequalities should women, some regions and ethnic minorities continue to be under-represented in these high-skill occupations.
- Algorithmic systems may also generate biases e.g. in recruitment and promotion.

So, how might Scotland make tech work for workers?

Digital skills will self-evidently be essential. People will need to be able to work alongside, and manage, technologies including robots. Data skills may have a 'halo effect', positively influencing all other skills. Though concerted action is being taken on the major shortage of digital skills, with demand increasing and new specialisms, such as AI and additive manufacturing, it may be the greatest barrier to adoption and our ability to shape these technologies.

Research has found that, in addition to such specialist skills, as more routine and non-routine tasks are automated, people and service skills will be of growing importance across a range of occupations. Creativity will also be highly prized. Employment in the public sector is forecast to grow, especially in roles related to demographic change and the education, training and retraining of the new workforce. Even in occupations in which overall employment is expected to fall, STEM, interpersonal and customer skills are expected to be key differentiators for more successful workers and workforces[73].

In a complex world, with organisations reorganising rapidly in response to the new technologies and markets, the demand for managers who understand the changes, can communicate both ways with leaders and frontline workers, and encourage and enable the collaborative effort will be higher[74].

Education and training should focus on skills which cannot be easily automated - including some 'traditional' skills for which there will continue to be a steady and, in some cases, increasing demand.

In its 'Skills for the Future' project[75], Skills Development Scotland, in collaboration with the Centre for Work-based Learning, is working with education and industry to understand the skills needed for the future.

'Skills for the Future' has identified self-management, social intelligence and innovation, and related skills, as key requirements for the future[76]. These are summarised following this section of the report. It is critical that education, skills and business should engage with the learnings from this project and work together to influence the changes which are necessary in the wider skills system and economy.

Education needs a fundamental rethink from early years to life-long learning. There continues to be a consensus that the aim and principles of design for the Curriculum for Excellence are right for the opportunities and challenges of life and work in the 21st century. However, its impact is falling short.

The Fourth Industrial Revolution economy is likely to value those with key skills, but also those with trained minds, a broad education and interdisciplinary learning, and a comprehension of ethics[77]. To make lifelong progress, people will need entrepreneurial mindsets and a capacity to adapt to changes.

The national shortage of computer science teachers is a barrier to more young people developing higher level digital skills. Should the bursaries announced by the Scottish Government[78] to attract people to change careers and train to become teachers not close this gap, consideration should be given to strengthening mathematics education and mainstreaming digital skills education through all subjects. Data analytics is an area of learning which should equally be part of all subjects. Creativity will be an increasingly important complement to technical skills and the arts should come together with STEM subjects to develop STEAM resources. The inclusion of early years learning and childcare in Scotland's new STEM strategy is welcome.

To nurture wider attributes will mean experimentation in the classroom and curriculum, underpinned by raising teachers' capabilities, assessing in more relevant ways and enlisting more parental support.

It will require increased resources, including investment in teachers. However, this needs to be linked to a profession-wide commitment to significant digital upskilling and the development of new models of teaching as part of education reform and the national focus on closing the attainment gap. This could include, for example, a transition to a flipped classroom model in which homework involves watching online lessons, while classwork involves interaction between teachers and pupils or students which explores topics in greater depth and aims to develop higher-order thinking and teamworking skills. The personalisation of education will be taken a stage further when AI enables online platforms to closely match the content it delivers with the progression of the individual pupil or student[79].

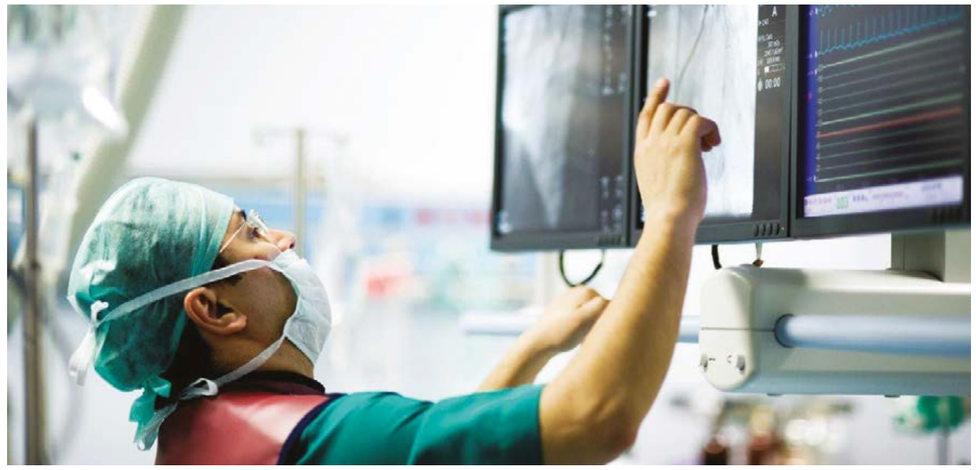
Young people are enthusiastic about challenges and engaging schools in real-life issues for their places and local businesses, and world, can prepare them for life and work - and lead to innovative solutions.

Post-school education should then provide a range of academic and vocational pathways into the labour market which develop higher-level skills including digital skills, work-readiness and adaptability. These should offer new models of learning, including accelerated routes, so that they are personalised and flexible around people's lives, work and goals. This will promote diversity in study and work.

