Llywodraeth Cymru
Welsh Government

Wales 4.0
Delivering Economic Transformation
for a Better Future of Work

September 2019

Review of Digital Innovation for the Economy and the Future of Work in Wales

Foreword

Chair of the Review, Professor Phillip Brown

I was delighted to be asked by Ken Skates AM, Minister for Economy and Transport, to Chair a review investigating how the rapid advances in digital innovation are likely to impact the economy and future of work in Wales. It has been an enjoyable - if somewhat daunting - challenge, given the scale and scope of such a review.

The influence of technology on the future of work is a hot topic. Against a backdrop of stagnant wages, public austerity and Brexit, there is considerable uncertainty about what digital innovation means for people's livelihoods and those of future generations. These concerns are well-founded as discussions around automation and Artificial Intelligence (AI) are often presented as a threat to jobs and personal privacy.

I have maintained an open-minded view of the future of digital innovation. There is a need to take some of the heat out of the debate to assess the realities and trends that will shape the future of work. Without doing so, there is a real danger that the perceived risks of digital dislocation leaves individuals feeling out of touch and, crucially, out of control when it comes to the influence of technology on their lives.

It was never realistic for this review to provide all the answers. Rather, I have set out some of the key challenges and opportunities for Wales and call for a national conversation to consider what digital innovation means for the people and communities of Wales, not just the high-tech innovative businesses of the future. Whilst the Welsh Government can have a positive input in shaping what comes next, it's not simply up to them to decide what to do – it's about all of us.

Therefore, this review is as much about a different way of thinking and daring Wales to do things differently. The culture shift now required within the Welsh Government, its agencies and wider leadership bodies, is the responsibility of all Ministers, officials and public sector leaders. There are already positive initiatives taking place in Wales. Some of which are showcased in the findings. Nevertheless, attention will need to be given to thought leadership and capacity building within the Welsh Government to deliver smarter and more collaborative ways of transforming the Welsh economy so that people can live meaningful and productive lives.
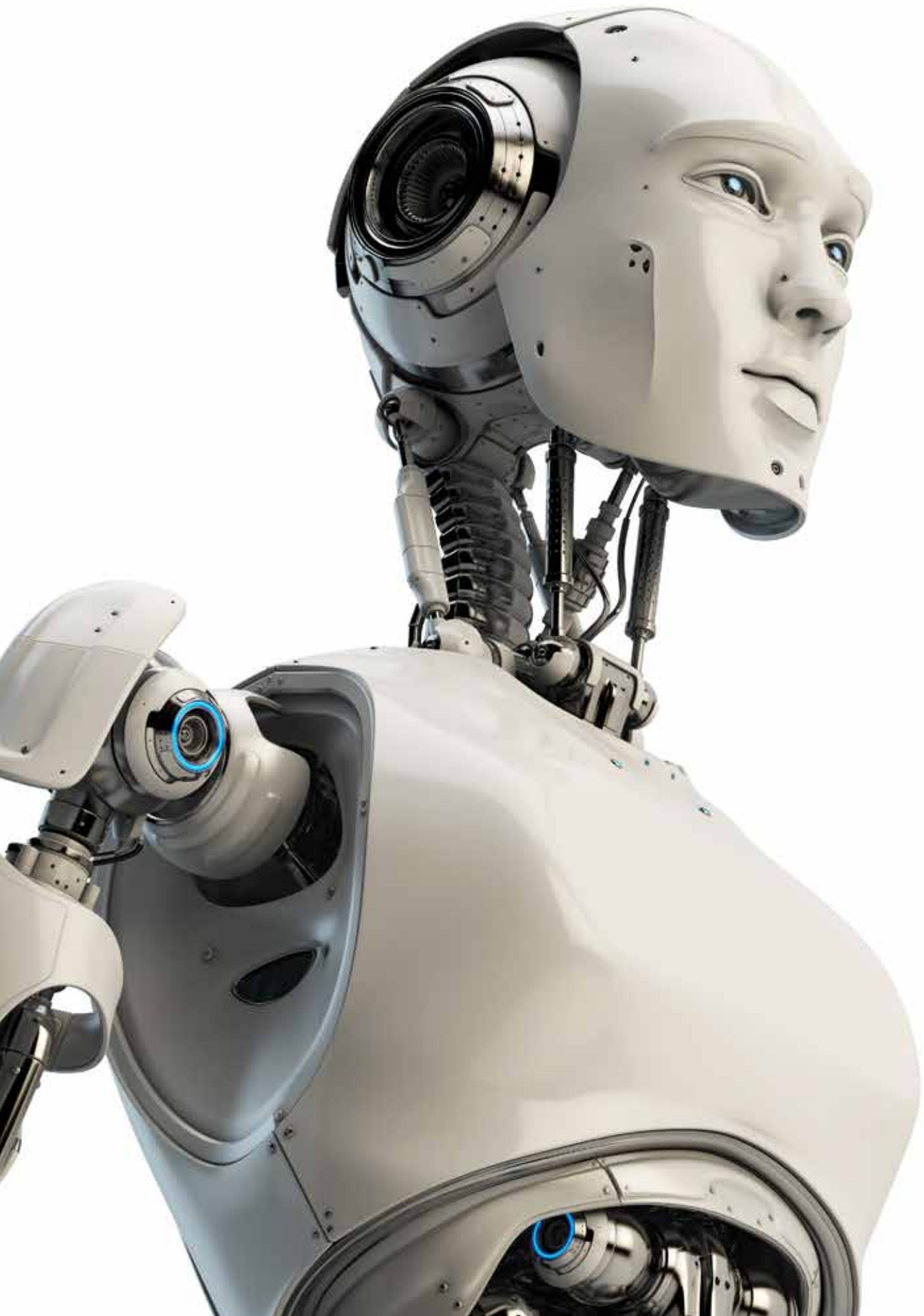
I have been impressed by many of the people that I met with during the review and encouraged by the optimism expressed about what Wales could achieve, despite an uncertain political, social and economic context. But I was equally struck by a deep sense of frustration given a perceived lack of national ambition, some resistance to change, and a lack of policy coherence, which makes it difficult to realise our true potential. If we do not address these frustrations, Wales will miss out on the opportunities presented by the fourth industrial revolution.

I want to thank everyone who participated in this review. This report draws on the collective intelligence of many people and organisations but especially the Expert Panel and secretariat led by Matthew Hicks. Expert Panel meetings were consistently insightful and constructive. I would also like to express a particular thanks to Caitlin Davies, Professor Andy Westwood, Tassaneeya Robinson, Karen Cherrett, Professor Kevin Morgan, and to those who wrote analytical briefing papers in support of this review.

I also thank Ken Skates AM and other Ministers for asking the right questions, and hope that this report will contribute to how they can be answered in ways that pave the way for a better future of work in Wales.

It is a pleasure to present the Panel's findings.

Wales 4.0   Delivering economic transformation for a better future of work

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Executive Summary

Digital innovation is a game changer. Economies, whether large or small, developed or emerging, have to confront major challenges to establish new business models, employment practices, and ways of skilling their workforce. But technology is not fate. While it presents considerable challenges, it also offers new opportunities to use digital innovation to improve the quality of jobs, business productivity, delivery of public services, and individual wellbeing. Through bold initiatives and creative leadership, Wales can transform the economic landscape to benefit everyone rather than just a select few, thus making the economy work for people in a sustainable and inclusive way. The challenge set out by this review is to make Wales a nation that dares to be different.

Other countries, including Finland, Estonia, Singapore and many others, are waking up to the challenges ahead and are experimenting with new approaches to guide their future prosperity. Wales must now take similar action or be left behind in a changing world. The consequences of a "do nothing" mindset will be dire in the long term for the wellbeing of our nation. This report is therefore a call to arms for the Welsh Government, partners, stakeholders and employers, to do things differently for the good of all.

The *Review of Digital Innovation for the Economy and the Future of Work in Wales* was announced by Ken Skates AM, Minister for Economy and Transport, to gain a better understanding of the opportunities and challenges presented by rapid advances in digital innovation including automation, AI and robotics. The review adopts a broad definition of digital innovation to include any novel products and services, or more productive ways of doing existing things, along with yet imagined things based on digital technologies. For the most part, we are talking about 'general purpose' technologies not restricted to one industry, such as ICT, but diffused across the whole economy.

The review is informed by an extensive period of consultation and engagement work both inside and outside of Wales which is set out in Appendix A. An Expert Panel of leading thinkers, researchers, practitioners and entrepreneurs made a significant contribution to the review along with the support of social partners in Wales. The review has received input from a range of experts, including those from Singapore and Denmark. We have also worked closely with the Office of the Future Generations Commissioner and its community of practitioners.

Key Findings: Will Robots Take Our Jobs?

Claims that up to half of jobs could be automated in developed economies within the next 10-20 years reflect longstanding concerns about the impact of new technologies on jobs. In the 1930s, John Maynard Keynes predicted mass 'technological unemployment' by 2030 as new technologies outpace efforts to find alternative uses for labour [1]. According to some media stories of 'robo-geddon', he could still be correct. Nevertheless, the conclusion of this review is that these claims are exaggerated, although the direction of travel seems clear with technologies becoming increasingly used as a substitute for human labour.

The review equally rejects the claim that the fourth industrial revolution, driven by AI, automation, Internet of Things (IoT), robotics, big data, etc. will follow previous industrial revolutions, where a period of upheaval is followed by economic growth, better job opportunities and higher wages. Here, the key policy goal is assumed to be one of reskilling the workforce in preparation for these new emerging occupations. Such ideas are, at best, complacent.

A key message is that over the next decade, digital technologies will result in both job displacement and creation, but of even greater significance is its impact on how we experience work. Digital technologies can be used to augment skills and improve job quality, but they can also be used to deskill and eliminate jobs. In short, they will not automatically resolve longstanding problems of job quality, low-wages or labour market inequalities. These issues are at the heart of the debate when considering the future of work in Wales and are critical considering Wales' ambition to become a Fair Work nation.

Participating in paid employment of whatever kind remains a core part of adult life, giving people a sense of purpose, a degree of economic independence, and a way of contributing to the lives of others. But the current compulsion to work can also be a source of exploitation. We fully endorse the recent deliberations into some of these issues by the Fair Work Commission,[2] along with efforts to narrow inequalities in income and wealth, which will mean rethinking the foundations of economic security.

While better quality jobs can add to national economic prosperity, many working people may not feel the benefits. There is a capacity problem at the heart of the fourth industrial revolution that means we cannot limit ourselves to just reskilling the workforce. Fundamentally, there are not going to be enough well-paid jobs for those who want them. Therefore, while we need to increase the size of the economic cake (in a sustainable way), and improve job quality, close attention also needs to be given to the difficult question of how we are going to redistribute the wealth of nations.

'Business as Usual' is Not an Option

In the early stages of today's industrial revolution, there is a very limited window of opportunity presented by the disruptive forces of digital technologies which is temporarily reducing the gap between established businesses and disruptors as the new rules of the game are established. The rise of a number of Asian economies is a good example of how new technologies are being used to accelerate economic growth and global competitiveness, although issues of environmental sustainability loom large.

The key question is how Wales responds to these challenges and opportunities and whether the actions of government, employers and individuals will contribute to creating a sustainable, prosperous and inclusive society. This can only be achieved by embracing a different way of thinking and a different way of doing things. Without radical action, the Welsh economy will not generate the wealth required to fund public services and large numbers of workers will be locked into a race to the bottom in jobs that are susceptible to automation.

Our site visits and economic analysis found that the Welsh economy is dominated by businesses that are locked into peripheral parts of global value chains with their headquarters, research, design and business intelligence function located elsewhere. This means that functions located in Wales tend to be less secure, more portable and hence more at risk of automation. At the same time, a recent UK study suggests that the government, employers and trade unions are not doing enough to prepare people for the future of work.[3] This highlights the need for an urgent national conversation in Wales which engages people and communities to consider their hopes for the economy and the future of work in Wales in 2030 and beyond.
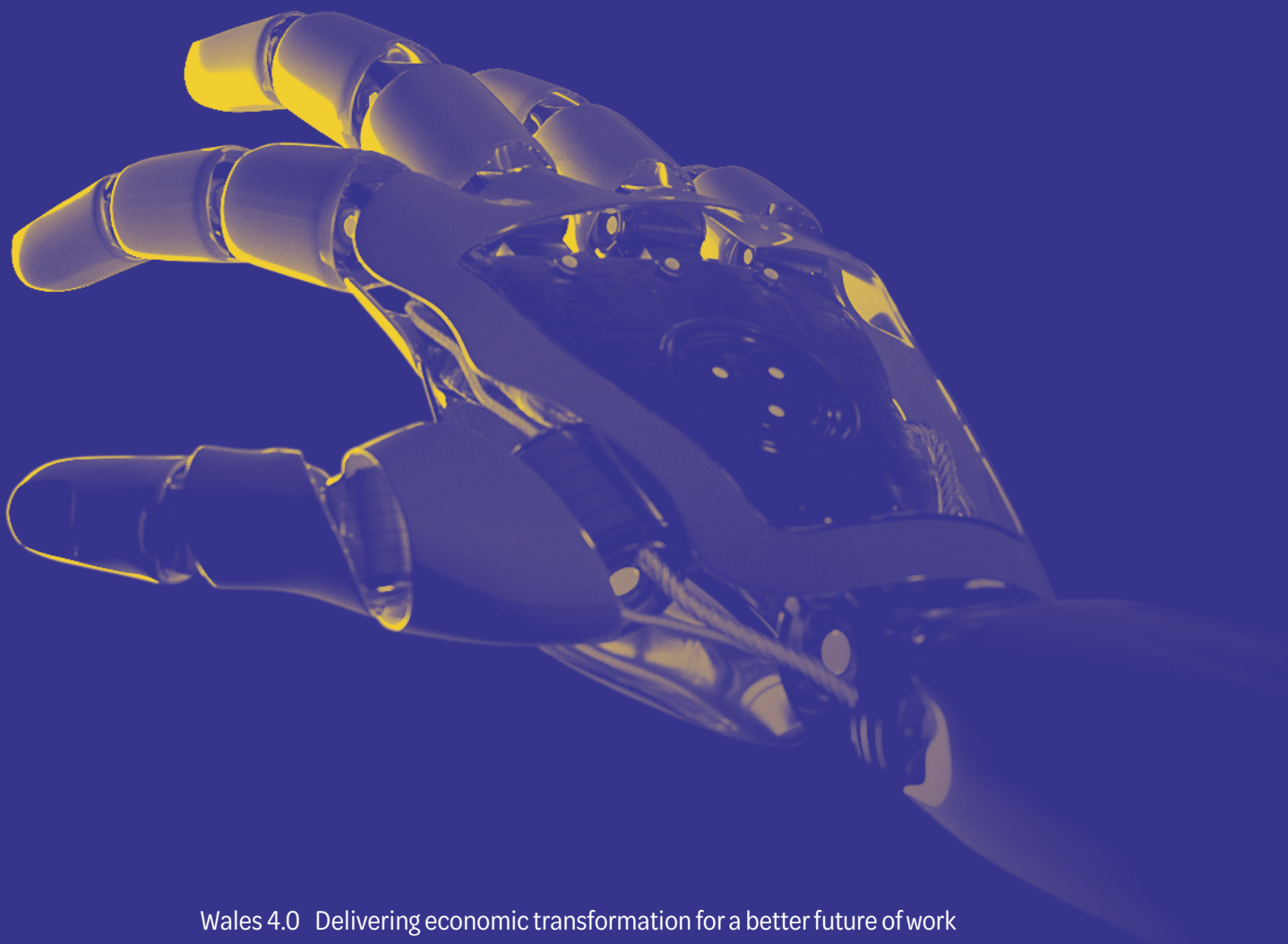
Delivering Wales 4.0

Our assessment of the available evidence suggests that we are at the beginning of an industrial revolution, facilitated by advances in digital technologies, including AI, machine learning, robotics, biotech, etc. which is transforming the Welsh economy as well as reshaping how we work, where we work, and what we do for a living.[4]

The Welsh Government and its partners have developed a number of policies and strategies aimed at delivering positive outcomes for Wales in the short term. Prosperity for All, the Economic Action Plan (EAP), the Employability Plan, etc. are all valuable initiatives, but are based on the economics of now. They do not consider how digital innovation is contributing to the long-term, rapid transformation of the Welsh economy and wider society. The Panel therefore calls upon the Welsh Government, stakeholders, industry and individuals to adopt a more holistic, joined up and bold approach in response to the opportunities and challenges that lie ahead. We have called this approach Wales 4.0, which is a national response to the fourth industrial revolution.

Wales 4.0 offers a way of presenting a new national strategy that can provide the basis for transforming key industries and grassroots economic activity, to build a productive, sustainable and inclusive society, with the wellbeing of today's and future generations at its core.[5] It builds on Wales' established and emerging strengths, and offers the opportunity to put the nation at the forefront of digital and industrial policy development.

Delivering Wales 4.0 involves the Welsh Government taking an informed and active role in facilitating industrial and digital transformation by setting out defined goals, with specific targets, and working to achieve them in a defined timescale.

This mission-orientated approach under Wales 4.0 is guided by four principles (MAPS):

- **Mainstream** digital in everything government does to the benefit of all and not seeing 'digital' as an isolated topic;

- **Align** its policy and programme interventions in relation to digitalisation so that they are effectively joined up and work to common outcomes and objectives;

- **Prioritise** those interventions which will have the greatest impact in the medium to long term in delivering Wales 4.0;

- **Scale** the things we do best and not be afraid to scale back, or stop doing, the things that don't work.

This review has identified a wide range of policy recommendations to support the delivery of Wales 4.0. These are presented under seven inter-related work streams aimed at offering strategic choices for immediate action. We have also set out several longer-term actions for consideration following the 2021 elections to the National Assembly for Wales.

Key Recommendations

- The Welsh Government should **set an ambitious vision for Wales 4.0** in response to the challenges and opportunities posed by the fourth industrial revolution and ensure that digital innovation is seen as a responsibility of all Welsh Government Ministers and officials. This vision should be informed by commencing a **national conversation with citizens on the future of work and the economy** in Wales aimed at encouraging discussion of the challenges and opportunities presented by digital innovation (including the growing influence of AI).

- Support the **creation of six Industrial Innovation Clusters (IICs)** each with a designated lead body to **develop Industrial Transformation Roadmaps (ITRs)**. The ITRs will identify current strengths and the potential for advancing digital innovation at a regional, national and international level. Each cluster should be supported to develop new platforms and shared services that can facilitate their transformation needs and draw in co-investment from industry.

- To support the work of each IIC, Wales should **establish an AI Institute for the Future Economy** to help position itself on the global map as a digital nation and facilitate a more integrated approach to the application of leading-edge research in AI across Wales.

- **Integrate existing business, skills and innovation support to form a single business diagnostic and transformation process**. To ensure the Welsh Government and its agencies have the appropriate expert capacity to support the transformation needs of both service-based industries, as well as the historic focus on manufacturing, action should also be taken to **extend existing forms of innovation support to businesses** (such as *SMART Innovation*).

- **Align the Welsh Government's International Strategy and marketing activities to the principles of Wales 4.0 and the six IICs**, as part of an outward looking approach to rebrand Wales and ensure Wales' international engagement work is supported by more sophisticated data analytics and real-time information which can identify potential international partners and networks.

- **Conduct a range of reforms aimed at building capacity within post-compulsory education** so that it is able to deliver the step-change required in preparing for the future of work in an age of lifelong learning. This will include supporting a number of curriculum reforms that can provide individuals with the broad-based education required for work and life, enhanced by a digital focused version of the International Baccalaureate, and informed by the development of **a new Skills Framework for Wales**. A series of capacity building projects should also be supported and aimed at **creating the multiversity institutions of the twenty-first century**.

- Substantially increase the Foundational Economy Challenge Fund to **support a series of Smart Places Wales demonstrators** aimed at mainstreaming new digital architecture within communities in order to deliver a better quality of working and community life.

- **Establish a new Lab for Work@Wales[4.0]** which will act as a central resource for industry, government and social partners to gain insight on future trends concerning technology and its impact on the economy and work.

- **Introduce a Future Economy Commission** reporting to Welsh Ministers and with membership drawn from international business leaders and experts. The new Commission should have responsibility for advising on the coordination, oversight and delivery of Wales 4.0 and ensure that national considerations take account of global opportunities.

Our recommendations reflect the scale of the challenge ahead. We estimate that delivering the step-change requirement will involve an initial £100m of public investment to be made available. We believe that with this level of investment, the Welsh Government can proactively help to improve Wales' economic prospects and the quality of working life.

The question now is whether Welsh Government and its key social partners are prepared to 'will the means' as well as 'will the ends' to make digital innovation and the future economy truly work for the people of Wales.

Background to the review

Digital technologies are transforming the economy with major implications for the future of work. Wales, like other nations, is subjected to headline-grabbing stories warning of robots taking jobs, widespread technological unemployment, and claims that up to 1-in-3 Welsh jobs are at high risk of automation.[6]

The *Review of Digital Innovation for the Economy and the Future of Work in Wales* was established to gain a better understanding of the current state of play, as well as the future possibilities, for digital innovation in Wales. The purpose being to take the conversation beyond the headline figures and set out what practical actions Wales can take to mitigate the challenges of digital innovation and harness the opportunities for the benefit of all.

The review was set an ambitious brief by a cross-portfolio of Welsh Ministers.[7] We have delivered to that brief despite competing for attention and resources against the backdrop of Brexit. Nevertheless, the review has been able to engage with a significant number of stakeholders both inside and outside of Wales, including through the work of a specially convened Expert Panel, along with the support of social partners in Wales. A Call for Evidence was also issued, and a summary report of responses has been published alongside this report. The review has also benefited from the input provided by a range of experts, including those from Singapore and Denmark, who supported the review with briefing papers to inform the analysis and recommendations. The engagement activity of the review is outlined in Appendix A.