The value in the Fourth Industrial Revolution economy of the higher-level, broad-based, critical-thinking which is developed in university education should be clear. Microsoft says: "If AI is to reach its potential in serving humans, then every engineer will need to learn more about the liberal arts and every liberal arts major will need to learn more about engineering [80]."There is a particular need to expand undergraduate and post-graduate opportunities in areas such as AI. It will also be essential that Scottish universities can continue to attract student, teaching and research talent post-Brexit.

At the same time, the need to redress long-term underinvestment in vocational education and training, including further education and apprenticeships, is widely supported. Conversion courses, such as Scotland's digital skills academy CodeClan can also help to meet industry needs.

We will work in an era when people find no market for their skills at earlier stages of their careers. Humans have no hope of winning a skills arms-race with robots, so midcareer



retraining(s) will be essential for many. There is a need to invest in and create a culture of lifelong and on-the-job learning.

Proposals for this include a 'Personal Training Credit' to support low-paid and low-skilled individuals to invest in their training and career, and a 'Personal Retraining Allowance' for workers who are made redundant and need to invest in upskilling[81]; extending tax breaks and allowances for capital to a generalised tax break for "skills investment"[82]; funding the up-front costs of education or training for anyone that needs it, at any point in their life, with greater repayments from those who go on to earn the most[83]; a 'flexicurity' social contract based on Denmark's model, combining a flexible labour market for employers, with high levels of pay as former employees job search and a generous training regime[84]; and providing a modern digital delivery platform with upskilling and reskilling content[85].

The costs of universal availability of high-quality, diverse, constantly-updated retraining opportunities would be great. Employees, employers and society would all benefit from them and could be expected to contribute. The Taylor Review and many others have suggested that the Apprenticeship Levy should be reconfigured into a wider and more flexible 'skills levy'[86]. Employers should also take a lead by ensuring that employees have time for and access to life-long learning and on-the-job training.

The costs of this need to be considered over a longer timescale, with a view of the whole economy and with reference to countries such as Singapore that are already investing in reskilling programmes.

As a short-term measure, the information and advice which is available to workers on midcareer progressions and changes on Scotland's excellent 'My World of Work' resource could be boosted.

It would be futile to change the education and skills systems if people enter workplaces in which a top-down structure prevails, and which does not empower them to make best use of their capabilities. They risk to quickly lose their skills and their motivation. Successful businesses will re-architect their ways of working, and this should include both their workforce and workplace strategies. Workers should be encouraged to rethink conventional concepts of work and think more like customers.

Employers should develop their strategies for new technologies in partnership with their workforces. There is evidence that technologies are more likely to be successfully integrated when leaders, managers and workers are all involved in the adoption process. This can improve procurement of the technologies which would have the greatest benefits, and acceptance and utilisation in the workplace. Positive communications between leaders and frontline staff can support the continuous incremental innovations which, over time, builds productivity.

Financial incentives to invest in new technologies should be improved. The forthcoming review of plant and machinery

valuations in the business rates system[87] will offer an opportunity to stimulate higher investment. We should aim for more of these decisions to be co-developed with workforces.

The Scottish Government's Strategic Labour Market Group[88] should make analysis of digitalisation and automation its priority. Informed by this work, Scotland's Fair Work Convention[89], bolstered by employer leaders, should produce best practice for co-development of technologies in the workplace. A priority could be lower productivity sectors in which this could support job redesign and upskilling.

The Taylor Review of Modern Working Practices found that platform-based working in the Gig Economy offers a flexibility which benefits some workers, but identified concerns about 'one-sided flexibility' in which employers only relate to workers through an app, transfer all risk onto the shoulders of workers and, in doing so, undercut other businesses[90]. It made welcome recommendations for fair and decent modern working practices by tackling exploitation, increasing clarity in the law and helping people know and exercise their rights, which the UK Government has accepted[91]. However, as the nature of work and business models continue to change it is likely that further reforms will be needed to employment rights, responsibilities and classifications to rebalance the relationship and enable workers to understand and influence their working practices.

Wider policies are required to support economic and social prosperity during the workforce transition, such as improved labour-market mobility via housing in growth areas or digitally matching people with vacancies. In the longer-term, these could include reduced working hours or a universal basic income.

There was sustained decline in the average working week from the first Industrial Revolution as new technologies were introduced to the workplace, productivity increased and there was rising pay and living standards. However, this progress has come to a halt in recent times. In the UK economy, workers, on average, work longer hours than in many other OECD countries. Yet, this does not result in higher economic output because productivity in these countries is, usually, higher than in the UK.

As the technologies for the Fourth Industrial Revolution are introduced into the workforce, more tasks are automated and productivity increases, reduced working hours, with increased job sharing, could help to avert technological unemployment and make automation work in the interests of society[92]. France has been trialling an approach of assigning part of a reduction to on-the-job training[93].

A Job Guarantee, offering anyone willing and able to work a community job at a socially inclusive minimum way, or a universal basic income, a regular, unconditional payment to every citizen in society, could also help to protect economic prosperity and social security in the longer-term. As working practices and patterns continue to become more flexible and less fixed, they could help workers, for example, by supporting people in times of transition between jobs and in retraining, and in a wider range of roles of social value such as caring, and by dealing with the possible widening income gaps[94]. A universal basic income could, its supporters argue, encourage entrepreneurship, including social, and participation in employment opportunities. Such a universal system could be more straightforward for the state to administer and help to decrease some costs for society.