The scale of the challenge for Wales

- Wales has made important strides over the last 20 years of devolution. Recent employment trends are positive, but most economic and social measures point towards Wales being the poor relation of England **[see Exhibit 1]**. Critically, there are too many people on low wages with salaries consistently below the UK average. The Gross Value Added (GVA) of what is produced also highlights the need to exploit the potential of digital innovation to move the Welsh economy into more skilled and knowledge intensive activities, especially now tax devolution means the Welsh Government budget will increasingly depend on the overall performance of the Welsh economy.

- The changes we are witnessing today suggest that twentieth century trends may be less reliable indicators of twenty-first century circumstances. We should not assume that the introduction of new technologies will automatically raise the demand for more skilled workers, increase productivity or reduce income inequality in Wales. When we look at historical rates of economic productivity and earnings, we find that the close relationship between the two that was evident in the twentieth century, has been broken.[8]

- In the fourth industrial revolution, the assumption that full employment is achievable at the same time as optimising productivity and growth is also being challenged as there may not be enough paid work to occupy the potential workforce. This is not necessarily a bad thing as, for example, Germany had the fewest average working hours per week of any OECD country in 2018 at just 26.[9] But we must plan ahead to protect well-being and ensure that people have enough income to live a decent life.

- As we embrace digital innovation, the benefits are predicted to exacerbate the gap between the haves and the have nots, urban and rural, both economically, and in terms of opportunity, life chances, health and well-being. The connections between these factors have already been identified in the Well-being of Future Generations (Wales) Act. In order to shape the future in ways that meet the aims of this Act, we need to ask how the benefits of digital innovation can be shared more equally across society.

Exhibit 1: Selection of key indicators for Wales

- 3.13m mid-2017 population estimate for Wales
- 3.23m projected population for Wales in 2030
- 75% employment rate
- 3.9% unemployment rate
- 8% workers are on minimum wage
- 21.8% economic inactivity rate
- 23% of working-age adults live in relative income poverty
- 29% of children live in relative income poverty
- £15,753 Wales gross disposable household income per head
- £19,514 UK gross disposable household income per head
- £509 Wales average gross weekly earnings
- £569 UK average gross weekly earnings

Sources: StatsWales, Office for National Statistics (ONS)

- Wales confronts the challenge of building new ties and strengthening existing ones with international partners to widen opportunities for collaboration and to secure additional investment. This reflects the fact that the world is undergoing a profound change. A HSBC study shows that emerging economies will account for roughly 50 per cent of global Gross Domestic Product (GDP) by 2030.[10] China is already the single biggest contributor to global growth, but another five Asian economies will be among the world's six fastest-growing economies; Bangladesh, India, Philippines, Pakistan and Vietnam.[11]

- The UK's future relationship with the European Union (EU) will undoubtedly have major funding implications for Wales. Unlike most of the UK, which secures EU funding for research and innovation through competitive Horizon 2020 programmes, Wales secures most of its EU research and innovation funding from the EU Structural Funds. During the current Programme funding period (2014-2020), the Welsh Government has invested £340m in Research and Innovation priorities. This represents 20 per cent of all EU structural funds allocated to Wales and continues to play a vital role in growing Wales' research capacity and infrastructure. The

UK Government's guarantee to sustain these funds after the UK leaves the EU will be crucial to delivering the recommendations presented in this report.

- Digital innovation is also changing business models and behaviours. A lot has been written about disruptive technologies and corporate restructuring, but the salient point here is the flow of value. As we order from Amazon or get our entertainment streamed from Netflix, our spending power is increasingly being syphoned offshore. This means that the retention of wages and tax revenue in the UK is diminishing at a time when we need to spend more on health, education and social security [see Exhibit 2].

Exhibit 2: The Growth and Impact of UK Internet Sales

The Growth and Impact of UK Internet sales

Tax and Labour returns per £100 spent
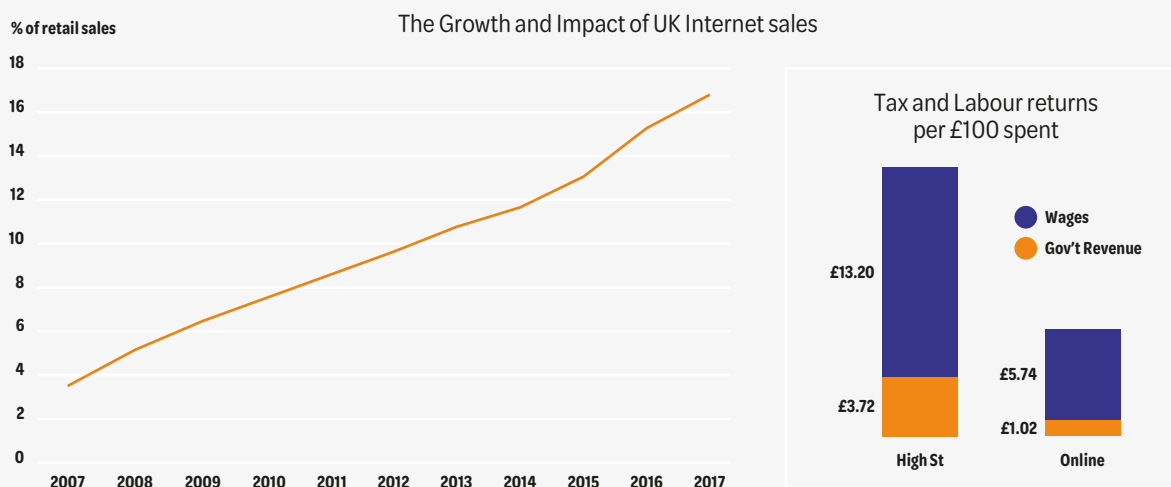
Prof. Calvin Jones, Cardiff University "Not so Smart? The City and the Digital Economy"
Sources: ONS (2018); Centre for Retail Research and Daily Mirror (2018)

- The scale of the challenge also includes increasing longevity, due largely to technological and medical advances. *The 100 Year Life* by Lynda Gratton and Andrew Scott, imagines the implications of large numbers of people in developed economies living to 100 years or more. They suggest that a child born in the West today has a 50 per cent chance of living to over 105 years, making the three-stage model of life - education, work and retirement - untenable. Government, employers and educators will have to rethink the linear approach which appears to guide a lot of current policy thinking. The proportion of people aged 50-64 working in the UK has already risen from 50 per cent in 2000 to 65 per cent in 2018.[12] If a larger proportion of people want to work later in life, employers will need to do more to support mature employees to stay in the workplace for longer.

- A possible reduction in the number of hours in the working week could also lead to an increased demand for more flexible or part-time learning which is currently under supported. Enhancing lifelong learning will become key to keeping people active and interested and to help them adapt and acquire different skills as their jobs get redesigned, they change career, or enter new roles. This additional free-time in the week may lead to an increase in the number of people taking a more active care role, so we may also need to rethink how we value different roles within society.

The rest of the report is divided into two main sections:

Section 1

We define key terms and assess the evidence on automation and its implications for the economy and future of work in Wales.
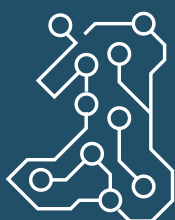
Section 2

We introduce Wales 4.0 as our national response to the challenges facing Wales and organise our recommendations under seven work streams.

Section 1

Automation, jobs and the future of work

What is digital innovation?

This review has adopted a broad definition of digital innovation to include any novel products and services, or more productive ways of doing existing things, along with yet imagined things based on digital technologies. For the most part we are talking about 'general purpose' technologies not restricted to one industry such as ICT, but diffused across the whole economy, like the development of electrical power in the late nineteenth and early twentieth century.

Digital innovation is being driven by advances across inter-related fields, contributing to the development of a portfolio of interconnecting technologies **[see Exhibit 3]**. At the same time, these technologies are creating new industries, such as gaming, robotics, cyber security, and wearable devices, as well as enhancing the customisation of products and services, such as in online content and media streaming services. As a result, they are leading to the breakdown of our historic view of traditional industrial sectors, occupations and consumer markets.
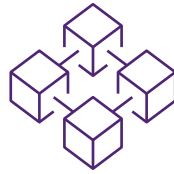
Exhibit 3: Key technologies relevant to digital innovation
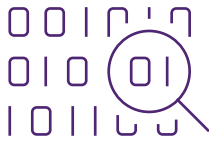
Artificial Intelligence (AI)
Technologies with broad cognitive capacities to comprehend, learn and perform tasks that otherwise would depend on human intelligence. AI is becoming a general-purpose technology with multiple applications across all parts of the economy and society.

Blockchain
Blockchain is the technology which underpins new digital currencies such as Bitcoin. Often referred to as a "digital ledger", it stores activity in a distributed network which cannot be altered retrospectively.


Big Data and Data Analytics
Big data are datasets with tremendous volume, exponential speed and immense variety which conventional software programmes are unable to acquire, cache, organise and therefore effectively analyse. Data Analytics is the process for analysing, modelling and transforming data in order to draw conclusions and make decisions, the aim being to extract value from the data available.

Cloud Computing
Cloud Computing is a general term for anything that involves delivering hosted services over the Internet. These services include those of Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS). Cloud Computing provides significant flexibility for organisations to work in an agile and dynamic manner, with services being accessible to any user where an internet connection exists.
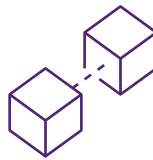

Internet of Things (IoT) and Digital Twins
A connection of a dynamic network of virtual and physical devices to communicate and exchange data on the internet via human-computer interfaces. A Digital Twin is a digital replica of a physical asset (the physical twin), they offer a virtual method for simulating activity in the physical world.

Additive Manufacturing and 3D Printing
A digitally controlled fabrication method in which 3D objects are created through a series of consecutive layers of material. Custom manufacturing means producing goods or ranges of goods specifically tailored to the requirements and needs of an individual customer. Individual products and ranges may incorporate numerous variations in terms of the components used, composition and appearance.
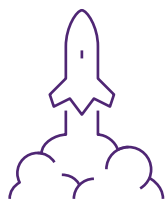
Autonomous Things
Autonomous Things, or sometimes referred to as or the Internet of autonomous things (IoAT), provide a way of bringing computers into the physical world. Ranging in size and scope from drone technology to personal vehicles, Autonomous Things utilise the power of multiple technology disciplines, including AI, which allow them to interact with the physical world with minimal human intervention.

Virtual and Augmented Reality
A 3D, virtual environment created by a computer system with human interaction through specialist devices (helmets, gloves etc.). Augmented Reality (AR) works differently by allowing images, labels and guides to be combined with real world images thereby enhancing the visual field of a user.

What is meant by the fourth industrial revolution?

In the late eighteenth century, steam, water and mechanical equipment transformed production in the UK. A century later, electricity and mass production revolutionised the economy and created mass consumer markets. The final decades of the twentieth century brought electronics and information technology, and now we have entered the early stages of the fourth industrial revolution, which some see as presenting 'unlimited possibilities' of billions of people connected by mobile devices offering access to real-time data and leading-edge knowledge which reflect *'a confluence of emerging technology breakthroughs.'*[13]

**Exhibit 4: Phases of Industrial Revolution**

First Industrial Revolution
From end of the 18th Century to late 19th Century

Mechanisation and the development of steam power, production mainly focused on agriculture, textiles, etc.
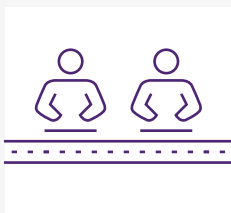
Second Industrial Revolution
From Late 19th Century to mid-20th Century

Advanced mechanisation based on factory mass production power by electricity. It also gave rise to increasing white-collar employment to support the growth of mass consumer markets and public services.
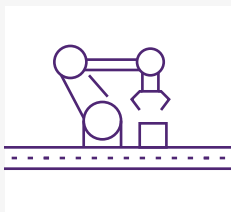
Third Industrial Revolution
Mid-20th Century to beginning of 21st Century

Growth of electronics, computing and the internet, fuelled by an exponential increase in computing power. It gave rise to a new wave of economic globalisation and the integration of corporate value chains, extended from manufacturing to service industries.
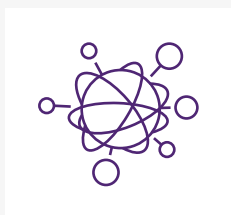
Fourth Industrial Revolution
From the early 21st Century and remains in the early stages of development

Digital transformation of business, public services, and the wider society, driven by rapid advances in Artificial Intelligence, Robotics, Data Analytics, Internet of Things (IoT), etc. It is challenging existing models of work organisation with major implications for the economy and the future of education, jobs and the labour market.

The development of the car industry in the second industrial revolution of mass production, created huge investment in new infrastructure, including road networks and led to large numbers being employed in factories doing low-skilled production roles on semi-automated assembly lines. It also contributed to the growth of white-collar office work to meet the growing need for a more systematic approach to organising sales, marketing, procurement, and human resource management.

Today, things including the extensive use of robots in car plants and the potential for autonomous vehicles to eliminate the need for people to drive

taxis, buses, or haulage vehicles - which characterise the fourth industrial revolution - has led to growing concerns about the future of work. This has resulted in attempts to calculate the areas of work that are most, and least, at risk of being fully-automated.

Although these are early days, it appears we have already reached a tipping point transforming the technological possibilities across the physical, digital and biological worlds.[14] But the fourth industrial revolution is not a unique age of technological invention, but instead an age of recombination. A study of American patents from 1790 to 2010 found that in more recent times, most patents involved the recombination or refinement of existing combinations of technologies rather than the creation of new technological capabilities.[15]

This reflects a wider point, because most innovation is not of the step-change or radical variety but incremental (refining, rearranging, repurposing) that flourishes when there is a culture of innovation.[16] While investment in R&D and world-class higher education play a vital role,[17] in an age of recombination, we need to focus attention on developing a culture of digital innovation across the whole economy and wider workforce.

Will automation lead to job losses?

Fears concerning the impact of automation on employment have a long history. David Ricardo, an influential nineteenth century economist, viewed the substitution of machinery for human labour as, 'often very injurious to the interests of the class of labourers.'[18] A century later, John Maynard Keynes anticipated mass 'technological unemployment' as the application of new technologies that would outpace efforts to find new uses for labour.[19] The aim of this review is not to reproduce or add to the plethora of studies already undertaken on this topic, but to assess recent claims surrounding the impact of digital innovation.

Our starting point is to consider what we mean by automation. At its most basic, automation is the substitution of human activity by machines. Today this is symbolised by robots doing increasingly clever things, such as clinical surgery or humanoid robots like Sophia who is able to hold a conversation (and is the first robot to be granted national citizenship in Saudi Arabia).[20] Automation also includes that which is less visible, such as the use of AI and machine learning to 'read' legal documents, control autonomous vehicles or redesign the work of people in contact centres using chatbots [see Exhibit 5].

Exhibit 5: Monty – The Monmouthshire County Council Digital Chatbot

Monmouthshire County Council has responded to financial pressures and increasing demands and expectations of its residents by becoming the first local authority in Wales to develop a chatbot to complement its customer service offering.

The chatbot, called "Monty", was launched in January 2019. It uses AI and learns about the questions people ask most often to develop quicker and better responses. The tool provides additional capacity, releasing council staff to support vulnerable people and those with more complex queries. It is also improving responsiveness as a higher volume of queries can be dealt with at any time of day.

Monmouthshire County Council worked with Cardiff based start-up WeBuildBots to develop the tool. It forms part of the Council's strategy to improve the wellbeing and prosperity of its residents through improving customer services and providing a wider digital offering. It is complimented by the Council's Community Hubs which, amongst other things, support people to get online for the first time and access digital services, hence assisting with digital exclusion.

It is also thought to contribute to economic development by stimulating a digital economy with skilled jobs and business opportunities, by presenting the region as a thriving and attractive location for tech industries and investment.
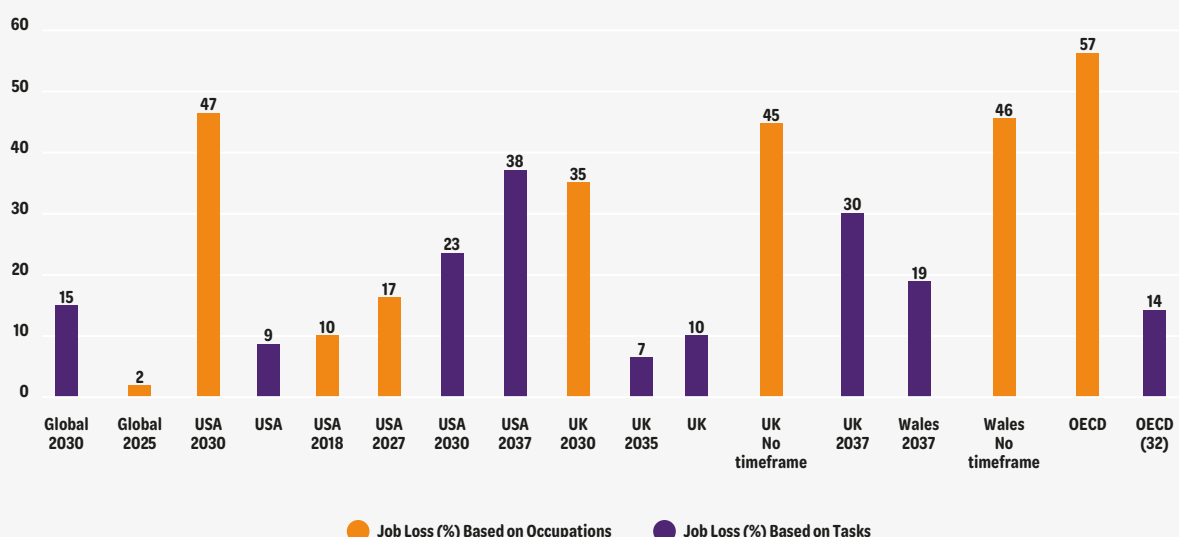
This review has drawn together research from various studies looking at the potential of digital innovation to replace human labour. **Exhibit 6** illustrates how the reported differences in 'threat' levels are particularly striking and inconsistent. We can see that studies which predict large-scale automation tend to focus on 'occupations'. This involves asking technical experts to assess how difficult it would be to find technological substitutes for humans in specific occupations, such as police officers, software engineers, or customer service agents.

However, other studies have questioned whether it is possible to gain an accurate picture by simply assessing occupations, without taking account of the range of activities bundled together under each job title.

They take a 'task' approach recording the various activities that are typically expected of people within each occupation and then ask experts to assess the risk of each task being automated.

When using a task, rather than occupational approach, the proportion of jobs at risk of automation declines. Frey and Osborne – one of the most widely reported studies into the impact of automation – estimated 35 per cent of jobs in the UK are highly automatable based on occupations.[21] However, Arntz and colleagues, as part of their work for the OECD, suggested only 10 per cent of jobs in the UK will be lost to automation based on tasks.[22]

Exhibit 6: Analysis of various studies examining the impact of automation on jobs

Job Loss (%) Based on Occupations   Job Loss (%) Based on Tasks

Category	Value
Global 2030	15
Global 2025	2
USA 2030	47
USA	9
USA 2018	10
USA 2027	17
USA 2030	23
USA 2037	38
UK 2030	35
UK 2035	7
UK	10
UK No timeframe	45
UK 2037	30
Wales 2037	19
Wales No timeframe	46
OECD	57
OECD (32)	14

Different methodologies for predicting the jobs most at risk also make it difficult to forecast the impact of automation on the employment of female and male workers as the available evidence is again characterised by contradictory findings. A PwC study estimates that more men than women are at risk of automation (albeit in the longer term), whereas an IPPR Report on Managing Automation, used a different methodology and found that a greater proportion of UK jobs held by women compared to men (46.8 per cent compared to 40.9 per cent of men's jobs) have the technical potential to be automated.[23]

Part of the problem is that much of the research on automation examines the technological feasibility of job automation which is not the same as these jobs actually being automated. What many of the existing studies on automation have failed to factor in is that it's never simply a question of substituting robots for people because it depends on a quality-cost equation made by employers of all sizes.[24] It is also contingent on how the latest advances in technologies are used by companies, governments and the wider population.

This explains why some tasks or occupations may not be automated even when the technology exists to do so, for the simple reason that it may make little commercial sense for companies when they have access to a supply of relatively cheap labour. If the cost of that labour increases due to minimum wage legislation or demographic shifts in workforce composition, they may decide on a technological solution. But it also suggests that if Wales is going to attract more international capital and to participate in higher value parts of international value chains, it is going to need a value proposition that is able to flourish in a quality-price competition with many other parts of the world. Recent news stories of companies leaving Wales are perhaps a testament to this principle in action, although Brexit is also likely to be a contributing factor.

Research evidence on the relative risks of automation also tells us far less about how new technologies are used to redesign occupations, changing the content, character and context of jobs. There's a commonly held view that automation and AI will have the most impact on routine jobs, but what is classed as 'routine' and 'high-skilled' may change in the context of digital innovation. We should not underestimate the level of human skill still required in 'unskilled' work.

Rapid increases in processing power are enabling companies to capture large amounts of the knowledge assumed to remain in the heads of what we call knowledge workers. This process of digital Taylorism - translating knowledge work into working knowledge, captured in digital software - is already having a major impact on professional occupations such as accountants, lawyers, consultants and teachers.[25] Therefore, we should not assume the AI and automation will attack from the bottom of the occupational structure to the top, but that its impact will be unevenly spread.

Will advances in digital innovation lead to new jobs?