Universal basic income trials are currently taking place in a number of countries and regions. There are many different potential models. North Ayrshire, Fife, Glasgow and Edinburgh councils, supported by the Scottish Government, are exploring the feasibility of Scottish pilots for universal basic income.

There would be many challenges for the introduction of these proposals. The labour market in Scotland is already facing a significant demographic challenge and there are major uncertainties about the timescales for automation. Without higher productivity, reduced working hours would decrease output, pay and tax receipts. A higher minimum wage could be introduced to compensate people on lower wages for a loss of hours, which may result in employers automating more jobs[95]. A universal basic income would have very high costs for public spending and could be a disincentive to work.

A package of proposals rather than a single silver bullet is likely to be necessary in the longer-term. Economy-wide transitions will be difficult and it is right for governments at different levels, businesses and workers to start discussing and find routes to test the practicalities of a range of options now.

Recommendations

- Fundamental changes are necessary in education and employment. Digital literacy, data analytics and specialist upskilling, for example in AI or additive manufacturing, are essential. In addition, as more routine and non-routine tasks are automated, the demand for high level, non-cognitive skills, social skills - self-management, social intelligence, and innovation[96] - will grow. People will need entrepreneurial mindsets and a lifelong capacity to adapt to changes. Education, skills, industry and social partners need to work together to influence changes:

  a. Resources should be increased and linked to system and profession-wide commitments to the development and introduction of new models of teaching and learning which are personalised and flexible around learners, like flipped-classrooms, and to the significant digital upskilling of workforces. Post-school education should provide a range of academic and vocational pathways, including accelerated routes, into the labour market which develop higher-level skills including critical-thinking, work-readiness and adaptability. There should be an expansion of undergraduate and post-graduate opportunities in areas like AI and data analytics. There will be a specific need to redress long-term underinvestment in vocational education and training.

  b. As a society, we should no longer view education and skills development as a high intensity, short period activity, but rather as an activity ongoing throughout a working life. Individual workers will need to take a stronger interest in developing and adapting their skills and careers. Jobs will need to be re-learned in an AI context and there will need to be support for midcareer transitions. A wide range of policies, such as tax and welfare, should be reviewed to identify what would encourage complementary commit to and investment in technologies, employment, skills development and lifelong learning, by workers, employers and government. Nordic countries show how flexible labour markets can be combined with higher investment in active labour market policies, including strong support for career transitions and retraining.

- Employers should develop their strategies for new technologies in partnership with their workforces. Technologies are more likely to be successfully procured and integrated when leaders, managers and workers discuss them. But there is concern that AI and data are being used in some workplaces, particularly but not only in the Gig Economy, to micromanage workers rather than improve job quality and employee wellbeing. The Fair Work Convention should develop and share best practice on employer-employee partnerships to introduce and utilise technologies and access data, including the potential for better quality of work, job redesign and upskilling, and higher performance and living standards.
  The Taylor Review of Modern Working Practices identified 'one-sided flexibility' for employers not employees. Action is needed now, but as AI changes the nature work it is likely that further reforms will be needed to employment law.

- In the longer-term, wider policies will be required to support economic and social prosperity. Options should be kept under review and piloted. Reduced working hours, with increased job sharing and part of the reduction assigned to on-the-job training, could help to avert technological unemployment and make automation work in the interests of employees, employers and society. A Job Guarantee, offering anyone willing and able to work a community job at a socially inclusive minimum wage, and/or a Universal Basic Income, could be options to support displaced workers in transitions between jobs and retraining due to automation and a changing labour market. The planned Universal Basic Income pilots in Scotland should be designed to help test this potential role in different social contexts.

Skills for the future: Meta-skills

Timeless, higher order skills that support the development of additional skills and promote success in whatever context the future brings

Self management

Taking responsibility for your own behaviour and wellbeing

Focussing
The ability to manage cognitive load by filtering and sorting information in order to maintain a sense of focus in an age of information overload and constant change

- Sorting
- Attention
- Filtering

Integrity
Acting in an honest and consistent manner based on a strong sense of self and personal values

- Self awareness
- Ethics
- Self control

Adapting
The ability and interest to continue to enlarge knowledge, understanding and skills in order to remain adaptive and resilient as circumstances change

- Openness
- Critical reflection
- Adaptability
- Self-learning
- Resilience

Initiative
Readiness to get started and act on opportunities built on a foundation of self belief

- Courage
- Independent thinking
- Risk taking
- Decision making
- Self belief
- Self motivation
- Responsibility
- Enterprising

Social intelligence

Awareness of others' feelings, needs, and concerns in order to effectively navigate and negotiate complex social relationships and environments

Communicating
The ability to openly and honestly share information in a way that creates mutual understanding about others' thoughts, intentions and ideas

- Receiving information
- Listening
- Giving information
- Storytelling

Feeling
Considering impact on other people by being able to take a range of different thoughts, feelings and perspectives into account

- Empathy
- Social conscience

Collaborating
The ability to work in coordination with others to convey information and tackle problems

- Relationship building
- Teamworking & collaboration
- Social perceptiveness
- Global & cross-cultural competence

Leading
The ability to lead others by inspiring them with a clear vision and motivating them to realise this

- Inspiring others
- Influencing
- Motivating others
- Developing others
- Change catalyst

Innovation

The ability to define and create significant positive change

Curiosity
The desire to know or learn something in order to inspire new ideas and concepts

- Observation
- Questioning
- Information sourcing
- Problem recognition

Creativity
The ability to imagine and think of new ways of addressing problems, answering questions or expressing meaning