Even where significant job losses are predicted, it is often assumed to mirror earlier periods of economic development, where a painful period of adjustment - at least for some workers - leads to more jobs being created than destroyed. Research by Deloitte found that in the 144-year period 1871 – 2015, technological progress had resulted in more job opportunities in England and Wales.[26] But to assume that history will continue to repeat itself in supporting more and better quality jobs is based on faith, not fact.

We know that the economic uncertainty being experienced through the prolonged Brexit discussions have already impacted investment in technologies by businesses across the UK. There are also government regulations to consider. For example, changes in financial regulations or physical infrastructure may be required for the widespread use of electric and autonomous vehicles. These factors are likely to alter the absorption of new technology across the economy thereby potentially slowing the pace of automation and holding back new employment opportunities.

On the question of job creation, we can find no evidence to support the claim that two-thirds of jobs that school children will enter don't yet exist. A PwC report on Will Robots Steal Our Jobs found that only 6 per cent of all UK jobs in 2013 were of a kind that didn't exist in 1990.[27] However, this does not mean that these jobs have remained unchanged but it does remind us that most job openings for those entering the job market will be 'replacement' jobs, as people retire or move into other positions, rather than new jobs being created.

In Wales, 91 per cent of job openings between 2014 and 2024, and 88 per cent of those in the UK, are predicted to be 'replacement' jobs. **Exhibit 7** shows the projected changes to employment in Wales on a sector basis between 2014 and 2024 using Working Futures, which is one of the data sources used by the Welsh Government. We have selected the expansion demand across 12 of the 22 sectors covered by Working Futures. It shows a much higher replacement demand in health and social work, wholesale and retail trades, and education (although these are relative to the overall size of employment within these sectors).

The predicted expansion demand in wholesale and retail trades by 2024 is surprising given the current plight of Wales' high streets and reports that jobs in the retail sector are at high-risk of automation. As with Working Futures, other studies that have looked at job creation, also need to be treated with

Exhibit 7: Changes in employment in Wales by sector, 2014-2024

Source: Working Futures, 2014-2024

● 2014   ● 2024   ● Expansion Demand   ● Replacement Demand
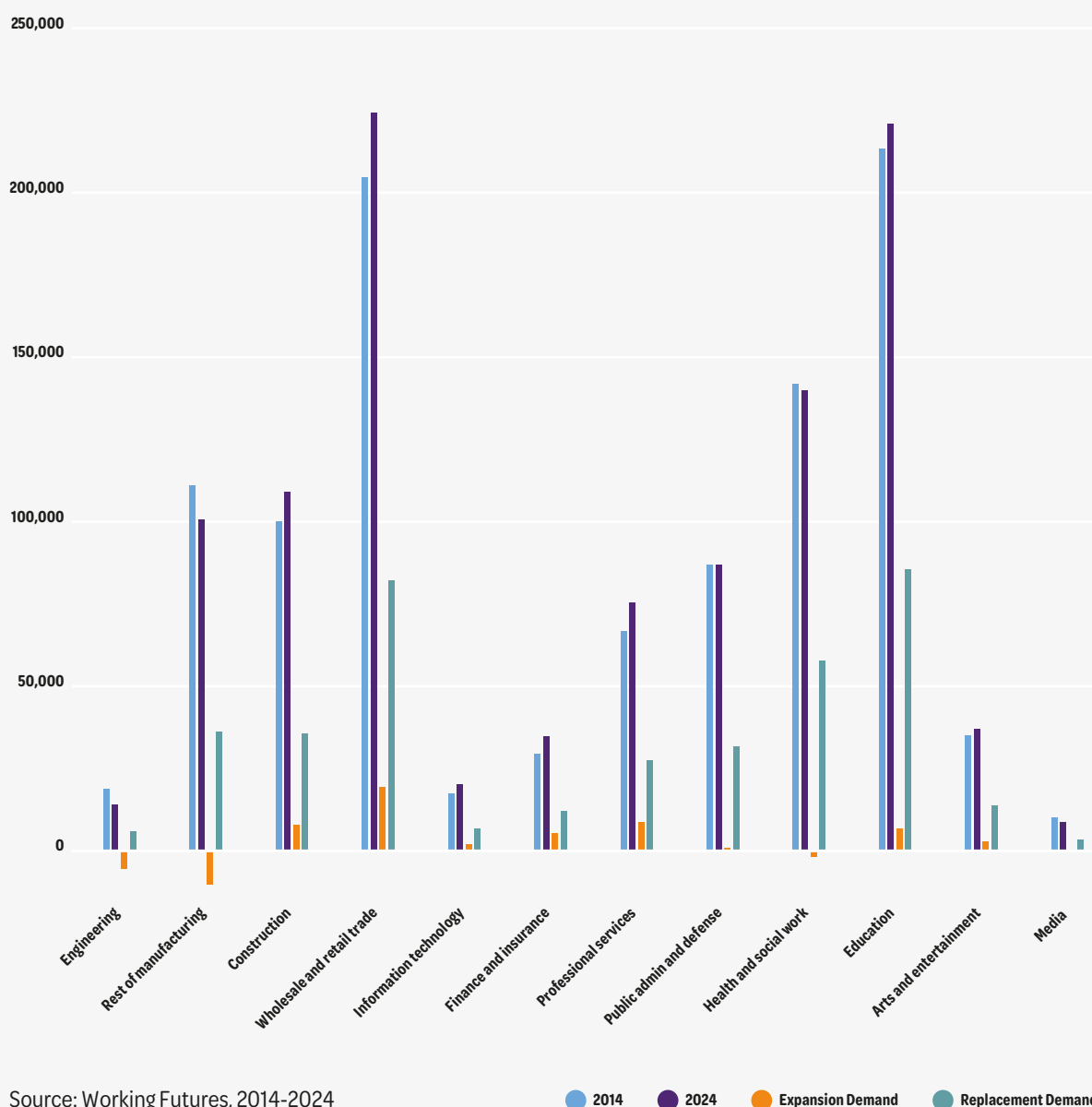
caution given potential flaws in research design and considerable variation across their forecasts. The World Economic Forum, for example, predict a global net gain of 4 per cent between the numbers of jobs lost and new jobs created, while a global net gain of 21 per cent of jobs is reported in a study by McKinsey.[28]

Despite such evidence, we've suggested that it can't be taken for granted that the digital revolution will be the same as previous industrial revolutions in that it creates more jobs than it destroys. This is not only because it's difficult to identify new areas of mass employment but is also due to changes in the way we think about a job, occupation or waged-work.[29]

The continuing shift towards more flexible contracts of employment, facilitated by new technologies, is forcing more people to make a living based on precarious models of economic participation such as zero-hours contracts, the gig economy, or as 'slashers' who have multiple part-time jobs.[30] There has been a lot of discussion about online digital platforms with the potential to disrupt many areas of employment in a diverse range of business activities, including travel, accommodation, retail, banking, education and training, and software development. Some of the most high-profile examples are Uber, Airbnb, Upwork, Profinder and Freelancer, along with online retailers like Alibaba and Amazon.

While some view these platforms as a quick and cost-effective way of linking supply and demand,[31] others view the on-demand economy as putting too much power in the hands of the platform impresarios. Some of these issues were covered by the recent report by The Fair Work Commission which provides an analysis of self-employment and use of gig platforms in Wales.[32] It estimates that in 2018, around 2.5 per cent of the workforce in Wales (36,900 workers) were employed on a zero-hours contract, which is marginally higher than the UK average of 2.4 per cent. It also notes that employment insecurity is not limited to those on zero-hours contracts, as it includes self-employment as well as those in previously secure jobs.

In Wales, around 38 per cent of jobs growth between 2007 and 2016 has come from self-employment. However, as the Fair Work Commission highlights, there is evidence of a decline in the quality of working life for some of those categorised as self-employed. There is also evidence that the rise in self-employment includes a disproportionate number of people with recent experience of unemployment, reflecting a scarcity of alternative jobs opportunities.

Summary

- There are some significant flaws in existing research methodologies and practices which make it challenging to provide robust predictions on the future of work. More inventive solutions are needed which draw on advances in data analytics to supplement the existing evidence base, giving us better intelligence and insight into how we should respond and target our scarce resources.

- We do know that digital innovation is reshaping the nature of work and will continue to do so. The future of work is not simply going to be characterised by routine jobs being replaced by high-skilled, high-waged work.

- Digital innovation is transforming work at all levels of the occupational structure. The pace and scale of this change is likely to accelerate, with the impact being felt across all sectors of the Welsh economy and all occupations, although to varying degrees. There is a limited window of opportunity for Wales to respond.

- Automation is just one of the many factors which will shape the future of work and the economy. Other variables such as the level of investment in R&D and innovation, regulatory changes and the switching of consumer markets also play a part. The state has agency here in aiding business to adapt to new markets, however it is not able to fully control the tide of change in the context of an ever-growing global digital economy.

# Is Wales more vulnerable to automation than elsewhere?

It is difficult to answer this question definitively given the weaknesses in the research design highlighted above, and due to a lack of available data on the impact of digital innovation specific to Wales. For the most part, we have to rely on UK data and then make some broad assumptions about how this analysis applies to Wales, particularly given the known differences in workforce demographics and prominence of different sectors and job roles. However, there is some evidence available to us which should be treated as indicative rather than conclusive.

If we consider PwC's analysis on the regional impact of AI and related technologies in the UK, Wales' job market is not significantly more vulnerable than other parts of the UK, apart from London and the South East.

Exhibit 8 shows a small net gain in the percentage of job creation for Wales between 2017 and 2037.

Future Advocacy, a thinktank that consults on new technologies and societal challenges, investigated the impact of AI for UK parliamentary constituencies. For Wales, the proportion of jobs at high-risk of automation by the early 2030s varies from 26 per cent to over 36 per cent. They predict that Wales' industrial centres in the North and South are likely to be hardest hit: Alyn and Deeside was identified as having the highest risk (at 36 per cent) and was ranked 4th in the list of all UK constituencies. They also identified Wholesale and Retail, along with Manufacturing, as the most automatable sectors for Wales.[33]

Exhibit 8: Estimated % change in regional jobs impacted by AI and related technologies in the UK 2017-37

Net effect   Displacement   Creation
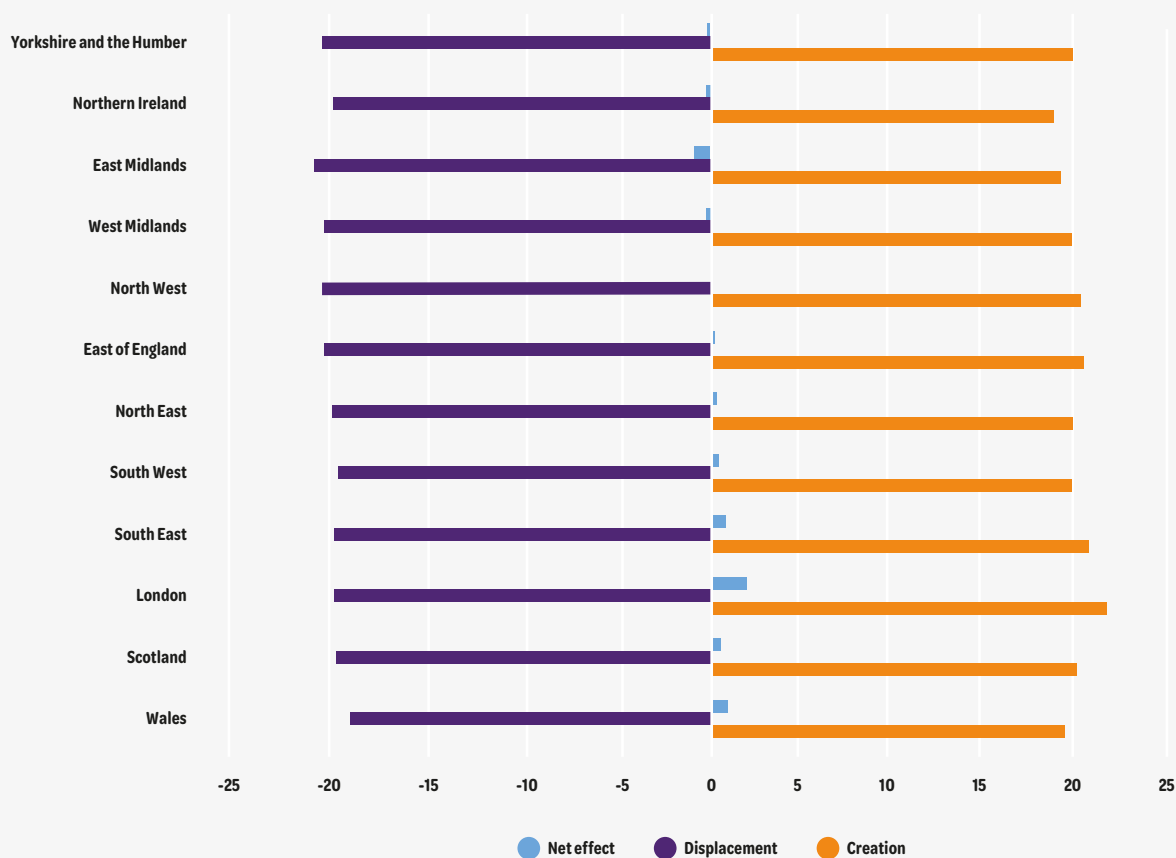
Source: PwC, UK Economic Outlook report, July 2018

Exhibit 9: Potential impact of job automation by UK industry sector
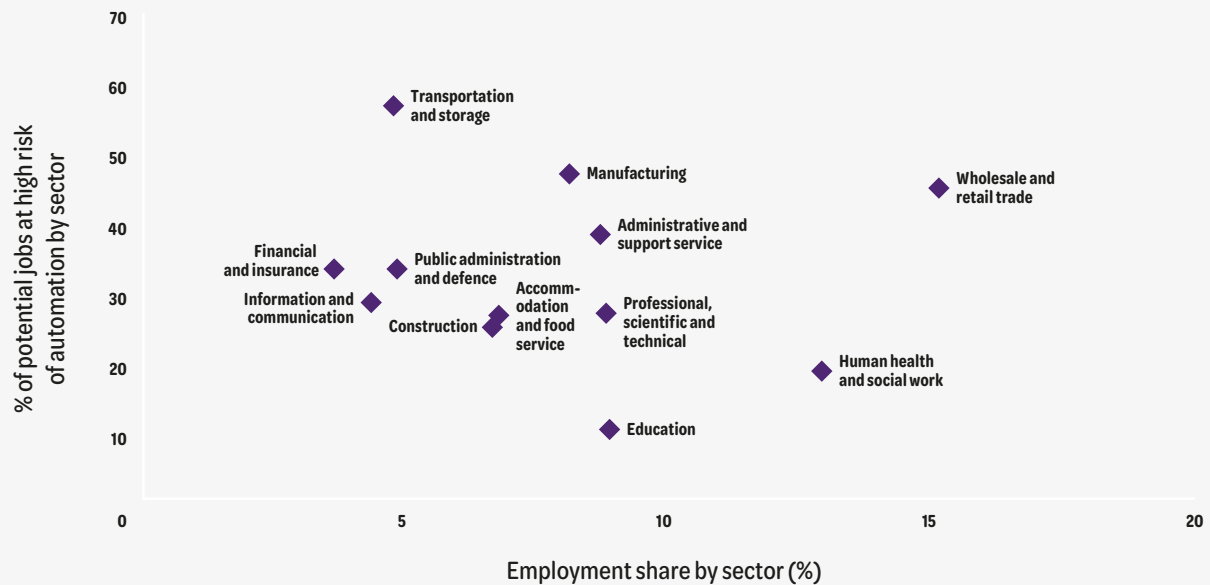
Source: PwC, UK Economic Outlook Report, March 2017

Exhibit 9 highlights some potential risk areas for Wales considering the impact of automation for sectors such as manufacturing, wholesale and retail trade, public administration and defence, and financial and insurance. All of which are significant areas of employment in the Welsh economy. Although human health and social work has a low potential risk of automation compared to other industries, the employment share for the sector is particularly large, suggesting the volume of jobs impacted could also be considerable. The same is true for wholesale and retail trade where there is both a high risk of automation and a large percentage of people working in the sector.

When we consider occupations rather than sectors, NESTA's report on *The Future of Skills: Employment in 2030*, identifies that 1 in 5 of the UK workforce are in occupations likely to shrink over the coming decade.[34] This compares to 1 in 10 of the UK workforce in occupations which are likely to grow over the same period.

Exhibit 10 sets out the top 10 occupation groups with the greatest and the lowest probabilities of future increased demand. The Nesta analysis is consistent with the PwC data **[Exhibit 9]** in highlighting the relative resilience of public sector jobs.

It also presents a positive outlook for creative, digital, design, and engineering occupations, but at the same time predicts a fall in manufacturing production occupations, along with administrative, secretarial and sales occupations.

The broad conclusion for Wales is that the relatively high proportion of the Welsh workforce (compared to the rest of the UK) in public services, may offer some degree of shelter from the threat of automation (at least in the short term). However, employment growth in occupations including creative industries, hospitality, sports and fitness, may be offset by falls in workforce share for manufacturing and financial and professional services (resulting from a decline in customer service and administrative positions involved in Contact Centres). By no means is this assessment conclusive considering we are making some broad assumptions based on a UK-wide analysis.
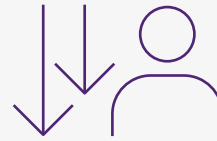
Exhibit 10: Top 10 occupation groups with the greatest and the lowest probabilities of future increased demands (UK)

The occupation groups with the greatest probabilities of future increased demand

1. Food Preparation and Hospitality Trades
2. Teaching and Educational Professionals
3. Sports and Fitness Occupations
4. Natural and Social Science Professionals
5. Managers and Proprietors in Hospitality and Leisure Services
6. Health and Social Services Managers and Directors
7. Artistic, Literary and Media Occupations
8. Public Services and other Associate Professionals
9. Other Elementary Services Occupations
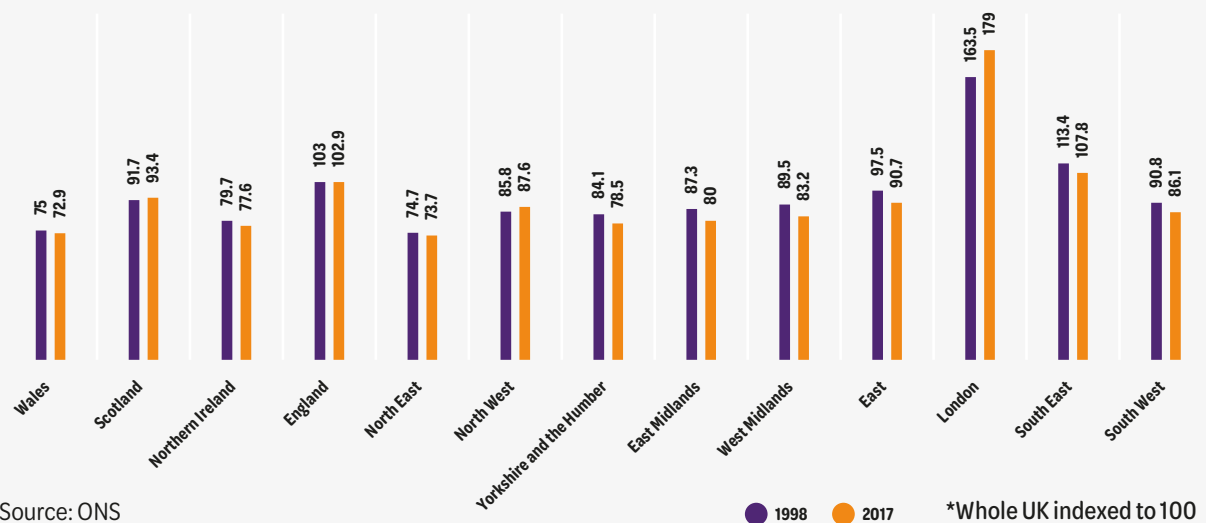10. Therapy Professionals

The occupation groups with the lowest probabilities of future increased demand

1. Mobile Machine Drivers and Operatives
2. Elementary Administration Occupations
3. Elementary Sales Occupations
4. Elementary Storage Occupations
5. Customer Service Occupations
6. Customer Service Managers and Supervisors
7. Assemblers and Routine Operatives
8. Elementary Agricultural Occupations
9. Other Administrative Occupations
10. Printing Trades

Source: Nesta (2017) The Future of Skills: Employment in 2030

Exhibit 11: Gross Value Added (£ per head) by area and year

Area	1998	2017
Wales	75	72.9
Scotland	91.7	93.4
Northern Ireland	79.7	77.6
England	103	102.9
North East	74.7	73.7
North West	85.8	87.6
Yorkshire and the Humber	84.1	78.5
East Midlands	87.3	80
West Midlands	89.5	83.2
East	97.5	90.7
London	163.5	179
South East	113.4	107.8
South West	90.8	86.1

Source: ONS   ● 1998   ● 2017   *Whole UK indexed to 100

Vulnerability to job automation in Wales also needs to be considered in the broader context of the Welsh economy. **Exhibit 11** uses Gross Value Added (GVA), the standard measure of the economic value of productive activity, to highlight the scale of the challenge confronting Wales, not only to prepare the workforce for rapid advances in digital automation, but to increase the value of economic activity in Wales compared with other parts of the UK. It's claimed that those working in central London produce 33 per cent more per hour than the current UK average.[35] But 33 per cent more of what exactly? If you make jewellery out of gold or tin, the market value (and hence GVA) are going to be very different, regardless of how skilled the workforce, as jewellery made from gold is likely to result in a much higher profit margin.

If Welsh companies are locked into low-value parts of UK, European and worldwide value chains, with little scope for higher value roles such as R&D, international procurement, or creating marketing campaigns, it is not only very difficult to improve the nation's GVA and narrow the Wales-UK income gap, but it also exposes the Welsh workforce to a quality-cost competition, especially as companies seek to automate less valuable parts of their value chains. Even if Wales was less vulnerable to automation than elsewhere in the UK, the key question is whether Wales can grasp the opportunities presented by digital innovation to create better jobs and increase the GVA of the Welsh economy.

Evidence drawn from a study of job vacancies requiring digital competences in Wales and the rest of the UK **[Exhibit 12]**, underlines the scale of the challenge. The proportion of job adverts asking for digital competences in Wales reveals a sizeable gap, despite some improvement since 2012. This gap exists across the occupational structure, with the largest difference being in professional occupations. Of greater concern is that the 90 per cent increase in data science adverts in the UK between 2016 and 2017 has not been mirrored in Wales, which has actually seen a 10 per cent decrease in the same period. A more nuanced picture is gained by comparing UK cities. It shows that Cardiff has a higher proportion of job openings asking for digital competences than Liverpool and Sheffield, but trails Bristol, Edinburgh and London.

There are clearly other issues that Wales needs to address beyond its economic structures and how to improve job quality in the context of workplace automation. As the qualification profile of working age adults shows, in 2018 Wales still had a greater proportion of people with no qualifications (8%) than England (7%), but a smaller proportion than both Scotland (10%) and Northern Ireland (14%).However, there were much greater differences between the local authorities of Wales than between the home nations, as the proportion of working age adults with no qualifications in both Blaenau Gwent and Merthyr Tydfil (15%) was three times that in Monmouthshire (5%).[36]

Wales also has fewer people with degree level qualifications, although this review would question whether this is an indicator of economic weakness as the qualification profile of the German workforce testifies.[37] It's the quality of provision across the whole of the education and training system that really matters, underlining the importance of national commitments to narrow inequalities in social class, gender, race and ethnicity.[38]

Further expansion of higher education may be desirable for reasons other than economic utility, but we need to be mindful of evidence of over-qualification in Wales, which stands at around 40 per cent and has shown little change over the last decade or so.[39] When supply exceeds demand, it can lead to 'brain drain'[40] as people move out of Wales to secure jobs equal to their qualifications. This further underlines the problem of job quality that needs to be addressed alongside changing skill requirements.

Exhibit 12: Comparison of job-openings requiring digital competences, Wales versus UK

Percentage of job advertisements requiring digital competences in Wales and the rest of UK (2012-2017)

UK: 48,122,450 job advertisements. Wales: 847,356 job advertisements

Source: Briefing Paper – Labour Market Analytics, Professor Manuel Souto-Otero

● UK ● Wales

Percentage of jobs advertisements requiring digital competences compared all jobs in selected Travel to Work Areas (Jan 2016 - June 2018)
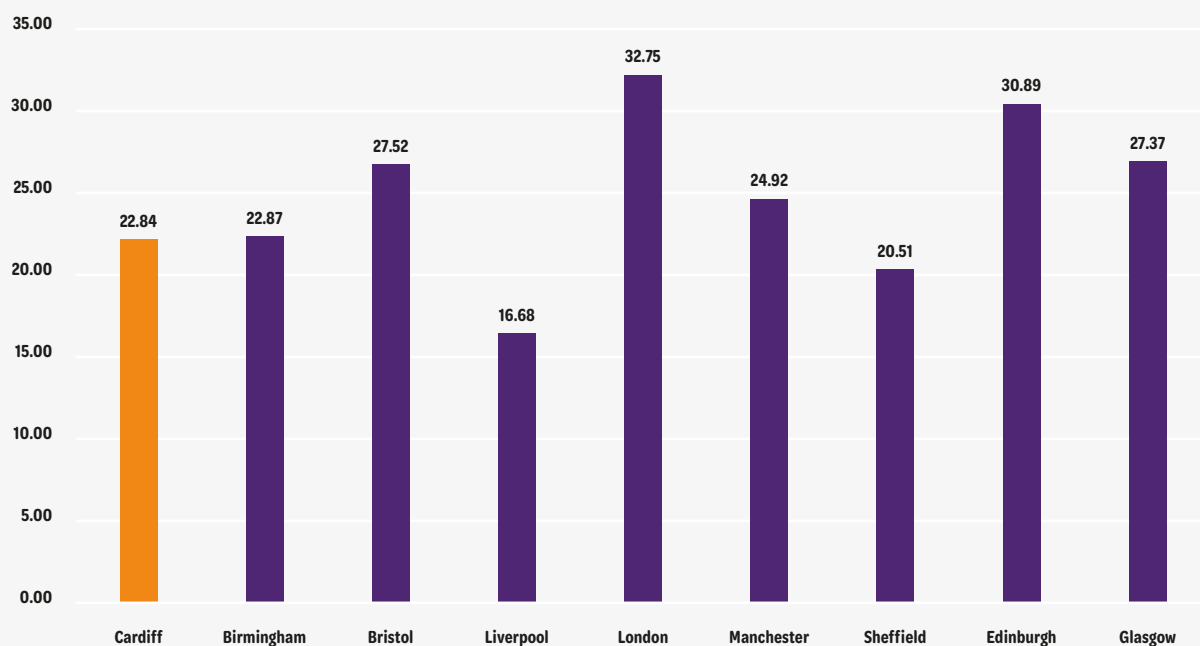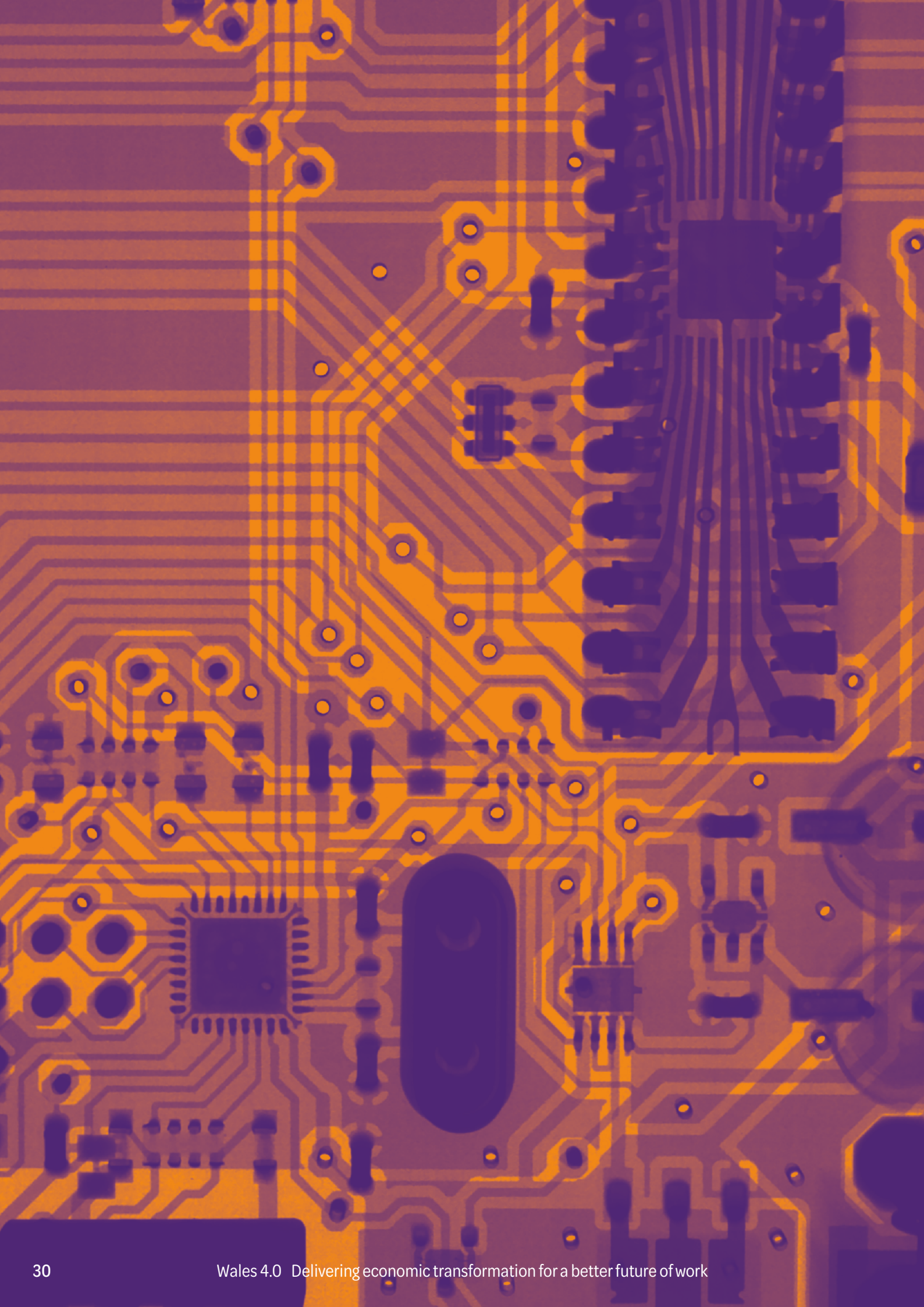

Number of job adverts: Cardiff: 166,474; Birmingham 662,263,Bristol: 439,129, Liverpool: 197,982, London: 4,786,034, Manchester: 773,111, Sheffield: 191,213, Edinburg: 270,335, Glasgow: 288,944.

Source: Briefing Paper – Labour Market Analytics, Professor Manuel Souto-Otero

● UK ● Wales

Wales 4.0   Delivering economic transformation for a better future of work

Section 1 Summary

To conclude this section, we will summarise our analysis by highlighting the following points:

- Digital innovation will create, destroy and redesign jobs but the pace and scale of this change is unpredictable. However, without robust action by policy makers and social partners, any response will be quickly overtaken as the window of opportunity to transform the Welsh economy is rapidly narrowing. This is not to say that existing policy and strategy work is ineffective, but that more radical and inventive solutions are needed if we are to deliver change at the speed and scale required.

- Technology is not fate, and Wales has the capacity to respond to automation in a manner which best reflects the needs of its citizens. It's about developing new cultural practices not just investing in technology.

- There is a capacity problem at the heart of the Welsh economy in that there is a struggle to provide enough good quality jobs, which is also true of most other developed economies, so transformation is needed. This is not just about being digital or investing in new technology, but strengthening the links between skills, innovation, job quality, productivity, and our international policies in order to provide a coordinated push which radically shifts the Welsh economy.

- There remains a need to contribute to higher value-added parts of global value chains if Wales is to benefit from the economic gains of digital innovation. Islands of excellence aren't going to be good enough to compete. A rethink is needed which supports the delicate balance between moving away from defending jobs in existing industries at high-risk of job automation and embracing emerging industries or clusters of the future.

- A fair and inclusive society can't be delivered through the labour market alone. The question of how to redistribute the benefits of economic production must stand alongside questions of wealth creation. Inclusive growth will require state intervention which takes a different approach from previous industrial revolutions. The state should set the mission but should not see itself as the central controlling factor.

- Delivering change will require strong leadership from government and key players which is underpinned by clear and more sophisticated measures of success, building on the objectives and indicators linked with the Well-being of Future Generations (Wales) Act.

Section 2

Wales 4.0: A national response
to the fourth industrial revolution

What is Wales 4.0?

Our assessment of the available evidence suggests that we are at the beginning of an industrial revolution, facilitated by advances in digital technologies, including AI, machine learning, robotics, biotech, etc. which is transforming the Welsh economy and reshaping how we work, where we work, and what we do for a living.[41] Indeed, few areas of life will remain untouched by these changes.

The fourth industrial revolution will not inevitably lead to more equitable outcomes or better jobs. Leaving things to the market will result in Wales being in a technological race to the bottom. Technologies will only contribute to creating better jobs if employers (both in the private and public sector) commit to a policy focus on improving job quality and skill augmentation.

Wales 4.0 offers a way of presenting a new national strategy that provides the basis for transforming key industries and grassroots economic activity to build a productive, sustainable and inclusive society, with the wellbeing of today's and future generations at its core. It builds on Wales' established and emerging strengths and provides the potential to put the nation at the forefront of digital and industrial policy development.

Wales 4.0 harnesses the opportunities for a new economic narrative – from coal mining to data mining – to reposition Wales as a digital nation. Wales is well known for its coal mining heritage and the industries and communities it spawned. Given the transformative benefits of digital innovation there is a real opportunity for Wales to be recognised in new fields of digital innovation including those relating to data mining. Unlike earlier forms of extractive industries, such as coal mining, data mining is not defined by a single industry, there are almost limitless possibilities of creating and recombining data and building AI capability across a number of industrial clusters from creative industries to smart manufacturing.

Wales 4.0 embraces new opportunities to connect and act globally. The fourth industrial revolution offers unprecedented potential to use leading-edge analytics to identify key global technological trends, companies and research activities. Wales already has extensive educational, trade and political networks, but under Wales 4.0 the aim is to significantly increase Wales' international reputation, lifting its global profile and making it a place people think of as a leader in digital innovation.

Wales 4.0 exploits digital innovation to transform the public as well as private sector. Digital government offers a different way of engaging with the people of Wales, being responsive to the genuine needs of end users, engaging them as stakeholders and contributors to service delivery rather than a policy challenge to be resolved. It involves a different model of service delivery to create new ways of building community networks and cohesion. It also facilitates the development of digital technologies for the purpose of creating a 'bottom up' economy, aimed at improving the quality of life rather than just equality of opportunity.

Wales 4.0 presents a new opportunity bargain for the people of Wales. It seeks to empower individuals through lifelong support for learning, work and economic security. It's a people-first approach, more engaged, less top down, and more responsive to individual diversity. Although waged work (employment) and the labour market will remain basic organising principles, the fourth industrial revolution will be characterised by job scarcity - a shortage of quality jobs – limiting the potential to rely on education reforms and workforce training to deliver meaningful employment and a living wage.[42] Scandinavian countries have looked to active labour market policies to get people back into work at the same time as mitigating financial insecurity associated with job loss. Universal Basic Income experiments are also being trialled in several countries and it's something Wales needs to review as a matter of some urgency.[43]

Delivering Wales 4.0

The Welsh Government and its partners have developed a number of policies and strategies aimed at delivering positive outcomes for Wales in the short term. Prosperity for All, the Economic Action Plan (EAP), the Employability Plan, etc. are all valuable initiatives, but are based on the economics of now. They do not take into account how digital innovation is contributing to the rapid transformation of the Welsh economy and wider society. In a similar way to climate change, digitalisation requires a long-term view which transcends existing political policies, processes and timetables.[44] It will require significant investment in relevant world-class research, workplace innovation, and 'bottom up' economic change.

A mission-oriented approach is therefore required to deliver Wales 4.0.[45] This involves Welsh Government taking an informed and active role in facilitating an industrial and digital transformation by setting out defined goals, with specific targets, and working to achieve them in a defined timescale.

A mission-oriented approach under Wales 4.0 should be guided by four principles (MAPS):

- **Mainstream** digital in everything government does to the benefit of all and not seeing 'digital' as an isolated topic;

- **Align** its policy and programme interventions in relation to digitalisation so that they are effectively joined up and work to common outcomes and objectives;

- **Prioritise** those interventions which will have the greatest impact in the medium to long term in delivering Wales 4.0;

- **Scale** the things we do best and not being afraid to scale back, or stop doing, the things that don't work.

Delivering Wales 4.0 requires bold cross-government action on digital innovation working with industry and social partners if we are to benefit from the opportunities that the future holds. A sustained commitment to a social partnership model, also involves new responsibilities on employers and trade unions, as well as government, to make the Welsh economy work for its citizens, and to empower people to shape their own lives in ways that they have reason to value.[46]

This review has identified a wide range of policy recommendations to support the delivery of Wales 4.0. These are presented under seven inter-related work streams aimed at offering strategic choices for immediate action. We have also set out a number of longer term actions for consideration following the 2021 elections to the National Assembly for Wales.

Our Seven Work Streams

Accelerating Industrial Transformation

The review has considered the range of initiatives underway in Wales, with many already contributing to digital capacity in the economy [see Appendix B]. Our approach has been to identify how Wales can build on these existing assets by aligning, scaling and augmenting industrial capacity through a process of industrial transformation which strengthens the Welsh Government's EAP and secures Wales' economic future.[47]

Our stark assessment is that urgent action is needed to take a more coordinated approach to identify synergies and emerging opportunities across these initiatives, and present Wales as an innovative and capable partner for business, investors, and research establishments. We believe this to be essential to future economic viability, and particularly so if we expect stakeholders from outside of Wales to invest or collaborate with us. For these stakeholders, having isolated initiatives will not be sufficient. They will want to see evidence of the Welsh economy 'on the move', demonstrated by a collective shift to engaging with new forms of digital innovation and the industries

which underpin their development. To understand what a joined-up approach to industrial transformation looks like, we have drawn on the policy initiatives on the future economy being pursued in Singapore.[48]

In Singapore, there are ongoing attempts to build long-term capacity in light of rapid technological change through an ambitious industrial transformation programme, to compete regionally and globally, rather than responding to short-term needs. Industrial Transformation Maps (ITMs) were first launched as part of a £2.5bn industry transformation package in their Budget 2016.[49] These maps are being supported by an identified lead body who coordinates stakeholder involvement and finds ways of accessing wider pools of investment. Clearly this level of budgetary support is challenging for the Welsh Government to consider given that the Economy Futures Fund stands at £20m. However, it highlights the emphasis other countries are placing on responding to the opportunities and challenges posed by the fourth industrial revolution.

This type of policy intervention is also being embraced by Scandinavian nations as a way of driving innovative

business models and forms of collaboration in light of emerging technologies, and in response to the restructuring of their respective economies. This action is being taken despite a number of these nations having been at the forefront of technology development for many years. Denmark is just one example we have drawn on **[see Exhibit 13].**

An important issue raised by these international examples is the role of leading-edge research and knowledge-driven innovation. There is a real danger that Wales will find it difficult to deliver the required level of industrial transformation unless there is a substantial injection of R&D funding.[50] In 2017 Wales accounted for only 2 per cent of the R&D expenditure in the UK but with approximately 5 per cent of the population, and the expenditure per head was only half that of England at just £238, trailing far behind Scotland (£466 per head) and Northern Ireland (£371 per head).[51] The spend in Wales as a percentage of GDP was 1.04 per cent in 2016, that's just half of the EU average of 2.07 per cent, and needs to triple by next year to meet the Europe 2020 target of 3 per cent of GDP.[52]

At the same time, Wales punches far above its weight in terms of research impact. A detailed analysis of performance data and citations in Wales: Protecting Research and Innovation After EU Exit, concluded that,

"over the past 18 years the Welsh Research base has produced publications that have performed collectively above the World, UK and EU average."[53]

The challenge will be to find ways for Wales to continue punching far above its weight in ways that contribute to establishing Wales as a digital nation.
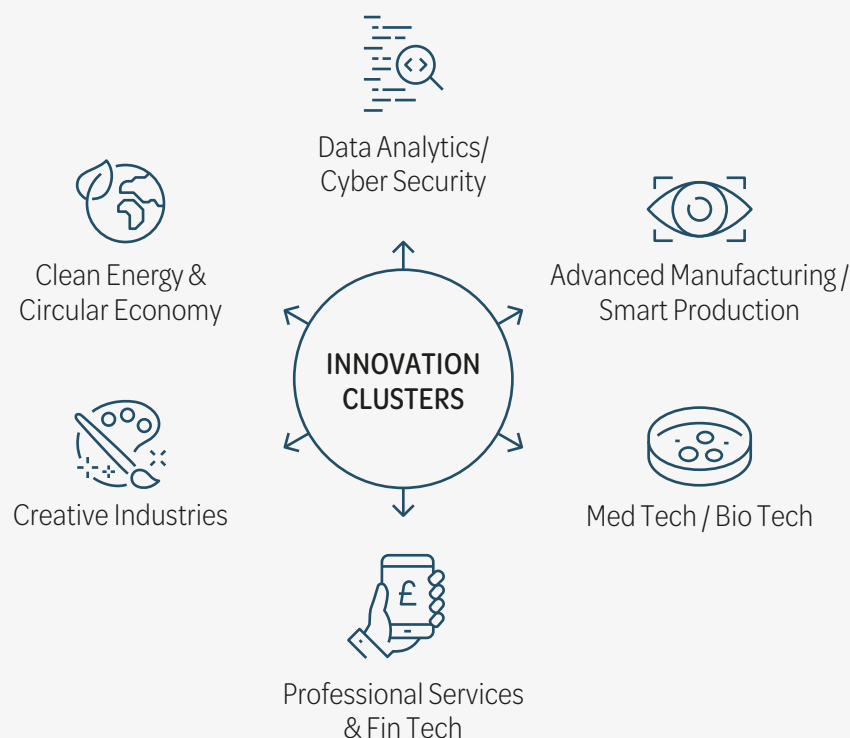
Exhibit 13: Digital Hub Denmark

The Digital Hub Denmark is a public-private partnership between the Danish Government, the Confederation of Danish Industry, the Danish Chamber of Commerce and Finance Denmark. The goal of Digital Hub Denmark is to support and strengthen the digital growth environment and to boost collaboration across private companies, researchers, and tech-entrepreneurs. It aims to initiate activities that can strengthen company access to specialised competences and position Denmark as a digital hub internationally, for example, in the area of new data-driven business models. Their ambition is to make Denmark the most thriving and attractive digital growth environment in Europe and is supported through four core elements:

- Digital platform to connect and coordinate private companies, entrepreneurs, and researchers through company specific challenges.