- Imagination
- Idea generation
- Visualising
- Maker mentality

Sense making
The ability to determine the deeper meaning or significance of what is being expressed and to recognise wider themes and patterns in information

- Pattern recognition
- Holistic thinking
- Synthesis
- Opportunity recognition
- Analysis

Critical thinking
The ability to evaluate and draw conclusions from information in order to solve complex problems and make decisions

- Deconstruction
- Logical thinking
- Judgement
- Computational thinking

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Skills Development Scotland

Centre for Work-based Learning in Scotland

Source: https://www.skillsdevelopmentscotland.co.uk/skills4-0 (forthcoming publication)

Case Study: *Digital, Change and Productivity* by the Scottish Retail Consortium

No industry, with perhaps the exception of newspapers, has been more affected by the rise in digital than retail. Customers and retailers have been early adopters of the advantages offered through digital technology.

In many cases that's been fantastic. Customers have benefitted from a golden era for shopping. Prices have fallen, choice has increased, and never before have shoppers been able to access so much information on products and pricing. SRC figures show nearly a quarter of non-food Christmas shopping was done online in December, with the proportion even higher in November 2017. Whilst high street sales have been flat in Scotland in 2017, online continues to grow as a proportion of consumer spend.

It's not just about price. Online shopping allows consumers to access a huge number of retailers, many of them small specialists, to find exactly the product they want. Rural consumers can now access an enormous range of products previously only available in Glasgow or London.

Retailers too have seen incredible opportunities. Traditional high street retailers have made significant investment in multi-channel offers, combining websites, social media, physical stores and even local drop-off points to make shopping as convenient as possible and to deepen the relationship with the consumer. From a warehouse or shop in a rural area it is possible to connect with customers across Scotland, the UK, or even internationally.

Digital is now offering unparalleled opportunities to enhance the consumer experience. Both virtual and augmented reality are already being used in store or through apps. Consumers can literally visualise how a coat of paint will look on a wall, or how a chair will look in a corner through phones.

However, the most seismic changes occur behind the scenes. Digital systems have replaced paper auditing for everything from stock control to absence management. That has huge implications for retail workers. Many of the lowest skilled jobs have been replaced by technology, a process which will only accelerate. That's not all bad. Many of the roles which will disappear are low-skilled and tedious. The new workforce will need better digital skills, and will be much more engaged in valuable, higher paid, often customer facing roles.

However, there will be significant economic consequences of this disruption. Since the financial crisis over 1,800 shops have closed, and 16,000 jobs have been lost. That's partly due to digital change, but also to a public policy environment which penalises retailers who operate physical premises and employ large numbers of people. Whilst some desirable areas are becoming retail destinations - such as Buchanan Street or Princes Street - other high streets are finding retail playing an ever-smaller role as consumers move online or visit these shopping centres.

Those changes have profound impacts on Scotland's places. Retail has provided quality entry level jobs, a path to progression, and businesses which communities rely upon. There is much government can do to alleviate these pressures, but the time for action is now, because in 10 years it will be too late. That's why the SRC is already working with the Scottish Government on the first ever Scottish Retail Strategy, to help develop a cohesive approach which puts productivity growth and engaging with both the benefits and challenges of digital change at the heart of Scotland's economic approach.

Case Study: *Health, Care and The Fit Home* by Albyn Housing Society Ltd

Leading Highland housing association, Albyn Housing Society Ltd has operated in the region for over 40 years, serving many of Scotland's most remote and rural areas. It therefore knows that community resilience must also be at the heart of everything it does.

Through a unique partnership with NHS Highland and a modular construction expert, Carbon Dynamic, the Society is now leading an innovative project that could enable people to live safely and well in their communities for longer, create jobs and support public services.

The origins of the project go back to 2008 when, sadly, a tenant was found dead in his home, having lain unnoticed for over a year. Vowing to minimise the chances of this ever happening again, Albyn commissioned new research exploring potential solutions, only to find that the ideal fix did not yet exist. Identifying both a need and an opportunity, the Society decided to develop its own system, one that could be adopted across its growing portfolio of homes.

Understanding the increasing pressure aging and lifestyle trends are placing on national health and care services, it focussed on a new solution supporting people to live independently at home for longer, thereby reducing demand on services and resources such as hospital beds.

The Society's Head of Innovation, Lucy Fraser, knew it was important to gain a full understanding of what tenants wanted and needed and to influence the approach taken by health providers and developers. She formed a like-minded collaboration with NHS Highland and Carbon Dynamic and together they have developed an entirely new customer-led concept of living, encompassing not just the actual home but also cutting-edge assistive technology.

Developed through co-design, including with potential tenants, young people and technologists, and built of modular construction, the 'fit home' will host various levels of sensoring equipment enabling the capture of data and associated predictive health analytics. This could help prevent episodes or events leading to ill health and hospital admissions. It will also include flexible spaces and walls for storing medical equipment. This will enable the NHS to support more people at home and allow for the possibility of earlier hospital discharges.

The pilot phase of 16 homes will provide proof of concept. The project concepts are being supported by a Scottish Government housing grant and funding from the Inverness-Highland City Deal, whilst researchers at the University of the Highlands and Islands will develop the proof of concept research with financial support from the Digital Health and Care Institute.

The Data Lab - the Scottish Innovation Centre to generate economic, social and scientific value from big data - is funding research into predicting falls, led by an AI expert at RGU.

Lucy comments: *"The central concept of the homes is that they will include ambient social, physiological and building sensors to collect data that can be monitored and responded to by a variety of agencies - potentially transforming the way health and social care is delivered.*

"The collaboration has resulted in an affordable, sustainable and successful model for the future - a model that is driven by need, rather than commercial gain. We hope to develop the Fit Homes as a social enterprise to generate revenue for reinvestment into our communities and services. We believe the concept has global significance, so we are very excited."

Digital place

Every era of industrial revolution is disruptive, with winners and losers. This applies to places as it does to businesses and skills. Growth in places in which the key innovations take place or which are attractive to the new industries they create can become supercharged. While established industrial centres which are not able to lead or adapt to the transformations can rapidly deindustrialise.

The UK has become by far the most geographically imbalanced economy in the EU, with yawning gaps in productivity not only between London and most other major cities, but, for instance, between other city regions, many cities and towns, and many urban areas and the most rural and remote areas.

In many developed countries, labour-intensive manufacturing in old industrial centres has been in decline for decades due to market changes, new technologies and globalisation. This downward spiral was stark in the UK. Some industrial areas within cities and industrial towns were left behind, with higher unemployment as workers were unable to transition to new roles or jobs locally, and 'locked-in' to lower growth, investment, educational attainment and social mobility, and to ingrained poverty.

The accelerated growth in Scotland's cities has also increased the productivity gap with rural areas. While there has been economic growth in some rural areas, significant investment in rural sectors such as food and drink, and unemployment rates are generally very low, other rural, and especially remote rural, areas have continued to experience lower investment, business creation and growth, and wages.

Populations in many post-industrial and rural areas have stagnated or are in decline, and are ageing.

In the same timeframe, many cities and those towns in which higher education institutions and science and technology clusters are located have thrived based on the businesses and skills associated with the rise of the knowledge economy and the ICT technologies of the Third Industrial Revolution. Cities are growing as they attract knowledge workers and young people from within and outwith Scotland.

The diversity of city economies is attractive to knowledge businesses and workers and supports a range of sources for growth and resilience at times of economic shocks. Many post-industrial towns and rural areas have always been or have become heavily dependent on a small number of sectors. These sectors are often public services or retail, which offer employment and an entry point to the labour market. Some also remain a location for manufacturing sites for key sectors of the economy.

This can make them slower to recover from recessions and vulnerable to future shocks and disruptive changes in sectors. The immense choice of products, easy price comparisons, customer data, rapid fulfilment of orders and reduced overheads of online shopping has already accelerated the decline of many high streets outwith prime location in the cities. Online banking is leading to branch closures.

Online to offline platforms which use data to match supply and demand for pre-existing resources, control the customer experience and, through network effects, capture a large share of value are also rapidly expanding disrupting other markets, such as Uber in transport and Airbnb in tourism. Businesses and places can no longer safely assume that customers or visitors 'will always come'.

Scotland's Economic Strategy and the UK Industrial Strategy include geographic rebalancing as a priority. The governments, in common with countries worldwide, are focussing on inclusive growth.

Place and the Fourth Industrial Revolution - An optimistic scenario

Data is a critical part of the infrastructure of place.

Through the Internet of Things and real time data, including data, reports and comments from citizens, services and infrastructure are constantly responding to changing supply and demand and communicating personalised content back to citizens. Digital platforms enable the sharing economy and more efficient use of assets. Private and public sector facilities are multipurpose and adaptable.

People's working environments are spread out and working patterns are highly flexible[97]:

- A hyper-connected, smart home, with Internet of Things, AI, robots, 4D telepresence etc.
- A local workplace with access to a wide range of co-working facilities
- A futuristic campus in the city in which knowledge workers come together to collaborate, with experiential facilities to work, play, socialise, relax and increase wellness

City centres are a playground for eating, drinking and staying, entertainment, health and wellness, retail showrooms, and the experience economy. The physical and virtual worlds are fully blended using technologies such as ambient intelligence, augmented reality, robotics and digital platforms.

The influence of the creative industries is across the economy. With additive manufacturing and customisation of products, there is more small scale sites and DIY in manufacturing.

Cities continue to be especially attractive to the young and mobile, but hyper-connected homes, workplaces and transport mean that people can choose to live anywhere and work productively. People highly-value a sense of authenticity and community about where they live. They want to access the experience economy, but also want to escape, disconnect and relax in natural settings.

Visitors expect to be able to connect instantly wherever they go for an enhanced experience and for personalised content which enables them to create self-guided activities and tours.

Mobility for people is by on-demand, autonomous electric vehicles with mobile workspaces, integrated mass transit systems, walking or cycling. Deliveries are made by autonomous vehicles.

There is a need to analyse these trends and potential impacts in different geographic areas of Scotland.

In the Fourth Industrial Revolution, there are opportunities and risks for all areas of Scotland. However, without policy intervention, the opportunities will be amplified for those areas which are already prospering, such as city regions, and the risks will be amplified for those which are not.

Cities, with their knowledge economies and economic diversity, attractiveness to skilled workers and young people, and larger markets, are best placed to grasp the opportunities, such as AI and robotics. However, Scotland's cities will not be immune from challenges - from threats of disruption to incumbent sectors, to the risk that the more deprived communities may be left further behind, to regulation and tax of the sharing economy, to buggy technologies, to the pains of growth, and so on.