- A National Centre for Research in Digital Technologies to support developments in the field of digital technologies and to enhance interdisciplinary research.

- Conferences and trial projects to strengthen the commercial use of data and new digital technologies in the development of new services and business models.

- International marketing to strengthen the awareness of Denmark as an attractive digital growth environment.

Industrial Innovation Clusters

In order to accelerate the transformation journey, and build on Wales' existing capabilities, networks and research capacity,[54] this review has identified six strategic Industrial Innovation Clusters (IICs) **[see Exhibit 14]**. The IICs should be viewed as strategic assets in enabling Wales to compete further up domestic and global value chains; an essential ingredient in building long-term capacity and ensuring Wales is able to benefit as the fourth industrial revolution gathers momentum.

Exhibit 14: Proposed Industrial Innovation Clusters (IICs)

Data Analytics/ Cyber Security

Clean Energy & Circular Economy

Advanced Manufacturing / Smart Production

INNOVATION CLUSTERS

Creative Industries

Med Tech / Bio Tech

Professional Services & Fin Tech

The focus on IICs takes Wales' approach to innovation beyond established manufacturing sectors to recognise the centrality of service-based industries (although the distinction between manufacture and services is less relevant as digital innovation is blurring conventional boundaries). The IICs also recognise that Wales will need to make alliances with industrial clusters and ecosystems outside of Wales. For example, South Wales has the largest cyber security cluster in Europe which is significantly enhanced by its close proximity to GCHQ in Cheltenham, a global network of cyber security experts, and links to major international companies within that ecosystem.
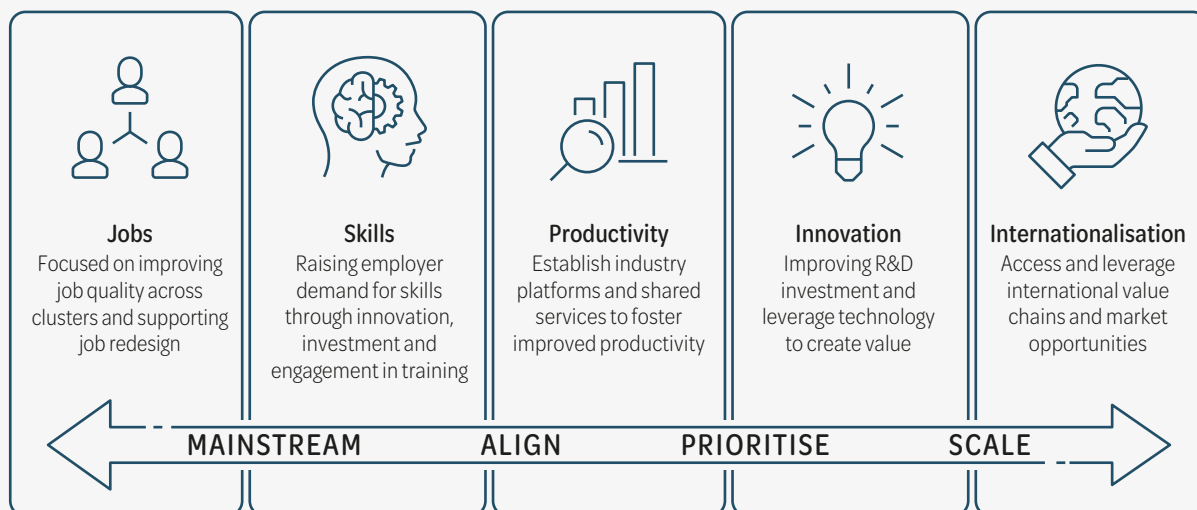
One of the challenges of delivering industrial transformation in Wales is avoiding the potential disconnect between governance and implementation models which allows the regions to take ownership over their future pathways to innovation and growth, but maintains an integrated approach to industrial transformation throughout Wales. This review has considered these issues in light of the regional approach described in the EAP. We do not believe there is a trade-off between a regional approach or national cluster approach (under the IICs), so long as there are clear lines of responsibility to coordinate investment and engagement, scale and join-up activity, and be ambitious.

In the absence of any overarching delivery plans from the Welsh Government, our conclusion is that Industrial Transformation Roadmaps (ITRs) provide the best mechanism for integrating the restructuring efforts in key industries where future economic capacity will need to be developed. **Exhibit 15** provides a breakdown of how ITRs should be utilised in Wales.

Exhibit 15: Applying Industrial Transformation Roadmaps (ITRs) in Wales

The aim of the ITRs is to integrate different restructuring efforts and join up areas of delivery, for example bringing together key aspects of the EAP and the Employability Plan. They are structured by five pillars of transformation and work alongside the guiding principles of Wales 4.0:

Jobs	Skills	Productivity	Innovation	Internationalisation
Focused on improving job quality across clusters and supporting job redesign	Raising employer demand for skills through innovation, investment and engagement in training	Establish industry platforms and shared services to foster improved productivity	Improving R&D investment and leverage technology to create value	Access and leverage international value chains and market opportunities

MAINSTREAM   ALIGN   PRIORITISE   SCALE

ITRs should be developed in collaboration with the work of the City and Regional Growth Deals to provide a strategic plan with clearly defined responsibilities and milestones. To support the development of ITRs, the Welsh Government will need to provide coordinated resources, including financial incentives, and fund expert advice to designated lead-bodies. It is also expected that industry - including anchor organisations - trade unions and workers, take ownership of the transformation effort. This aligns and strengthens the 'something for something' ethos behind the Welsh Government's Economic Contract and provides a mechanism for linking public investment to the ITRs.

Focusing on the industrial transformation process will also help to mobilise and pool investment available for the ITRs, moving Wales away from the contentious subject of grant funding to individual employers. The emphasis being on hand-ups and facilitation, not handouts. The Development Bank of Wales is already building capacity in this area with its £20m Wales Tech Seed Fund and £55m Wales Life Science Investment Fund. However, Wales will need to consider long term capacity for funding industrial transformation activity via the IICs, particularly in terms of full cycle R&D expenditure to accelerate industrial deployment at scale.

In order to receive public investment, employers should be required to demonstrate how they contribute to digital innovation meeting at least three of the cross-cutting pillars outlined above. This could be achieved by refocusing the terms of the Economic Contract and ensuring Wales 4.0 is properly reflected in the Calls to Action as a top-level aim.

The ITRs will also provide the opportunity to develop a one-stop-shop support platform for businesses aligned to a particular IIC. These digital platforms will share insights and new shared services both within and across clusters to promote accelerated growth, particularly in terms of mid-sized employers and support required by emerging technology businesses. Core services available via a platform could include:

- Sharing insights, intelligence and best practice across the cluster;
- Connecting entrepreneurs and growth-oriented companies to national and international funding and investment opportunities, including for example crowd sourcing;
- Identifying emerging technologies and business opportunity in Wales and beyond, and support those companies able to build capacity and to take key parts of the cluster further up the value chain; and,
- Creating networks of businesses and identify digital talent pools to help companies leverage technology to add value and access international markets.

The advancements being made in AI have far-reaching implications for the future of all six IICs. With AI featuring within the UK Government's Grand Challenges as well as the Welsh Government's EAP, it is clearly viewed as a major source of economic competitiveness. Analysis by PwC suggests Wales will see an impact from AI by 2030, which will at least be as large as 9.8 per cent of GDP.[55] It is important Wales is able to take more direct action in response to the opportunities posed by AI and provide a central core of capability which can strengthen each of the IICs. This could provide the starting point in supporting the First Minister's manifesto commitment to,

> *"Work in a social partnership with business to identify where Wales has an advantage - with the ambition of becoming world leaders in the application of AI in these fields."*[56]

In a similar style to UK Catapult Centres, Fraunhofer Institutes in Germany and Scottish Innovation Centres, this type of intervention is consistent with the Diamond Review of Higher Education Funding and Student Finance Arrangements in Wales (2016) and the Reid Review of Government Funded Research and Innovation in Wales (2018), in that it seeks to encourage more applied research, including amongst Higher Education (HE), Further Education (FE) and other institutions, as well as in businesses. However, given the wide-reaching impact of AI, any investment needs to be of a significantly larger scale, reflecting the ambition to enhancing Wales' international status as a digital nation.
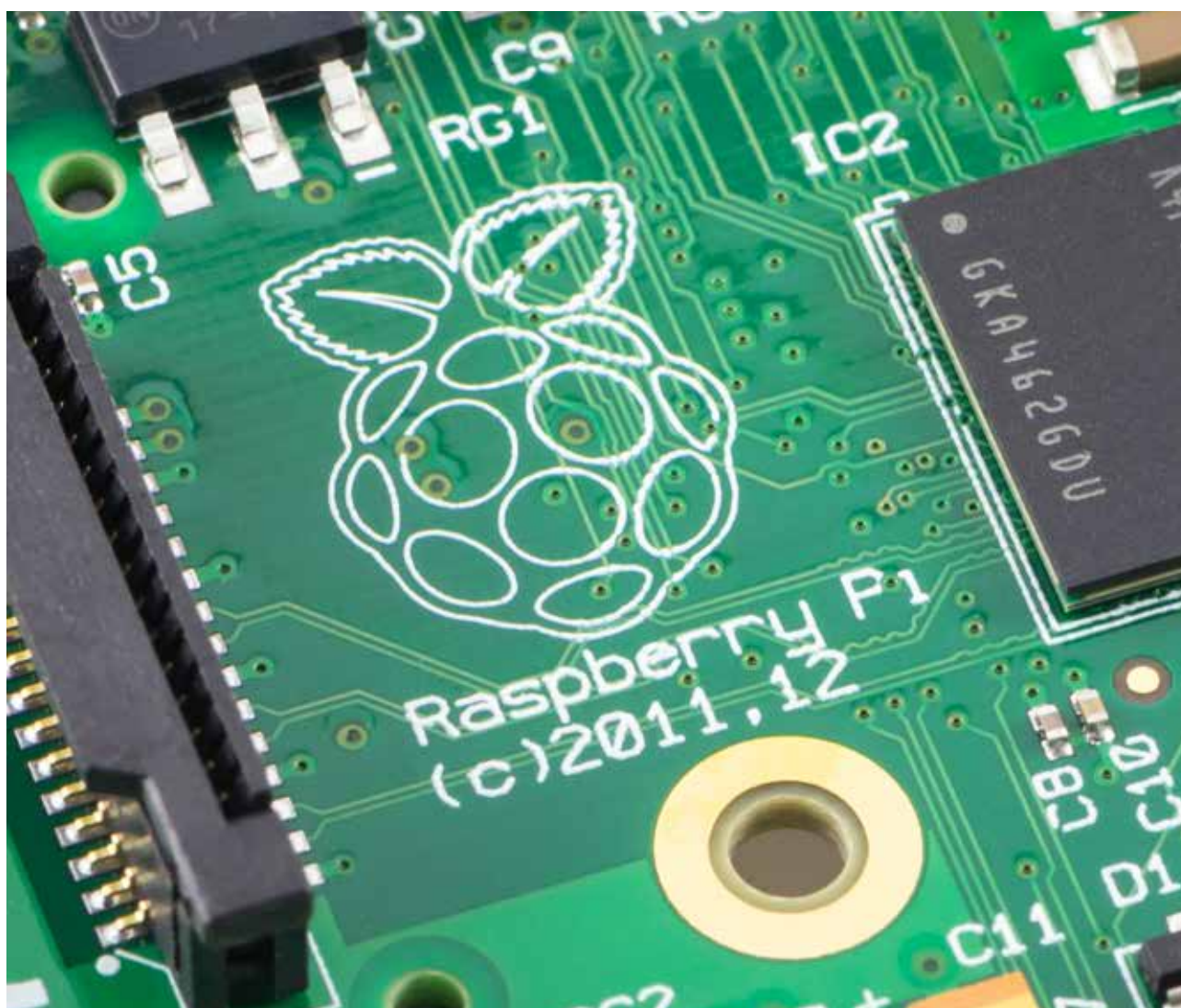
Summary

Opportunities

- Provide support to emerging industrial strengths in digital innovation based on Wales' existing collaborations and initiatives.

- Introduce an industrial transformation policy which supports and gives greater purpose to the implementation of the EAP and the Welsh Government's emerging focus on regions.

- Establish Wales as a centre of excellence for AI in order to capitalise on its potential economic benefits, building on recommendations from both the Reid Review and Diamond Review.

- Strengthen the terms of the Economic Contract by giving greater prominence to digital innovation and the core pillars required to enhance industrial transformation.

Challenges

- The budgetary pressures of taking bold action in support of a programme of industrial transformation.

- Supporting a cluster approach to industrial transformation which can align with the regional approach being taken forward by the Welsh Government.

- Current levels of R&D expenditure in Wales compared with other parts of the UK and internationally.

Recommendations

The Welsh Government should take action to:

- Launch an ambitious programme of industrial transformation to boost the Welsh economy and capitalise on the opportunities presented by digital innovation. This programme should **support the creation of the six IICs** identified above and enable interventions to come forward at a cluster level which deliver the five pillars of industrial transformation (skills, jobs, productivity, innovation and internationalisation). Emerging clusters not included in the initial list should be able to seek recognition based on a compelling economic and wider societal case.

- Publish **Industrial Transformation Roadmaps (ITRs)** for all six clusters. Each roadmap will include an evidence-based assessment of current strengths, weaknesses, opportunities and threats. The ITRs are consistent with the productivity maps put forward by the Reid Review, however they take Wales a step further by taking a much wider view of industrial transformation to collectively explore issues in relation to job quality, skills upgrading, support for innovation and the internationalisation of products and services. The ITRs will provide the basis for securing the resources to be allocated to each IIC, with the emphasis on industry co-investing in delivering solutions, and government providing initial start-up funding. Despite the focus on co-investment by industry, supporting the IICs and the future implementation of the ITRs is likely to require a substantial increase in resources which may not be available from the existing Economy Futures Fund or by pooling other funds, such as the Flexible Skills Programme. We estimate an initial resource of £30m in order to provide the step-change required, subject to the ambition and practical needs of the each ITR and the co-investment put forward by industry.

- Establish an **AI Institute for the Future Economy** to position Wales on the global map as a digital nation and to facilitate a more integrated approach to the application of leading-edge research in AI across Wales. A primary goal of the Institute will be to provide a central core of capability which strengthens the development of the IICs. It will also seek to aid AI developments in the delivery of public services, together with translating AI applications to support Welsh employers [see Appendix C for further details]. In the first instance, the Institute is likely to require initial funding of £10m, with a target budget of £50m. This could be resourced by various means such as winning further funds from UK R&D sources identified in the Reid Review, as well as funds from the private sector in Wales and internationally.

- **Embed the five pillars of industrial transformation within the terms of the Economic Contract and Calls to Action** and ensure there is a more vigorous obligation on employers to prepare themselves for the future ambition of Wales 4.0. In a similar way to Climate Change, industrial transformation should not be seen as an optional activity but a core construct in the relationship between the Welsh Government and the business community.

From 2021/22 onwards, the Welsh Government will need to consider:

- How its devolved taxation powers could be used in order to provide resources to underpin the delivery of the ITRs alongside industry. For example, via some form of levy arrangement, particularly with respect to the Economic Contract, given a need for employers to co-invest in the workforce development requirements across clusters.

- Whether the existing Research Excellence Framework (REF) and Quality-related Research (QR) allocations are fit for purpose in the context of Wales' long-term ambitions.

Supporting Business for Better Jobs and Skills

A major consideration for this review has been whether the range of business, innovation and skills support services in Wales are able to facilitate digital transformation at the firm level in ways that build workforce capacity rather than simply reducing costs and automating labour. If we are to counter the risks of jobs and skills being automated out of our economy, Wales must develop a culture of transformation which encourages more employers to embark on a digital journey which uses technology to create better jobs and allows them to compete in value-added parts of national and global value chains.

Wales has a good record in responding quickly and supportively to retrenchments in its traditional industries, such as automotive or steel where taskforces have been established to take urgent action in response to an immediate crisis. The ProAct Scheme was another intervention that provided training opportunities and wage subsidy for workers during a period of industrial downturn. However, as digital innovation has general-purpose applications across industries, it may not be viable (or sustainable) for the Welsh Government to continue to take similar action in response to a transformation process driven by AI and automation which will impact the whole economy.

A new approach is therefore needed where companies and workers are no longer in response mode, often waiting for government to do something. This is particularly acute in circumstances where consumer behaviour is rapidly and irreversibly changing business practices. A case in point being financial services where the shift towards online banking and contactless payments has resulted in the UK closing more than half of its bank branches during the past 30 years.[57] The state will still have agency in aiding businesses to adapt to new markets, but it is not able to fully control the tide of external forces which digital innovation will continue to bring about.

Business support in Wales has evolved in response to these changing circumstances, including the development of an online platform to provide core business information linked to funding opportunities. Alongside Government backed initiatives, support for start-ups is also coming from a wider network of providers, for example via Banks (e.g. Barclays Eagle Labs and NatWest Accelerator have sites in Wales) and incubators (e.g. Tramshed Tech and IndiQube) that offer access to peer networks, financial advice and technical support. The University of South Wales recently set up an incubator in Cardiff to support graduate entrepreneurs. This type of business engagement and support is particularly relevant to Wales given the strong culture of graduate start-ups compared with other nations.[58]

As well as providing core services via Business Wales, the Welsh Government is supporting 'sandbox' and networking initiatives like *Be the Spark*. It is also seeking to develop the 'missing middle' of employers via initiatives such as the Accelerated Growth Programme, all underpinned by significant investment now available from the Development Bank of Wales and the 'something for something' narrative at the heart of the Economic Contract. The Welsh Government's SMART Innovation programme has also evolved as an earlier adopter of Industry 4, however it is our view that this type of intervention needs to be in a position to extend its reach into a broader set of industries beyond traditional areas of smart manufacturing.[59]

Despite the breadth of services now available in Wales, we need to consider business support against the wider backdrop of transformation taking place globally. This review has examined a number of international commercial software tools being rolled out which enable employers to identify work functions, roles and tasks that can be automated. Some of these appear to have the primary purpose of stripping out costs and, critically, labour. These tools are a clear risk for Wales given its aspiration of becoming a Fair Work Nation.[60]

The Welsh Government currently provides its own range of tools to provide guidance and diagnostic support for employers. Its skills assessment tool (via the Skills for Business Gateway) has a focus on skills but this appears disconnected from conversations about levels of innovation and R&D expenditure under programmes like SMART Innovation, which uses a separate and more detailed diagnostic tool and is linked to a series of direct interventions (R&D vouchers, dedicated advisor support, etc.). Clearly each of these examples have their

own merits, however these may not be clear from the perspective of the user or have the singular capacity to challenge some of the commercial diagnostic and support tools available on a commercial basis. In short, there is an opportunity for greater alignment and technology-driven innovation in how guidance and diagnostics support is provided to business.

Stakeholders engaged as part of this review have questioned where government intervention in business, skills and innovation support, is best placed going forward. This includes whether such services are sufficiently targeted, risk based and proactive in meeting the demands of an increasingly diverse and complex set of businesses as they look to adapt to the fourth industrial revolution. We have identified three broad categories of approaches to digital innovation being taken by businesses **[see Exhibit 16].**

Our findings reflect those of the Digital Maturity Survey for Wales which points to growing digital maturity in the SME community.[61] The survey also shows that only 1 in 4 SMEs are using electronic payment software and, while there has been an increasing use of other cloud computing services, there remains

little use of project management, human resource management, or enterprise planning software.

The challenge here is ensuring business support services are able to keep pace with the rate of technological change whilst providing the depth of technical expertise required, especially for those employers who fall into our 'Converted' category and have the potential to scale-up to become mid-sized, if not international companies. Our concern is that this could be challenging in Wales given the refresh rates for a number of business support services are often aligned to 3-5-year procurement cycles.

Exhibit 16: Categories of business approaches to digital innovation
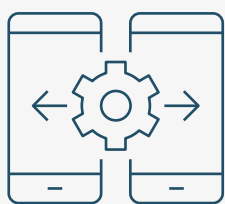
The Connected

They share the language of digital, it is part of organisational culture. They are the individual and organisational disruptors born into the transformation process with digital being part of their DNA (and not viewed as a standalone topic for an IT Department or designated staff to deal with). Often small or micro businesses, these businesses have significant growth potential if adequately supported.
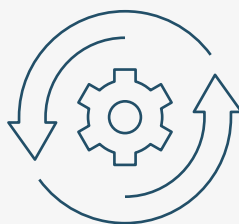
The Converted

Those organisations who are seeking to develop and amplify their use of digital technologies. They represent a broad spectrum of organisations, both large and small, and include those starting their digital journey to those established businesses with more advanced thinking for utilising new and emerging technologies.

The Contented

These are organisations who may not be aware of the potential of digital innovation. They may not feel they need to engage with digital technologies because they'd rather stick to the way things have always been done or do not feel they have time to engage, often viewing anything hi-tech as too expensive to deliver.

The landscape for business support services in Wales is not short on initiatives but is in danger of becoming saturated. There are a number of government agencies and interventions that are potentially duplicating provision and competing for the same performance indicators, often with a heavy emphasis on the number of jobs created or jobs protected. This is a challenge for many of the businesses in our 'Connected' category who may be excluded from support programmes simply because they cannot achieve the job targets set by the Welsh Government. Yet their products and/or services could be invaluable to the future profile of Wales as a digital nation.

There is an opportunity for the Welsh Government and its agencies to consider their offer to employers in the context of a changing landscape of business support. This offer should recognise the changing demands for services and have a greater focus on changing culture and practice under our pillars of industrial transformation, not simply focused on job outcomes. The intention here is to proactively support employers to innovate; accepting that the culture of innovation is, by definition, a risky business which may require government support, and that not all businesses may survive the journey.