A Centre for Cities report found that all UK cities are likely to increase jobs across both the public and private sectors, with AI, automation and other technological changes creating new jobs, but that some jobs are at risk. While Dundee is among the 10 UK cities with the highest per centage of current jobs which are likely to shrink by 2030, Edinburgh and Aberdeen are among those with the lowest, and Glasgow is around the national average.

It is also forecast that Aberdeen and Edinburgh will be among those with the strongest growth in high-skill private sector jobs, often based on new technologies[98].

Scotland's cities will need to keep pace with global cities in the innovations of the Fourth Industrial Revolution, but also trade on their identifiable characteristics - their authenticity and community.

Scotland's towns and rural areas would especially benefit from the technologies, for example to close the productivity gap, address demographic challenges in the workforce and service delivery, or improve mobility. However, the market may not consider the opportunities attractive enough to invest. This would significantly widen the digital gap between cities and other areas of Scotland.

The most vulnerable areas will be those which are heavily dependent on a single or a small number of sectors in which roles can be automated. It is also possible that early application of the technologies increases productivity, reduces the threat of closure, and protects some jobs - or even creates a centre of excellence. Understanding the balance of risks and opportunities here should be a priority.

This should inform immediate action to support people and regions where labour markets are most concentrated and which may be left further behind, aligning economic and skills strategies.

So, what might Scotland's places do with the technologies?

Scotland has made considerable progress with extending high speed fibre broadband nationwide. This includes the Digital Scotland Superfast Broadband programme, ensuring 95% of all Scottish premises have access to high-speed broadband infrastructure from at least one industry provider by the end of March 2018; and the Scottish Government's commitment to deliver 100 per cent superfast broadband (>30 Mbps) to all premises by 2021 via the Reaching for 100% (R100) programme.

While Scotland's geography and population density continue to be a challenge, especially in rural areas, mobile networks have also made significant progress in Scotland in recent years, particularly on 4G. Though predominantly private investment, the Scottish Government's Mobile Action Plan, ensuring the Scottish Government and the mobile operators are committed to working together on a range of measures aimed at improving mobile coverage across Scotland, has helped investment conditions to improve coverage further. This includes ensuring Scotland is "5G-ready" and also seeking to maximise the commercial impact of the Emergency Services Mobile Communications Programme, a world-leading 4G network for the 'blue light' services.

This digital strategy should be joined-up with the energy and transport strategies, and with public services and skills strategies. Scotland's newest hospitals have been designed to use robots and this should be the case across infrastructure. The expansion of childcare needs to incorporate digital technologies and skills development. Housing developments need to be fit for the Internet of Things. New digital technologies should be used in the construction and monitoring of buildings and utilities.

Infrastructure is a key enabler of successful places, but it has to be used productively.

Many of the strategic opportunities are at a regional level and it makes sense to align decision-making and resources. The shared focus of the UK and Scottish governments on the regional growth agenda is welcome. This needs to apply demonstrably to all regions, not only cities.

Regions, communities and their businesses require a 'fit for the Fourth' digital infrastructure and will need to excel in working with digital platforms which increasingly are global digital infrastructure. For example, Airbnb is now a route to the global market for many tourism businesses. However, places and businesses will also need to collaborate to promote their brand and capture their share of value, getting the basics right at a place level while identifying their sustainable sources of differentiation.

A good example of how this can be catalysed at a local level is the Scotland's Towns Partnership's Digital Towns programme, particularly its Greenock project. This will take a 'whole-town' approach to a digital platform which will enables personalised communication

with a range of users and local collaboration on opportunities, blend physical with the virtual, and improve digital skills and inclusion.

Greenock's assets will be promoted in a fresh, contemporary and inclusive way to attract visitors, start-ups, young people, and workers and their families, and underpin investment. Local traders will be supported through better data analytics collection and a collaborative marketing approach.

Experimentation should be encouraged and enabled in the physical and virtual worlds. Frontrunner businesses already use virtual environments to simulate what new technologies could mean for them. A virtual tool could be created for communities and local businesses to inform A-B testing of ideas[99].

The public sector has a key role through its purchasing and regulating powers.

It can stimulate innovation through public challenges and Open Data initiatives. The CivTech model[100] is based on national challenges, but there is potential to apply its approach at regional or local levels. To do so, the public sector would need to further improve defining the outcomes it seeks for digital technologies and governance, procurement and project management will need to be more agile.

Agile regulation should enable technology-based market changes which have the potential to serve customers better, but shape it in the wider interests of society, for example in new mobility services.

A programme should be developed to prepare the public sector and spread best practice for applying AI[101]. This should include operational improvements, but also issues for workforces and communities. People who know about AI and robots tend to be more positive about their benefits for society[102].

Health and social care challenges are perhaps the highest priority for innovation. Due to current demographic profiles of post-industrial and rural areas, there is the opportunity to locate more data driven technological research and innovation in these areas, stimulating new business growth[103].

As the tech sector works with government on the economic, social and environmental challenges for places including post-industrial and rural communities, it would benefit from developing the skills of and increasing its recruitment from these areas, to improve its knowledge of the issues and to address the acute skills shortages for the industry. The digital skills and creativity of local young people should also be harnessed by engaging educational institutions in the digital strategy for their local community.

Creation of citizen digital champions could increase confidence in new technologies in public services.

As the Fourth Industrial Revolution changes business and public service models there will be new vacant land and buildings. The time a building lies empty or land is left vacant the surrounding community suffer the consequences. 'Meanwhile uses' aim to bridge to gap until long term regeneration can occur by gifting use to the community for social interaction and activities[104].

Data is the infrastructure which can make the Fourth Industrial Revolution work in the interests of society and communities - and the means of inclusively defining what those interests are and of updating strategies responsively as technologies, markets and social and community interests change.

There is both the need and the opportunity to improve data at regional and community levels.

North Ayrshire Council has piloted an inclusive growth diagnostic which is now being rolled out across Ayrshire and will provide evidence to inform the priorities of the new Regional Partnership and proposed Ayrshire Growth Deal. Scotland's Place Standard tool enables people to comment on what is working well and needs to be protected, and what needs to be improved, in the physical and social fabric of a community[105]. Shetland has used its online and app versions particularly successfully[106]. It is important that those who are currently digitally excluded also continue to be brought into discussions.

Recommendations

- Regional opportunities should be a priority for regional agencies (including the new South of Scotland Agency), partnerships and future investment deals. Where this is the case it makes sense to align decision-making and resources. Health and social care challenges offer opportunities to locate more data driven technological research and innovation in post-industrial and rural areas.

- Regions will, however, face challenges if their labour markets are more highly concentrated and there will be a need to manage risk to avoid deprivation. We should do everything we can to avoid the negative long-term effects of past eras of industrial change. Predictive action should be taken to support people and regions which may be left further behind, aligning economic and skills strategies for sectors and regions which automation may impact most.

- Communities should be supported to get the basics right. There are emerging examples of how this can be catalysed at a local level through collaborative 'whole-community' approaches. Experimentation should be encouraged and enabled in the physical and virtual worlds. A virtual tool could be created for communities, local businesses and social enterprises to simulate what new technologies could mean for them and inform A-B testing of ideas.

- All parts of Scotland will require a 'fit for the Fourth' infrastructure. This means deploying the next generation of digital networks, but also making the technologies of the Fourth Industrial Revolution integral in all infrastructure and in housing where beneficial. Smart infrastructure, including sensors, the Internet of Things, data, and robotics, can improve the performance of infrastructure, better match supply and demand, and inform the design of new infrastructure.

Case Study: *Tourism in Digital Greenock* by the Scotland's Towns Partnership

Birthplace of James Watt, Greenock is one of Scotland's most historical industrial towns, having grown from a small fishing village to a globally-connected centre for successful businesses, including ports, shipbuilding, textiles and electronics. However, it has suffered from deindustrialisation in recent decades and Inverclyde has become Scotland's second most deprived area, with a falling population.

Now, based on the same excellent marine location which once spurred its industrial growth and the legacy of those assets, Greenock is taking a forward-thinking approach, raising the town's ambitions digitally, economically and socially. This is the Inverclyde Digital Project, the most ambitious of 30 Digital Towns concepts being piloted by towns with Scotland's Towns Partnership and Digital Scotland which aim to improve infrastructure, skills and participation, and create scalable best practice models.

Tourism is a huge element of Greenock's pilot because it is currently failing to capitalise on the prime opportunities offered by the 105k passengers who come into Greenock Ocean Terminal each summer - including people with ancestors who lived and worked in the area or who emigrated from the port.

With investment plans for a new state-of-the-art visitor centre at the terminal and further expansion and development of the recently-opened James Watt Dock Marina, the opportunity is increasing.

It is hoped that the pilot will help to promote Greenock as a fascinating destination for a broad range of visitors, specifically taking into account that many of the visits to Greenock, such as those from cruise ships, are likely to be day visitors, offerings need to be short, sharp and instantly appealing.

A central town website will showcase the range of activities and experiences open to visitors. These can be explored online well before passengers book their visit, enabling them to plan in advance.

With the trends to 'Live Like A Local' and be self-guided, a series of freely and easily downloadable mobile app tours will offer town and countryside tours to suit every age, requirement and ability. This will include short,

bite-sized Greenock walks on themes - such as town heritage or art and history - tailored to suit the specific on-demand need of short-stay passengers unfamiliar with the area. Apps will be available in foreign languages, improving information without covering the town in signs.

Use of 360 panoramic photography and immersive virtual tours will give residents and visitors greater visibility and enhanced experience of Greenock's business and public assets and tourist attractions.

A central and comprehensive digital platform will promote the entirety of Greenock's 'Eat, Drink, Stay' options - cafes, restaurants, pubs, bars, nightclubs, pubs, B&Bs, hotels, camping spots and self-contained accommodation in one easy-to-access place. Increased networking and collaboration via town social media channels will raise business profiles and confidence, connect traders with customers, appeal to visitors and cruise passengers, and encourage valuable feedback from residents. Real-time communications can help to manage demand at pinch-points during busy times.

This approach of blending physical with virtual could then be developed and extended across Inverclyde because Inverclyde Council has committed to invest in Town Centre Wi-Fi across the area. Moreover, the proposed 'Digital Bridge over the Clyde' project, is aiming to digitally twin Greenock and Dumbarton, a natural progression in joint digital collaboration, learning and development.

Greenock's vision is, therefore, to be a digital centre of excellence, at the forefront of the reinvention of the Clyde's industrial coastline and the growth of new industries to replace those which were lost.

Conclusion

The Fourth Industrial Revolution will give rise to profound changes in Scotland's economy and society.