We do not underestimate the scale of the challenge in finding new ways of encouraging employers to be innovative and support their employees to retrain for workplace change. There has been a fall in the total number of training days across Wales in recent years, from 5.6 million in 2013 to 4.4 million in 2017, and the proportion of employers who train has remained stagnant at approximately two-thirds.[62] Of the third that do not provide training, 70 per cent suggested all of their staff are fully proficient or there was no need for training to be undertaken. There is a risk that without greater levels of employer investment and engagement in areas like workplace training, employer demands for skilled

and job-ready individuals will continue to squeeze capacity from the limited public funds available for post-compulsory education, training and skills support.

The Welsh Government has already established the three Regional Skills Partnerships (RSPs) tasked with influencing the provision of skills and driving investment in training by developing responses based on local and regional need. Although the Welsh Government has taken steps to review the role of RSPs, their function appears almost exclusively focused on supply-side interventions. This represents a missed opportunity for the RSPs to take an active role in the industrial transformation process, supporting employers to innovate for skill augmentation and better jobs. It is also a missed opportunity to address why some employers are failing to engage or invest in training. This review believes that the efforts of RSPs are being hampered by inadequate data sources that fail to capture the impact of digital innovation on labour demand and workplace skills.

In addition to the function of the RSPs, Trade Unions also have a strong and mutually beneficial role to play in supporting firm transformation. Union learning, supported by Wales TUC Learning Services, is an established training mechanism in Wales that could be positively engaged and expanded to play a greater role in both unionised and non-unionised workplaces. This review has heard evidence of the impact made by Unions in facilitating the implementation of new technology alongside employers **[see Exhibit 17]**. The social partnership model could be a lever to support digital innovation, job redesign and training initiatives, and also act as an early warning system for identifying companies where new technology and processes may lead to job losses or a need for retraining.

Exhibit 17: Digital skills learning at Dwr Hafren Dyfrdwy

Dwr Hafren Dyfrdwy (formally Dee Valley Water) is a utility company which supplies drinking water services to parts of North East Wales and parts of North West England. Its parent entity, Dee Valley Group PLC, was purchased by Severn Trent in February 2017.

As an employer Severn Trent had previously worked with the GMB Union in upskilling its workforce in the use of rubberised 'tough books' and tablets to ensure real-time information could be cascaded back to the organisation. The aim was to ensure call centre staff could provide up-to-date information on any local issues as well as standardising the way information was stored and kept. Traditionally, operational staff would collect a paper copy of their daily work plan from headquarters and fill in paper forms throughout the day. Once the jobs were completed, they would return the forms to the office and staff would type them into the system.

Although Severn Trent had been using a digital system of real time information, Dwr Hafren Dyfrdwy had not. Many of the Dwr Hafren Dyfrdwy staff had been in post for some time and had digital literacy needs. Staff were fearful about not being able to use the systems or having the necessary skills to cope with such a change in their working lives. In response, the union supported the rollout of a series of digital literacy and word processing courses.

The union engagement was recognised by the management at Dwr Hafren Dyfrdwy as being crucial to the introduction of the new technology and work processes. The organisation also reported a significant improvement in digital skills across the workforce.

Summary

Opportunities

- Make improvements to business, skills and innovation support services by giving proper consideration to skill augmentation and job quality.

- Bring together existing schemes and initiatives to support employers to develop a cultural of innovation and become more competitive in ways consistent with the Wales 4.0.

- Enhance the work of RSPs by putting a greater focus on demand-side interventions which improve the absorptive capacity of businesses to innovate for skill augmentation and job redesign.

- Utilise social partners and Union Learning to support workers at risk of automation or whose roles will be significantly impacted by changes in technology.

Challenges

- Having a business support offer that can keep pace with the rapid advances being made in technology and the new categories of firms that are emerging.

- Raising employer awareness, investment and engagement, particular in areas such as workforce development and training.

Recommendations

The Welsh Government should take action to:

- Integrate its existing business, skills and innovation support to form a **single business diagnostic and transformation process** which brings together the five pillars of industrial transformation and underpins all engagement work undertaken with employers. The new process should also:

  - Capitalise on the growing maturity of business to access and utilise new digital technologies, particularly within the SME community.

  - Facilitate the development of shared services in collaboration with IICs rather than grant allocation for specific needs, although these are not mutually exclusive.

  - Develop tools to enable employers to risk-assess themselves in terms of the potential impact from automation and access expert support.

  - Digitalise the diagnostic element of the process and at the same time move to open source analytics so that new tools, apps and add-ons, can quickly emerge.

  - Provide a 'lite' version of diagnostic tools in order to make it more readily available to small and micro employers.

- **Extend the existing innovation support available to business** (such as SMART Innovation) in order to respond to the growing transformation needs of service-based industries whilst maintaining the historic focus on manufacturing. There will need to be a significant scaling to ensure that Welsh Government and its agencies have the appropriate expert capacity on the latest technological trends in specific industries to command the credibility of company managers and executives.

- **Reform the Regional Skills Partnerships (RSPs) as Regional Enterprise Partnerships (REPs)** thereby shifting their existing remit to focus on demand-side interventions which seek to increase employer capacity for quality jobs, skills and innovation. A key aim of the REPs should be to raise employer demand for, and investment in, training, rather than simply extracting capacity from existing funding for adult skills provision.

- **Scale the Wales Union Learning Fund (WULF) with a stronger focus on supporting workers at risk of automation** from both unionised and non-unionised workplaces. The focus should be on new ways to support job redesign in the deployment of new technology and methods to enhance the Union focus on training and development plans.

From 2021/22 onwards, the Welsh Government will need to consider:

- Whether significant inroads have been made in reducing some of the complexities of its business support arrangements, including those supported by outside agencies, or should more radical action be taken to harmonise arrangements. This could include the creation of an overarching body – 'Enterprise Wales' – which is external to Welsh Government and houses all business engagement and support activities.

Connecting and Acting Globally

Wales is fast becoming a hotbed for technology products and services, with its growing technology sector being supported by 3,600 companies, employing 45,000 workers and turning over £1billion.[63] Organisations like AI Wales (with over 700 members), Cyber Wales (the largest Cyber cluster in the UK) and Py Data Cardiff (over 600 members), now have significant traction in influencing UK Government policy and initiatives.

Despite these positive figures, feedback from stakeholders is that Wales is rarely seen as a significant international player in digital innovation. Promoting Wales as a land of cycle tracks and castles may appeal to the tourism market, but it does not show the nation's true potential to international investors. A case in point being the promotional material produced by the Welsh Government's trade and investment arm under the strapline *"This is Tech"* which underplays the diverse strengths of Wales' vibrant and growing technology industries. A more ambitious approach is required if Wales is to attract the attention of the rest of the UK and wider world in a highly-competitive international marketplace.

Countries like Estonia have made digital a core asset in transforming their economy and government services. As a result, it is now seen as an international leader in this area despite having a population of just 1.3m people. Estonia's rise as a trailblazer in the use of digital innovation began with the launch of electronic-governance (e-governance) in 1997. For over two decades, they have introduced successive schemes which mainstream digital throughout the delivery of government services including e-tax (2000), digital ID (2001) and i-voting (2005). These schemes have collectively strengthened their position as an international leader in digital innovation.

Wales has a wealth of natural and human resources offering a massive opportunity for Wales to be bold and reinvent a new national (internal) and international (external) brand around data mining and as a digital nation. Scaling and promoting its key tech engines in areas like AI, cyber security and data analytics would go a long way to achieve this. A strong, coherent and consistent narrative could also put it on the front foot in terms of competing for future investment opportunities and to move Wales into more valuable parts of global value chains in a post-Brexit landscape.

The GlobalWelsh investment portal **[see Exhibit 18]** is a recent initiative aimed at targeting Wales' business diaspora to support Welsh-based companies. Its success rate at attracting inward investment would be greatly enhanced if Wales could rebrand itself. Not only to attract the attention of the Welsh community currently living around the world, but also those with few (if any) current connections to Wales.

We are encouraged by the appointment of a Minister for International Relations and Welsh Language and the draft of the Welsh Government's new International Strategy, elements of which are consistent with the idea of Wales as a digital nation in the fourth industrial revolution. We believe this strategy should not only be outward facing but also inward serving, so that the people and communities of Wales can understand and engage with the next generation of technologies and industries being developed here in Wales.

Intelligence and data analytics should be seen as a central feature for any national and international engagement work to ensure our limited resources are appropriately targeted and provide the best return. This means ensuring that Wales has access to better international data sources which can identify key technology trends, companies, universities, and individual talent.

Exhibit 18: GlobalWelsh Investor Portal

GlobalWelsh, Wales' not-for-profit grassroots diaspora organisation, recently launched its Investor Portal, the first and only investment platform dedicated to driving Diaspora Direct Investment (DDI) into Wales. It offers a way of linking entrepreneurs and investors within the global community of individuals who have a strong connection to Wales. The new online portal will support early stage companies, founded in Wales or by members of the diaspora, to showcase their businesses and attract investment and support from investors within the Welsh diaspora. For investors, it will provide a one-stop-shop where they can browse, engage and invest in Wales' most exciting and innovative businesses. The key aims of the portal are to:

- Help start-up and growing businesses develop valuable and long-term relationships with investors

- Champion the views and interests of the diaspora and Welsh businesses

- Raise awareness of businesses in Wales and within the diaspora

- Set the industry standard on investment best practice in Wales

- Increase Wales' prosperity by driving inward investment

Built by the Welsh fintech company, Delio, the non-regulatory portal will allow investors to self-certify, browse live investment opportunities, open a direct dialogue with business founders, perform their own due diligence, and form syndicates with other GlobalWelsh investors on the portal. The portal was borne out of a growing need for seed funding for early stage businesses in Wales, a growing start-up community in Wales, and an increasing demand from members of the diaspora who are looking to give back through investment and mentorship.

The transformation work at both a firm and cluster level which we described previously has the potential to align with the investment decisions and initiatives that will form part of any international engagement work. However, this will require further investment to ensure Wales' overall international R&D and business profile is raised and to avoid the past mistakes of creating 'cathedrals in the desert', where large scale public funded initiatives failed to deliver the promised innovation and economic development.[64]

The international visibility and profile of Welsh HE is also a key feature of Wales in the world. Global Wales is a higher education partnership together with the British Council, aimed at promoting Welsh higher education to the rest of the world. There is an opportunity for their activities to be scaled and for a more strategic approach to be taken in building Wales' reputational capital gained from being part of international networks around teaching and research. There is far more at stake here than getting more foreign students to attend our universities, it is also about developing research and deepening our reach in a number of strategic locations, such as through establishing new postgraduate programmes.[65]

Summary

Opportunities

- Rebrand Wales as a digital nation, building on our emerging capabilities in areas like AI, cyber security and data analytics (from coal mining to data mining).

- Utilise new data analytics to provide greater insight on networks and relationships globally, both new and existing, and use this intelligence to better target the Welsh Government's resources overseas.

Challenges

- Being able to construct a coherent narrative for Wales which can compete with established countries like Estonia.

Recommendations

The Welsh Government should take action to:

- **Ensure its International Strategy is fully aligned to the principles of Wales 4.0** and the clustering identified previously. This should include revisiting the marketing tools and material used by the Welsh Government to promote the technology industry and wider economy in Wales. To enhance this work, the Welsh Government should consider holding an international conference on the fourth industrial revolution and the future of work which can showcase Wales to the world.

- **Develop more sophisticated data analytics and real-time information that can inform the international engagement work of the Welsh Government** and ensure international offices and resources are more joined up and operating strategically. The data analytics work should also be used to identify newly emerging international partners and networks as well as making links to the development of the six IICs.

- **Increase the international profile of research and programme development** of Welsh HE institutions and research institutes in relation to Wales 4.0, by providing resources to expand the activities of Global Wales so they are able to support new teaching and related research initiatives.

Delivering Education and Skills for the Future of Work

Success in a future digital world relies on investing in people, not just technology. The challenge of an ageing society, where far more people are likely to remain in work or return to the labour market in later life, will put further pressure on Wales' education, training, employability and careers services, to support people in different stages of their work and life.

Wales is already making progress in the area of educational reform with the new curriculum for 3 to 16-year-olds aiming to mainstream digital as part of a broad educational experience for all children and young people.[66] The Digital 2030 framework and the new Commission for Tertiary Education and Research, also represent a step in the right direction in seeking to provide a digital competent and more joined-up post-compulsory education and training sector.[67] However, the education and skills system will continue to need the resources, flexibility and imaginative reform agenda to accommodate more complex needs which come with greater emphasis on learning throughout life.

This is particularly important given that the definition of what we perceive as high-skilled work is less apparent and that the knowledge and skills required to remain employable over the life course are more diverse and in need of regular updating. This will require rethinking what is taught, how it's taught and where it's taught, as well as the quality of learning experience, how it's assessed, how we recognise achievement (certification), and how it's funded. There is no ready-made blueprint for how this can be achieved, but institutions will need to prepare themselves for this change.

In recent times, a number of FE and HE institutions have embarked on a process of reform which has resulted in a greater focus on widening access, expanding their social mission, integrating apprenticeship and vocational training (including higher apprenticeships),[68] along with their contribution to business innovation and regional economic development. These actions are consistent with the multi-dimensional institutions which are likely to emerge as Wales builds itself a world-class post-compulsory education system in response to the *Hazelkorn Review*,[69] and will make collaboration more seamless across institutional silos.

These new arrangements reflect the recent suggestion from Andrew Haldane, Chief Economist at the Bank of England, with regards to universities becoming 'multiversities' in the fourth industrial revolution.[70] He says, "The future university may need to be a very different creature than in the past. It may need to cater for multiple entry points along the age distribution, rather than focussing on the young. And it may need to cater for multiple entry points along the skills spectrum, rather than focussing on the cognitive. It would, in short, need to be plural rather than singular – a 'multiversity', rather than a university."

The challenge of building a strong and dynamic post-compulsory education system is not something unique to Wales. If we look at the recently published Augur Review of post-compulsory education in England, it has shifted the national spotlight on to how FE can help boost social mobility and productivity, provide lifelong learning and respond flexibly to new working patterns.[71] It also points to the 'missing middle' between FE and HE institutions given a need to bolster higher technical education. This reflects the fact that the UK's technical education system is very weak by international standards. Only 10 per cent of 20-45 year-olds hold technical education as their highest qualification, placing the UK 16th out of 20 OECD countries. By 2020, the UK is set to fall to 28th out of 32 OECD countries for intermediate (upper-secondary) skills. The Diamond Review did note that 'expanding higher vocational and technical education promises many benefits for Wales' economy and society.' But this is a small part of HE in Wales as in the rest of the UK.[72]

Improving higher vocational and technical education is just one aspect to consider in a complex range of issues facing post-compulsory education in Wales, particularly as the future of work evolves and the demand for more complex skills grows. Nesta's report on the future of skills highlights how the workforce will need broad-based knowledge in addition to specialist skills that are needed for specific occupations.[73] It shows that interpersonal skills, higher-order cognitive skills, and systems skills are likely to have the greatest demand, with 'active learning', judgement and decision-making all scoring highly, together with an

ability to express ideas and to think creatively and critically **[see Exhibit 19]**. Connected to this is the need for people to be ethically informed citizens in an era of 'fake news' and as advances in AI and machine-learning come to influence key channels of communication used for work and in everyday life.

Exhibit 19: Top 20 highest ranked skills, knowledge areas and abilities to future demand for UK occupations*

01	Judgement and decision-making	06	Systems evaluation	11	Critical thinking	16	Inductive reasoning
02	Fluency of ideas	07	Deductive reasoning	12	Instructing	17	Problem sensitivity
03	Active learning	08	Complex problem solving	13	Education and training	18	Information ordering
04	Learning strategies	09	Systems analysis	14	Management and personnel resources	19	Active listening
05	Originality abilities	10	Monitoring	15	Coordination	20	Administration and management

* These features are based on occupational information contained in the Occupational Information Network (O*NET) online database

Source: Nesta (2017) Future of Skills: Employment in 2030

The challenge for Wales, like many other nations, is that qualifications, rather than skills, provide the main currency within our education and training system. The Welsh Government's Employability Plan, for example, has an explicit target to 'eliminate the gap between Wales and the rest of the UK at all qualification levels in ten years', which leads us to question whether Wales is best served by targeting educational attainment as measured through certification rather than focusing on the diverse range of skills required to deliver the digital citizens of the future? Qualifications are a poor proxy for skills and if Wales is to deliver the innovation-driven growth which is needed to support our social and economic transformation, it will need to go beyond the 'paper chase' of examinations, testing and certification, with an emphasis on rewarding skills rather than simply qualifications.

Feedback provided to this review has indicated a preference from industry towards a 'T' shape learning profile, where general skills and knowledge, including both STEM and non-STEM, make up the horizontal bar, and these are then combined with levels of specialist training or work experience, such as accountancy or software engineering, to form the vertical bar of the 'T'.[74] Under this model, there is a strong case for rejecting the traditional distinction between STEM and non-STEM subjects and the tendency to pit sciences against arts, considering that what it means to 'educated' and 'employable' depends on both.

This approach is better aligned to the future of work because we anticipate more people having to convert to new fields as a result of automation and job redesign, maybe even several times during extended careers. For example, we could see accountants moving into cyber security given a common focus on analytical skills. This requirement challenges the early specialisation which is encouraged through current 'gold standard' qualifications like A-Levels, thereby making it difficult to achieve a broad-base of education that prepares individuals for learning throughout life.

In short, digital innovation is breaking down occupational structures and having an influence on the pathways to becoming competent within a particular profession. It also highlights how the rapid diffusion of technology across occupations means a more dynamic and sophisticated taxonomy for workplace skills is needed as occupational structures and pathways are redesigned as a result of technological change and automation. The current system of using National Occupational Standards (NOS) to influence the content and development of some qualifications and training courses is unlikely to provide the level of responsiveness needed to keep pace with the rate of change, particularly in the absence of strong sectoral bodies to lead the reforms.

A number of institutions have also emerged in Wales over recent years, such as the National Software Academy and Institute of Coding, in order to fulfil demand for higher-level specialisms in digital skills. Despite being highly-regarded, this review has concerns as to whether these institutions are effectively joined-up or scaled to meet long-term demand. Without a coherent approach to how these initiatives connect with the demands of employers, there is a risk of a growing skills mismatch, as well as a lack of reform and mainstreaming across post-compulsory provision, particularly with regards to sharing best practice and pedagogy between institutions.

The mainstreaming of digital skills is a particular important issue for Wales if we are to develop digitally competent citizens capable of engaging with an increasingly digitalised world. A major challenge aligned to this is using the implementation of the new curriculum reforms to address the gender and class differences in mathematics, computer science and ICT, which are potentially contributing to the fact that women make up less than 30 per cent of the digital workforce in the UK.[75] This gender imbalance is also reflected in females making up just 50 (9.5 per cent) of the 525 apprentices training in the fields of IT, software, web and telecoms in Wales in the 2017/18 academic year.[76]

A recent Lloyds Banking Group survey also highlights the scale of the wider digital exclusion in Wales compared with other regions of the UK, with just 66 per cent of the population having the five basic digital skills according to the Tech Partnership Basic Digital Skills framework, which is the lowest of all the UK regions.[77] A stark reality check given that the Welsh Government's current Programme for Government has the aim of helping 95 per cent of people gain at least the basic digital skills needed for the 21st century by 2021. This review has not explored the reason for Wales' digital skills divide compared to other regions of the UK, however it does raise a broader question of how the Welsh Government can widen its engagement with citizens in the debate about skills and lifelong learning beyond the efforts of existing schemes like Digital Communities Wales. It also highlights the challenge of how to achieve a cultural shift in the way people engage with education and lifelong learning, coming to see digital skills as part of everyday life, no longer restricted to purpose-built schools, colleges or universities, but woven into the fabric of our communities and public services.

There are some good examples of where Wales is looking to provide individuals with the tools to invest in their future skills. These include trialling Personal Learning Accounts and the recently launched Working Wales scheme. The miFuture App is another example of a made in Wales innovation where technology is providing a better way of connecting young people with career opportunities [see Exhibit 20]. Taking these initiatives into account, there is an opportunity for Wales to take a more ambitious approach to its employability support and make use of platform software and advances in careers and labour market analytics to develop a single portal that provides individuals with real-time information, advice and guidance on skills, employment, training, work experience and career planning.

Exhibit 20: miFuture App

miFuture has created a better way of connecting young people with employment opportunities. Founded by Gemma Hallett, Pontypridd-based miFuture recognised that the practice of asking young people to submit CVs typed up on traditional computers is at odds with a generation raised on mobile devices. Seven million young people in the UK are transitioning from education and training to employment and thousands of organisations are looking to hire them. Unlike any generation before them, they're completely digital native – 98 per cent do online activity through a mobile device and don't own Microsoft Word or printers. There's a real mismatch of communication and processes when it comes to supply-and-demand in recruitment.

miFuture has allowed young people to connect with employers using an app that matches them with career opportunities. Employing a swiping mechanic popularised by a number of dating apps, miFuture lets users swipe right to apply, left to decline, or up to consider opportunities. Career opportunities are presented based on users' qualifications, skills and interests. The mission of miFuture is to mobilise a generation towards employability. It has established links with organisations like Prince's Trust Cymru to reach those furthest from the labour market and in generational poverty.

Summary

Opportunities:

- To encourage strategic thinking about what a transformed model of tertiary education could look like in Wales at the level of the individual learner, employer and community.

- Create a common skills taxonomy for Wales which can keep pace with job redesign resulting from new technologies within the workplace.

- Join up specialist institutions to mainstream digital education in Wales thereby sharing best practice and pedagogy.

- Utilise online platforms and more sophisticated labour market analytics to improve careers support, job search, guidance to learning opportunities and access to work experience.

Challenges:

- Resource pressures of supporting the lifelong learning needs of individuals, along with a lack of capacity at all levels of the education system to deliver significant reform.

- Delivering the complex skills required for future work using a system which is heavily predicated towards qualification attainment rather than agile skilling.

- Reducing the gaps in digital skills based on age, gender and social background as well as between Wales and other parts of the UK.

Recommendations

The Welsh Government should take action to:

- **Deliver curriculum reforms in post-compulsory education and training in Wales** (similar to those being taken forward for 3-16 year-olds). These reforms should shift the focus from examinations, testing and certification, to emphasise knowledge, learning and skills. The aim being to remove early specialisation, the tendency to 'teach to the test' and eliminate the artificial choices between STEM and non-STEM subjects. It will also require an alternative to A-Level examinations which this review considers is best supported by the introduction of a broad-based, dynamic and digitally focused version of the International Baccalaureate.

- **Support a number of 'multiversity' capacity building projects** aimed at breaking down institutional and social boundaries across post-compulsory education in Wales. Projects should support the multi-dimensional institutions which will be needed to underpin the world-class post-compulsory education system envisaged by the Hazelkorn Review. The multiversity demonstrator projects should therefore focus on building professional capacity at all levels to ensure that the education and skills sector can deliver the step-change required to prepare for the future of work in an age of lifelong learning. They should also develop novel approaches for widening access to higher vocation and technical education.

- **Review the role of specialist education and training academies**, such as the National Software Academy and Institute of Coding, to assess if they are adequately prepared to meet current demand and potential future expansion in support of our proposals for industrial transformation in Wales. An assessment should also be made as to where specialist academies can work more closely with schools, FE, HE and work-based learning institutions in mainstreaming specialist digital training and help to reduce the digital divide, in terms of gender, age and social class differences, in the context of the current digital workforce.

- **Develop a new Skills Framework for Wales** to achieve a better way of matching jobs to people and people to jobs. Given the time, effort and resources required to develop a new skills framework, we recommend testing the applicability of the framework recently developed in Singapore given that it has been developed with a focus on industrial transformation and job redesign.

- **Publish a delivery plan alongside its Digital 2030 framework** which details how it intends to meet the Programme for Government commitment of helping 95 percent of people to gain at least the basic digital skills needed for the 21st century by 2021, given that mainstreaming digital skills is crucial to achieving engaged citizens.

- **Extend Job Support Wales** to provide support for individuals who are in work and are in jobs identified at potential high-risk of automation or who have already been retrenched. The aim being to proactively support individuals to minimise the impact of job redesign or job displacement as a result of automation by offering early intervention to reskill for existing or alternative employment.

- **Create a one-stop-shop platform for end users** that brings together existing careers and employability support in order to allow all individuals to:

  - Capture their skills, experiences and job histories in an online profile;
  - Risk assess their current occupation and skills profile and proactively locate suitable training, work experience, and alternative employment;
  - Connect online with employers to discuss skills, training and work experience opportunities;
  - Learn about careers, training and job opportunities in real time (this will require the platform to make use of advancements being made in labour market analytics);
  - Access their Personal Learning Account and make decisions as to how that account should be invested.

From 2021/22 onwards, the Welsh Government, supported by the new Commission for Tertiary Education and Research, will need to consider:

- Reviewing whether current policy reforms in Wales are being implemented in a way that enables all citizens to participate in the digital world and lifelong learning irrespective of their age, background, location or needs.

Mainstreaming Digital in the Foundational Economy

The idea of creating stronger and more resilient communities by focusing on the foundational economy is a key strand of the EAP. The recent Welsh Government statement on the foundation economy describes how the food we eat, the homes we live in, the energy we use and the care we receive are basic services on which every citizen relies, and which keep us safe, sound and civilised are all part of the foundational economy.[78] We agree. It provides a clear focus on 'the industries and firms that are there because people are there.' But we also believe there is a need to find new ways to mainstream digital so that the people 'who are there' are able to create their own start-ups, cooperatives, and businesses as an active expression of community participation and co-creation.

This involves taking advantage of the quiet revolution taking place on our own doorsteps which is blurring the distinction between home and work, production and consumption, with more people spending at least part of the week working from home rather than the usual five-days-a-week commute.

Digital innovation also offers the potential to localise production (distributed manufacturing), exemplified by *Riversimple* who are designing hydrogen vehicles in Wales based on a model of neighbourhood production, all made possible by advances in additive manufacturing (3D printing).[79]

The significant changes taking place on the high streets of Welsh towns is also a part of this quiet revolution, linked to changing consumer habits as we buy more online, use mobile banking, text or email rather than posting letters, etc. This creates new possibilities to repurpose the community spaces which are no longer required for retail in order to provide multipurpose social spaces which combine work, learning and entertainment under the same roof.[80] It is also consistent with the concept of a 'circular economy' which aims to minimise waste and recycle resources for as long as possible.[81] This way of thinking about mainstreaming digital within communities is something Near Me Now is supporting by working with businesses and towns as part of a new digital high street **[see Exhibit 21]**.

Thinking radically about new ways to mainstream digital infrastructure offers real opportunities to work with communities in order to develop a sense of place to underpin our ambition for Wales 4.0. It also builds on the focus of the Welsh Government's new £3m Foundational Economy Challenge Fund (although this budget seems small given the size of the challenge) and provides a tangible focal point for the 'civic' and 'place' agendas for education institutions, as championed by the Minister for Education.

Exhibit 21: Near Me Now

Caerphilly-based Near Me Now is aiming to revitalise the UK's ailing high street. Its innovative app technology provides a platform likened to social media for the high street coupled with a digital toolkit. This gives businesses the ability to collectively communicate, transact and advertise within their local community.

The app aims to create micro economies where people in the local community are feeding back into their immediate retail community, supporting local regeneration on the high street in a digital way. Near Me Now shows how digital technologies can present different options for business. Digital is not all about ecommerce, it can be used to strengthen the presence of the physical shop front, both on the high street and in the community. The app has already proved a success among Cowbridge's independent retailers following a trial in the town last year.

Near Me Now is now partnered with tech company Thud Media, based at the Gloworks in Cardiff Bay and branding consultants BAIT Studio. The Centre of Excellence in Mobile and Emerging Technologies (CEMET) based at the University of South Wales are also assisting with AR for the app. In June 2019, Near Me Now won App of the Year at the WalesOnline Digital Awards.

The advantage of focusing on Mainstreaming Digital Infrastructure (MDI) is that it is a collective rather than individualised approach to resources, which can be built around communities and places. It provides the opportunity to think beyond top-down, high-profile initiatives and to consider how digital applications can contribute to social and economic innovations that improve the quality of life for individuals, households and communities.[82]

Wales has already made significant progress in providing its communities with access to key digital infrastructure with Superfast Cymru having increased the number of homes and businesses with access to broadband. There are now over 94.7 per cent of premises able to get Superfast and Fibre broadband, up from 29.4 per cent in 2010, with the ongoing roll-out reaching more homes and businesses every week.[83] The aim of this review was not to assess the current position of digital infrastructure in Wales, as this is a task for the National Infrastructure Commission for Wales, but we have worked closely with the Commission Chair to share ideas and feedback from stakeholders. We also recognise that the funding and regulation for investments in digital infrastructure are mostly reserved to the UK Government.

However, from our engagement work, it is clear that Wales still needs additional support to invest further and faster in digital infrastructure, especially given the need for 5G connectivity to achieve the scale of digital innovation required to design and deliver new services and workforce models. Indeed, there are a number of major digital infrastructure projects which have already been put forward through regional plans, such as the proposed installation of a transatlantic cable from North America into Oxwich Bay, which have yet to be taken forward but could benefit different parts of Wales.

While access to the internet, broadband or 5G connectivity is crucial here, MDI also applies to the provision of wider infrastructure needs, such as those relating to skills and training, so that people are able to benefit from digital technologies in order to learn, work, and flourish within their own communities while connected to the wider world.[84] MDI therefore provides a different way of thinking about digital in the context of traditional infrastructure and the foundational economy which aligns with the First Minister for Wales' commitment to infrastructure – both physical and digital – in order to help 'crowd-in' private investment, and equip people with the skills and training needed to make the very most of their talents and abilities.[85]

If we are to mitigate the widespread displacement effects of digital innovation and ensure places as well as people aren't left behind by further waves of technological disruption, Wales will not only need to find new ways to mainstream digital infrastructure within our communities but also consider the medium-term introduction of a Universal Basic Income.[86] The focus of which should be on creating an active model of social inclusion and participation in light of the mounting evidence that the central organising principle of waged work at the heart of the national opportunity bargain is not working for many people in Wales, and in many other developed countries.
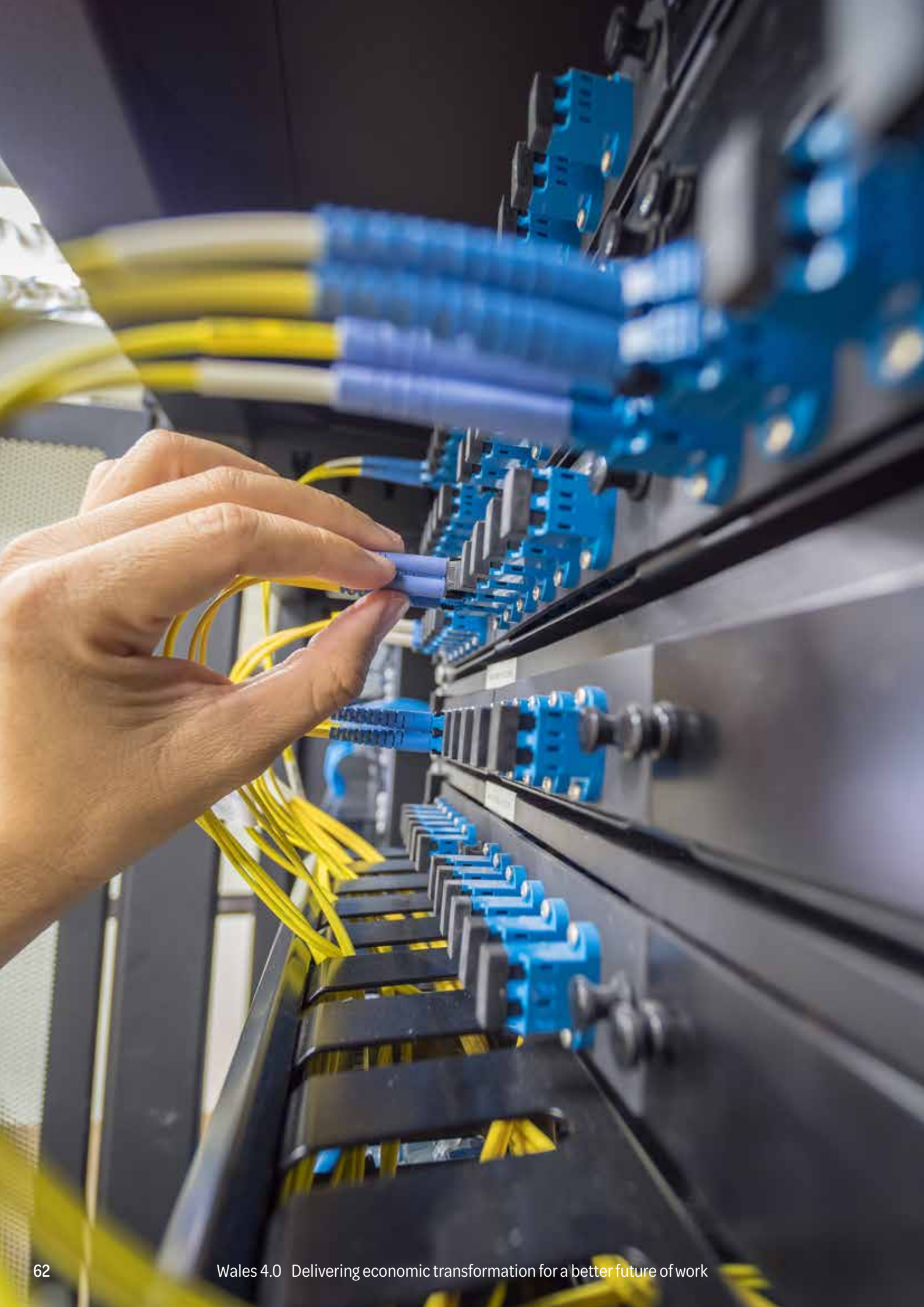
Summary

Opportunities:

- Mainstream digital infrastructure as part of the work being taken forward on the Foundational Economy.

- Take bold decisions on digital infrastructure in order to capitalise on new markets and business opportunities.

- Exploit the potential of digital innovation to provide the digital means of production (as well as consumption) to local communities as a way of bolstering 'bottom up' economic development and building more resilient communities.

- Mitigate the potential widespread displacement effects of digital innovation on people and communities by both mainstreaming digital and evaluating a Universal Basic Income model for Wales.

Challenges:

- Ensuring Wales gets a fair share of funding for digital infrastructure given the reserved powers in place with the UK Government.

Recommendations

The Welsh Government should take action to:

- Substantially increase the Foundational Economy Challenge Fund to **support a series of 'Smart Places Wales' demonstrators** with the aim of mainstreaming new digital architecture to support a better quality of working and community life. Demonstrator sites will provide a test bed for using digital twinning applications, such as the Internet of Things (IoT), to monitor how people interact and make use of new technologies within local contexts and to assess the benefits (or otherwise) of mainstreaming such initiatives in other parts of Wales. We recommend that collaborative bids be sourced on a people-first approach in full consultation with individuals living in the villages, towns or cities seeking 'smart' status funding. In the first instance, these bids should focus on issues such as building inclusive communities, sustainability and decarbonisation (including the Internet of Energy) and 'bottom-up' economic innovation.

- Encourage the National Infrastructure Commission for Wales to expedite the delivery of digital connectivity to rural communities and households in Wales, establishing the right to a minimum standard of digital connectivity to participate in economic and social life. We would also recommend the Commission put immediate consideration to the best way for Wales to take advantage of our proximity to the transatlantic digital super highway, especially between New York and London to enhance Wales' position as an international gateway for developing and delivering new digital applications.[87]

- Conduct policy work to understand how the approach to mainstreaming digital infrastructure could be linked to an alternative model of social security. This should consider the recommendations recently put forward by the Fair Work Commission as well as international experiments on Universal Basic Income.

Becoming a World Leader on Skills, Work and Industrial Analytics

In order to support the aspirations of this review and aid the Welsh Government in making informed decisions about the economy and the future of work, Wales will require access to new insight, foresight, and predictive tools, that can better map and anticipate technological innovations, industrial transformation and changing labour market requirements. This intelligence will be critical in supporting a number of areas of education, labour market and economic planning, including for example the delivery of the EAP, the function of RSPs (which we have recommended repurposing) as well as future investment schemes operated by the Development Bank of Wales.

Currently industrial and labour market intelligence in Wales appears heavily reliant on survey data, such as the Labour Force Survey (LFS) and the Employer Skills Survey (ESS), with neither able to provide the real-time capability for modelling skills displacement, augmentation or substitution. They also have limited capacity for making predictions about the future of work in Wales. This represents a significant weakness in policy formation and practice in Wales, particularly given that a number of these intelligence sources are provided to RSPs and other bodies in making judgements on the future deployment of Wales' adult skills provision.[88]

In Denmark, there were concerns about the ability of their existing information sources to capture insight on how digital technologies were leading to a convergence of skills and occupational tasks across sectors (e.g. software engineers and data analysts). This led Danish researchers to examine new ways to reform their existing model of workplace training, under what is called the AMU system, to better track emerging skills in real-time. If skills policies are to support and keep pace with innovation policies, it is imperative that Wales is also able to adopt similar mechanisms for analysing emerging skills needs, which are linked to those employers that represent leading-edge practice with regard to the application of new and emerging technologies.

Wales already has significant resources on its doorstep which can enable new approaches in capturing and using data, including the ONS Data Science Campus, Supercomputing Wales, the Centre for Doctoral Training in AI, and the new Administrative Data Research Wales (ADR Wales), although none of these appear to be taking a lead in this specific area of work. Companies like Amplyfi in Cardiff, use DataVoyant™ software to provide predictive insights and business intelligence by conducting deep-web analytics to construct trend data with the capability of predicting

key technological drivers in different industries. Appendix D provides an example of how Amplyfi uses AI to harvest surface and deep-web data to visualise today's drivers of manufacturing production.

Compared to existing intelligence sources and survey data available for Wales, these tools offer an early warning system for understanding where growth opportunities are likely to emerge as well as establishing whether there are already existing links to Welsh or UK companies, universities, etc. However, our starting assumption is that we are a long way from AI and machine learning being able to perform industrial or labour market analytics in ways that are immediately meaningful to non-specialists. Considerable translation work will continue to be required by researchers in order for government and other social partners to fully benefit from new analytics software, alongside other new and existing data sources.[89]

A number of countries across the globe are already investing their resources into dedicated Productivity Commissions to provide the functionality to think in the long term about the key challenges associated with the future of work.[90] An opportunity exists for Wales to tap into these networks and position itself as a leading international player in the development of real-time tools for industrial transformation and skill augmenting automation.

However, there are currently a number of factors holding Wales back from making this a reality, including:

• A lack of high-quality data on the changing occupational and skill requirements derived as a result of technology being used to automate production or process innovation in private and public sector organisations;

• Robust modelling (e.g. how skills are substituted by technology and where human-machine complementarity takes places);

• Insufficient understanding of how technology plays out in real-time when considering broader economic dynamics (e.g. the position of Welsh businesses in global value chains, etc.).

As such, capacity building and a commitment to new ways of working are needed to address a number of these points.

Summary

Opportunities:

- Wales has significant expertise in relation to data analytics and the exploitation of big data. It is possible to apply this expertise and become a world-leading partner in tracking technology trends, skills and automation, changing labour market requirements, etc.

- To add value to existing research tools and datasets by exploiting new forms of machine learning to make predictions about the future of work in Wales and its economic outlook.

- Link with the network of Productivity Commissions already set up across a number of countries.

Challenges:

- Existing research tools are not able to keep pace with the rate of technology change.

- Bold decisions are required if Wales is to switch from established methodologies for capturing insight and intelligence work to include new forms of data analytics and machine learning.

- There is a capacity issue within Welsh Government which will need to be supported if new tools and techniques are to be applied.

Recommendations

The Welsh Government should take action to:

- **Establish a new Lab for Work@Wales[4.0] which can act as a central resource for industry, government and social partners** to gain insight on future trends concerning technology and its impact on the economy and work. This action should be subject to the outcome of a proof of concept study. We propose that the Lab be arms-length from the Welsh Government to ensure a level of independence and based on a hub and spoke model to ensure its relevance and value for all regions of Wales. Given the focus on experimental analytics, it could be co-located with the proposed AI Centre for the Future Economy.

- Ensure the RSPs are supported to develop deeper insight into the complex skills, abilities and knowledge required to support emerging occupations linked to new technology development, working with the Lab and engaging with those employers at the leading edge of digital innovation. This insight should also feed into the proposed Skills Framework for Wales.

Delivering Digital Government and Leadership

This review is reporting to a cross-portfolio of Ministers given that digital spans a number of ministerial portfolios and departments. Although this is positive and highlights the critical role digital innovation plays in underpinning the work of the Welsh Government, it also emphasises the potential for confusion as to where leadership for this important policy area truly sits. This includes whether all departments and functions within the Welsh Government are pulling in the same direction.

This review has found it challenging to identify key individuals or teams within the Welsh Government who were able to provide a coherent and strategic view of the Welsh Government's ambition with regards to supporting digital innovation, other than within the context of their respective policy or delivery areas. For the most part, the approach being taken by the Welsh Government was defined to us through the listing of key initiatives or projects, or by highlighting individual businesses in receipt of some form of government support.

Our concern is that leadership is too dispersed and ownership for delivery is being placed with a handful of key Civil Servants or in the confines of individual initiatives, policy boards or external reference groups (of which there are many). For example, this review has engaged with the Council for Economic Development, the Innovation Advisory Council for Wales and the Wales Employment and Skills Board, who are all discussing issues concerning digital, AI and automation. However, these discussions are potentially happening in isolation and are limited to discussing areas of existing policy and programme development. The Welsh Government does not appear to be engaging with a wider network of external advisors or international business leaders, unlike countries such as Singapore, which is taking advice on long-term global trends in areas like digital innovation.

This is not to say the Welsh Government is not supportive of reinventing itself as a digital nation. Indeed, the First Minister set out his ambition for a 'Digital Wales' as part of his manifesto for Leader of the Welsh Labour Party:

'As First Minister, I will publish a digital strategy that sets out how we will harness the power of automation and AI for the public good in Wales. My Government will place digital inclusion at the forefront of our work, ensuring that all Welsh citizens are connected and engaged... The fourth industrial revolution offers Welsh businesses opportunity to be at the cutting edge. My government will work in a social partnership with business to identify where Wales has an advantage - with the ambition of becoming world leaders in the application of AI in these fields.'

The risk here is that a new Digital Strategy is seen as the panacea for all things digital and simply draws together a list of existing interventions being supported by the Welsh Government. Learning from the experience of the Sweden and Finland **[see Exhibit 22]**, the Welsh Government should consider what it hopes to achieve with such a strategy and whether it is currently structured and working in a coherent manner to deliver such a bold and ambition approach to digital, which adopts new ways of working and seeks to make the long term and structural changes needed under our ambition for Wales 4.0.

This review has outlined a number of key recommendations which cannot be delivered by simply appointing a lead minister for digital or by singling out a ministerial position for overseeing the approval of digital related policy. All ministerial briefs will need to take responsibility and leadership.