The central message of this report is that Scotland should now create a national focus on a discussion about the development of an economic and social strategy for the technologies of the Fourth Industrial Revolution. There is an urgent need for Scotland-specific economic modelling on the great trends of this new digital age and their impact on life and work on which to base this strategy. Scotland can be ambitious and optimistic in our aim to be an economic and social frontrunner as an innovator, adopter and adapter to these new technologies to increase prosperity and progress the public good.

It would be counterproductive to try to slow the pace of change; rather we should try to match it in the pace of our policy reaction. In this, we should use the technologies that the Fourth Industrial Revolution is introducing, such as machine learning and data, but, ultimately, people need to make decisions about how to use technologies. Many of the most profound economic and social reforms in previous industrial revolutions were initiated by informed, creative and passionate people and groups.

The partners in this report will be taking forward thinking and actions on some of these critical issues.

SCDI will be working on a new long-term, blueprint for the Scottish economy in a post-digital age, as well as reporting on automation and digitalisation in relation to data on the future of work, industrial strategy and investment in Scotland, inclusive growth for rural areas, and the future of the tax system. SCDI's Young Engineers and Science Clubs and partners will continue to roll out digital challenges and resources to Scotland's primary and secondary schools, including computational thinking and robotics.

ScotlandIS will continue to represent and support Scotland's digital technologies industry as the sector's businesses and organisations create and deliver new digital products and services. The focus areas of this work include Mobility as a service, cyber security, data-driven innovation and skills.

BT Scotland will continue to work with public sector partners to deliver the world-class, high-speed fibre broadband network needed by Scottish businesses and communities in the digital revolution. This includes working with organisations such as Scotland's Towns Partnership to help Scottish towns reach their full digital potential. Meanwhile, EE, as part of BT Group, will continue its investment in its 4G network in Scotland, ensuring that mobile coverage and capacity in Scotland continues to grow to meet demand.

The RSE will be publishing a series of advice papers on the formulation and delivery of industrial and innovation strategies for Scotland which would benefit the country economically and socially.

Above this, what is needed is strategic leadership, from governments, industry and civic organisations, and inclusive discussions with the Scottish people, to create a national vision with shared priorities and actions. We urge all those with an interest to work together in an enlightened way on this strategy.

Where can you find out more?

Discussions highlighted that there is much good work on these issues. However, some of this may not be known or seem joined-up to those who are not closely following the work.

It was felt that it would be useful to map some of this activity, while acknowledging that this list is not the complete picture.

Scottish and Local Government

Scottish Government report[107]
Realising Scotland's full potential in a digital world: A Digital Strategy for Scotland

Scottish Enterprise report[108]
Potential impacts of automation for Scottish businesses

Expert Panel on the Collaborative Economy report[109]
How can Scotland take advantage of the opportunities and overcome any regulatory, economic and social challenges?

CivTech[110]
Accelerating tech solutions from businesses to solve problems identified by the public sector

Local Government Digital Office[111]
Delivering a digital first approach that enables councils to provide better services to citizens

The Data Lab Innovation Centre[112]
Enable collaboration to generate economic, social and scientific value from big data

Skills Development Scotland and the Centre for Work-based Learning in Scotland[113]
Understanding the skills for the future

CodeClan[114]
Digital skills academy for Scotland

Scottish Towns Partnership programme[115]
Pilot Digital Towns projects and guidance

UK Government

UK Government report[116]
Industrial Strategy White Paper, including AI and data driven economy Grand Challenge. Increase awareness of the advantages of advanced data analytic technologies and promote greater diversity in the AI workforce Appointments to Office for AI, AI Business Champion and AI Council: early 2018

Independent review of AI for UK Government[117]
Make the UK the best place in the world for businesses developing AI to start, grow, and thrive

Made Smarter Review report[118]
Industry-led review on how UK manufacturing can increase adoption of digital technology

UK Government Good Work Plan[119] in response to Taylor Review report[120]

Inclusive Economy Partnership[121]
Tackling challenges of Financial Inclusion and Capability, Mental Health and Transition to Work, for low to middle income households
Test phase for first projects: Q1 2018

Digital Catapult[122]
'Machine Learning Garage' programme to promote AI to start-ups and all businesses

Think tanks and NGOs - Scotland

STUC
Automation in the Scottish labour market
Report to be published: early 2018

IPPR Scotland reports[123]
Future of work and the skills system in Scotland

CBI Scotland report[124]
Drivers of regional productivity
Business-led productivity taskforce: early 2018

FSB Scotland report[125]
Digital disruption and small business in Scotland

Future Digital Leaders[126]
Online resource and knowledge hub supporting future digital leaders

Think tanks and NGOs - UK and International

UK

RSA report[127]
Research into the future of work

IPPR programmes[128]
Commission on Economic Justice and programme on New Skills at Work

Nesta reports[129]
Research into employment and skills in 2030

Tony Blair Institute for Global Change report[130]
Harness technology's potential for good and mitigate displacement effects of rapid change
Forthcoming programme of work: 2018

Website with examples of AI in action[131]

CBI report[132]
How businesses can embrace artificial intelligence, blockchain and internet of things

Centre for Cities Outlook 2018[133]
The likely impact of automation and other trends on cities, identifying where job losses are most likely and which places are best placed to see growth in new areas

International

OECD programme[134]
Demographics, globalisation and technologies effects on job quantity and quality, and inclusive growth, and what this means for policy

McKinsey programme[135]
Technology, jobs and the future of work

UNI Global Union (representing over 900 trade unions worldwide) programme[136]
The future world of work, including principles on workers' data rights and ethical AI, and retraining and job changes

Footnotes

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