Much of the agenda and the specific recommendations we are making demand new approaches from R&D to business support and education and training. In turn, this will require new and enhanced capacity within public bodies in Wales to deliver these changes. Evidence provided by the Future Generations Commissioner, who has responsibility for monitoring and assessing progress towards the objectives set for the public sector under the Well-being of Future Generations (Wales) Act, found that although there are initiatives taking place in some public organisations across Wales, these tend to be limited to digitalising offline processes, such as moving forms online, requesting appointments digitally, or creating online telecare services.

Exhibit 22: Digital Government in Sweden and Finland

Sweden's Digital Strategy

The Swedish Government established a Digitalisation Council (Regeringskanseliet, 2017) as part of its national digital strategy, to promote the implementation of its overarching digitalisation policy. The aim of the Council was to enhance co-ordination between different governmental and public organisations, as well as between public and private actors. The Digital Council was established as a response to growing concern following multiple studies and reviews of Sweden's innovation performance which showed that it was losing momentum due to a lack of policy coordination and ineffective governance mechanisms, including collaboration between the local, regional and national levels.

Finland's 'Place to Experiment'

The Finnish Government launched the digital platform Kokeilun Paikka4.0 (Place to Experiment) to enable the 2025 vision of a Finnish experimental culture with new ways to develop public services. The platform provides a means for collecting feedback, advice, and funding sources, and at the same time facilitate links between innovators and government (and vice versa). Ultimately, the aim is to transform the method of developing services from a top-down process to more open innovation be it through co-creation, crowdsourcing, or crowdfunding for public sector innovation, contributing to reshaping citizen-government boundaries and relations. The digital platform separates innovations into three levels: the strategic level, pooled pilots and partnerships, and the grassroots level.

The Act lists seven corporate areas where change must happen in the public sector if the national wellbeing goals are to be realised.[91] These include areas like workforce planning, financial planning, risk management, asset management and procurement, all of which could benefit from the opportunities presented by digital innovation. As Lee Waters AM has already observed in his report System Reboot – Transforming Public Services Through Better Use of Digital, "there is a gap emerging between the digital expectations of citizens and the reality of Welsh public services." He goes on to say:

'Digital change isn't just about technology, it's about a change of culture. It's about being open. It's about using data to solve problems. Instead of designing services from the viewpoint of what a health board or a local authority thinks a citizen needs, a digital approach involves designing services that meet the needs of the end user. A series of reports over the last three years have set out a consistent picture of Welsh public services failing to capture the potential of digital approaches to improve outcomes for the people who use public services, and deliver cost savings for the public sector. We know enough to know that we need to change, we now need to take action.'

This review hasn't had the capacity to examine the range of public service transformation work taking place across all parts of the Welsh Government and wider public bodies. However, we would highlight that there are clear opportunities for Wales to think differently about how digital innovation can help to mobilise its public assets. This will require a collective discussion with public bodies about how that can be achieved, something which is outside the scope of this review and forms part of the work that the Welsh Government is already taking forward following the System Reboot report.

The government at all levels has a key role to play in 'willing the means' as well as 'willing the ends' in delivering the ambition for Wales 4.0. Government itself will need to be transformed by rethinking policy-making, service design and building capacity to deliver the digital agenda.

Summary

Opportunities:

- Long term benefits for Wales in mobilising its public assets to support digital innovation.

- Align existing advisory panels and fora in order to free up capacity to bring in fresh insight from international business leaders and experts on digital innovation.

- Join-up delivery across government through a unified strategy for Wales 4.0.

Challenges:

- Digital is a complex subject involving multiple policy areas, agencies and layers of government and therefore structuring action around a new Digital Strategy could be challenging.

Wales 4.0 Delivering economic transformation for a better future of work
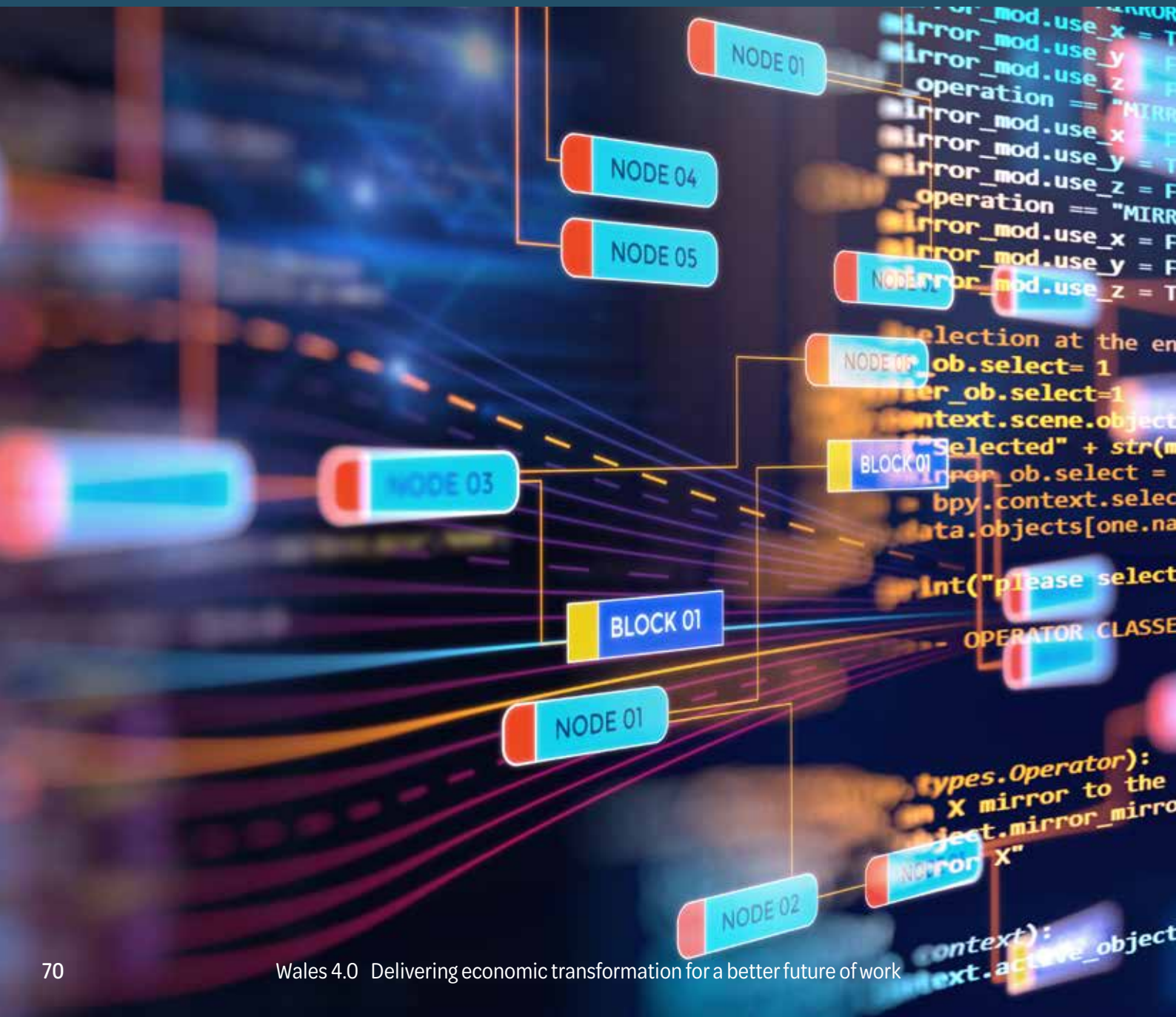
Recommendations

The Welsh Government should take action to:

- **Ensure that digital innovation is seen as the responsibility of all Welsh Government Ministers and officials**, with a number of digital 'leads' appointed to think strategically about how ministerial portfolios interact and come together to fulfil the ambition that is required to deliver Wales 4.0.

- **Establish a Future Economy Commission** with responsibility for advising on the coordination, oversight and delivery of Wales 4.0, and reporting to Welsh Ministers on an annual basis. The Commission should provide ongoing advice to the Welsh Government and its agencies and identify issues of strategic importance concerning digital innovation and its impact on the economy and the future of work. Membership should be drawn from international business leaders and experts who can ensure that national considerations take account of global opportunities. The Future Generations Commissioner should be a standing member of the Commission. In taking forward the Future Economy Commission, the Welsh Government should revisit the role and remit of a number of existing advisory functions, such as the Innovation Advisory Council for Wales and the Wales Employment and Skills Board.

- Conduct a national conversation with citizens to encourage discussion of the challenges and opportunities presented by digital innovation and the ambition of Wales 4.0. This will require an imaginative approach to engaging people of all ages through school, colleges, universities, community organisations, social media, etc. This insight will be invaluable in crafting a dynamic and unifying strategy for Wales 4.0 and informing the work of the Future Generations Commissioner for Wales.[92]

- Mainstream innovative capacity in the public sector, to help inform and implement digital solutions. This could be facilitated by a team of technical experts deployed to work with public sector organisations to support the implementation of new technology, new models of procurement, etc. in line with ideas already set out in the System Reboot report.

- Commit to an internal programme of capability which can be built upon alongside other public bodies to ensure that policy makers have an up to date understanding of the current trends in technologies and are able to speak the language of new and emerging technology businesses. This could build on existing initiatives like the MIT Industrial Liaison Programme or make use of a similar fellowship scheme involving other nations and regions. It should also capitalise on the Welsh Government's existing Memoranda of Understanding, such as with the Basque region of Spain where collaboration is already taking place on technology and business innovation.[93]

- Bring together the recommendations of this report to form a delivery plan which can underpin the EAP and Employability Plan as well as setting out how the Welsh Government intends to deliver the ambition of Wales 4.0.

A Race Against Time

Wales is at a tipping point as the fourth industrial revolution offers a limited window of opportunity for the nation to reposition itself in the UK and wider world. To do nothing is to forfeit the chance to create a different outlook for Wales and a better future of work.

This report outlines proposals for how Wales can transform its economy to deliver better jobs and increase national prosperity whilst responding to the major challenges and opportunities posed by digital innovation. We have argued that this can be achieved in a sustainable way that benefits the many rather than the few, in line with the Well-being of Future Generations (Wales) Act and the work already undertaken via the EAP, the Employability Plan and a number of the reforms taking place across education and skills.

This review has considered its recommendations based on the scale of the challenge ahead. We estimate that delivering this step-change requirement will involve an initial £100 million of public investment to be made available. With this level of investment, the Welsh Government can proactively help to deliver an economic transformation for a better future of work. It will also facilitate the preventative approach needed in response to the long-term market forces which are likely to drive more closures of manufacturing plants, call centres, and other workplaces.

In short, we are in a race against time. The bold steps now required come at a time of great political, financial and fiscal uncertainty. There will inevitably be false starts and setbacks but resetting the direction of travel will energise the nation in ways that come with a clearer sense of economic, political and social ambition.

Appendix A: Evidence and Engagement Work

The review has held conversations with a range of stakeholders from both within and outside of Wales, comprising of organisations and individuals from the public and private sector, from the larger corporates to SMEs. Members of the Expert Panel have met on a regular basis to assess evidence submitted to the review. The review has sponsored a number of additional group sessions and workshops including a 'Digital Innovation in Wales' seminar held in October 2018 and a 'Future of Skills Workshop' held in March 2019.

Expert Panel

- Professor Phil Brown, Cardiff University (Chair)
- Professor Andrew Westwood, University of Manchester
- Dr. Bertie Muller, Swansea University
- Carys Roberts, Institute for Public Policy Research
- Jacob Ellis and Kate Carr, Office of the Future Generations Commissioner
- Karen Cherrett, PA Consulting
- Lee Jones, Lloyds Banking Group
- Mark John, Tramshed Tech
- Marsha Ward, The Number Hub
- Peter Sueref, British Gas
- Richard Jones, Proxima Group
- Rob Ashelford, Nesta
- Sophie Howe, Future Generations Commissioner
- Tegid Roberts, Cadarn Consulting, Swansea University
- Professor Tom Crick MBE, Swansea University

List of Briefing Papers

- Review of UK Industrial Strategy, Professor Andy Westwood
- Digital Wales - Insights and issues from Nordics and beyond, Hanne Shapiro
- Future of Education and Skills, Professor Ewart Keep
- Labour Market Analytics, Professor Manuel Souto-Otero
- Lifelong Learning, Industry Transformation and the Future of Work in Singapore, Professor Johnny Sung
- Overview of Employment in Wales, Professor Alan Felstead
- Professor Ralph Fevre, analysis of Call for Evidence responses

Social Partners

- Federation of Small Business (FSB)
- Confederation of British Industry (CBI)
- Wales Trade Union Congress (Wales TUC)
- Wales Social Partnership Unit
- ColegauCymru
- Universities Wales

Meetings

- IQE
- Office for National Statistics (ONS)
- Monmouthshire County Council
- Welsh Government (various officials from Health, Economy, Skills and Infrastructure)
- Development Bank of Wales
- John Lloyd Jones OBE, Chair of the National Infrastructure Commission for Wales
- Innovation Point
- David Jones, Chief Executive, Coleg Cambria
- Kellie Berne, Cardiff Capital Region
- James Smith, DevOps
- Ewart Keep, SKOPE, Oxford University
- Johnny Sung, Director of the Centre for Skills Performance and Productivity (CSPP), Singapore
- Hanne Shapiro, Member of the Council for the Future of Work, World Economic Forum
- Department for Business, Energy and Industrial Strategy
- Mayor of London's Office
- Swansea Bay City Deal
- Tech Nation
- Welsh Economy Research Unit, Cardiff Business School
- Innovation Advisory Council for Wales
- Global Wales
- Wales Employment and Skills Board

- Professor Justin Lewis, Director of Clwstwr
- Fair Work Commission (Professor Linda Dickens)
- Welsh Government Council for Economic Development
- Professor Johann Sienz, Factory of the Future, Swansea University
- Professor Biagio Lucini, Computational Foundry, Swansea University
- Professor Peter Burnap, Airbus Centre of Excellence in Cyber Security Analytics, Cardiff University.
- Professor Roger Whitaker, School of Computer Science & Informatics, Cardiff University
- Barry Liles, Pro-Vice Chancellor, Skills & Lifelong Learning at University of Wales: Trinity Saint David's
- Professor Rick Delbridge, SPARK, Cardiff University.
- Lauren Crowley, Community Union / Commission on Workers & Technology
- Professor Peter Halligan, Chief Scientific Adviser for Wales

Events and Site Visits

- Wales TUC Union Learning Representatives Conferences including roundtable with Union Representatives
- Tramshed Tech
- Lloyds Banking Group (Newport Contact Centre and London Development Labs)
- Atos AI Lab, London
- Amplyfi
- Digital Innovation in Wales Seminar
- Saigon Hi-Tech Park, Ho Chi Minh, Vietnam
- MIT Work of the Future Conference, London

Business Roundtable (North Wales)

Facilitated by Business Insider with support from:

- Weekly10
- Moneypenny
- Airbus
- Federation of Small Business
- Comtec
- AMRC Wales
- Networld Sports
- Coleg Cambria
- Chetwood Financial

Future of Skills and Lifelong Learning in Wales Workshop

Supported by representatives from:

- Qualifications Wales
- JISC
- ColegauCymru
- Oxford University
- ACCA Cymru Wales
- Learning and Work Institute
- Wales TUC
- Cardiff Capital Region
- Universities Wales

Call for Evidence

Respondents to the Call for Evidence included:

- Innovation Point
- Universities Wales
- Penarth Town Council
- Monmouthshire Housing Association
- Liaison Ltd
- Institute of Civil Engineers Wales
- Federation of Small Businesses
- Prince's Trust Cymru
- Age Cymru
- Newport City Council
- South Wales Police
- Neath Port Talbot Cabinet
- ColegauCymru
- Welsh Government Equality Team
- Wales TUC
- Welsh Institute of Dermatology, University Hospital of Wales
- PA Consulting
- Principality Consulting
- Powys County Council
- Business in the Community
- Simply Do Ideas
- Unite the Union

Appendix B: Initiatives in Wales Relating to Digital Innovation

The list below reflects the range of initiatives this review has been able to identify through its engagement and research activity. This is not an exhaustive list, but it shows the range of initiatives taking place in Wales.

BUSINESS SUPPORT ACTIVITIES

4Manufacturing Tool, Knowledge Transfer Network/ Innovate UK

A practical diagnostic tool to help advisors guide businesses through the key areas of digital manufacturing and create a step-by-step plan of implementation. www.4manufacturing.co.uk

SMART Cymru, Welsh Government

Co-investment to encourage businesses to implement innovative processes and undertake R&D for sustainable growth.

SMART Expertise, Welsh Government

Supports industry-led and collaborative R&D projects between businesses and research organisations; translating research into commercial solutions.

SMART Innovation, Welsh Government

Focuses on increasing the innovation capability of Welsh businesses by assisting them to invest in sustainable research, development and innovation. It supports specialist advice, guidance and consultancy on research, development, high-value manufacturing, innovative design, intellectual property and the commercialisation of new ideas.

SMART Partnerships, Welsh Government

The Knowledge Transfer Partnership (KTP) scheme helps businesses in the UK to innovate and grow. It does this by linking businesses with an academic or research organisation and a graduate to bring the latest academic thinking to deliver a specific, strategic innovation project. KTPs are jointly funded by Welsh Government, Research Councils and Innovate UK.

PUBLIC SECTOR COLLABORATIONS

Data Cymru & InfoBaseCymru

Supported by the Welsh Local Government Association (WLGA).

An initiative to support evidence base and data collection which represent the views of local governments in Wales. A range of information for Wales can be accessed via InfoBaseCymru. https://www.data.cymru/eng/data

GovTech Catalyst, UK Government

An emerging technology fund focussing on solving public sector challenges and is available across public bodies. Challenges must address a current service or policy delivery problem where an innovative digital solution is required. www.gov.uk/government/collections/ govtech-catalyst-information

Data Science Campus, Office for National Statistics (ONS)

The Campus has been created to respond to the challenge of measuring fast evolving forms of economic activity and the opportunity to exploit huge amounts of new data and information to help policy makers, researchers and businesses. The Campus acts as a hub for the whole of the UK public and private sectors. www.datasciencecampus.ons.gov.uk

Wales Institute of Digital Information (WIDI), University of Wales Trinity St David (UWTSD) and NHS Wales Informatics Service (NWIS)

This collaboration is aimed at providing work experience, placements and projects for students as well as to facilitate a vocational focus to course design. www.widi.wales/ and https://nwis.nhs.wales

Active Building Centre (ABC), Swansea University

Jointly funded by the UK Research & Innovation (UKRI) and a cross-departmental Welsh Government support package. ABC aims to accelerate the development and adoption of active, energy-positive buildings, effectively helping to create a new industry.
www.swansea.ac.uk/press-office/news-archive/2018/chancelloroftheexchequerannounces36millionukfundingforswanseauniversitycleanenergyinnovation.php

Advanced Design and Engineering (ADE) programme, UWTSD

Provides advice on Industry 4.0 and works with companies to increase their capacity and capability to engage with advanced manufacturing technologies and materials, facilitating the adoption of advanced manufacturing techniques.
www.uwtsd.ac.uk/for-business/european-projects/

Advanced Engineering Materials Research Institute (AEMRI), TWI

Specialising in advanced modelling and simulation, full large-scale mechanical testing and advanced automated non-destructive evaluation for critical flaw detection, AEMRI is due to open in 2020 as part of TWI's non-destructive testing facilities. www.aemri.co.uk

Advanced Manufacturing Research Centre (AMRC), part of the High Value Manufacturing Catapult and delivered in partnership with the University of Sheffield

Due to open in September 2019 on the Airbus site in Broughton and has been established to support businesses to engage and adopt Industry 4.0 technologies demystifying and de-risking the process through research, collaboration and knowledge.
www.amrc.co.uk/facilities/amrc-cymru-wales

Airbus Centre of Excellence for Cybersecurity Analytics, partnership with Cardiff University

This first Centre of its kind in Europe is delivered in partnership between Cardiff University and Airbus. It aims to position the UK as a leader in cybersecurity analytics through working across industry, academia and government to provide a focus for cybersecurity analytics in the UK. www.cardiff.ac.uk/research/explore/research-units/airbus-centre-of-excellence-in-cyber-security-analytics

AI Centre of Competence

A collaboration between IBM POWER Platform and NVIDIA GPUs (Minsky), hosted at the M7 Headquarters in Cardiff. This facility provides a platform for Data Scientists, Software Developers and IT specialists to design, test and deploy proof of concept solutions prior to their wider roll out. www.m7ms.co.uk/m7-cocai.htm

AI, Robotics and Human Machine Systems (IROHMS), Cardiff University

A new Centre for Artificial Intelligence, Robotics and Human Machine Systems (IROHMS) which aims to consolidate and build on current capacity in the University's School of Engineering, Computer Science & Informatics and Psychology.

ASTUTE 2020 (Advanced Sustainable Manufacturing Technologies), Swansea University in partnership with Cardiff University, Aberystwyth University, University of South Wales and the UWTSD

Part of the Swansea Bay City Deal in Neath Port Talbot, it will develop, demonstrate and accelerate the uptake of disruptive smart manufacturing technologies. The partnership of five of Wales' research institutions offers highly qualified practitioners to support industrial Research, Development, and Innovation.
www.astutewales.com/en

Brain Research Imaging Centre (CUBRIC), Cardiff University

The £44m centre brings together world-leading expertise in brain mapping, brain imaging and brain stimulation. Research facilities include Europe's most powerful brain scanner, the Siemens 3 Tesla Connectom MRI system, and a specially adapted MRI scanner of which there is only one other in the world. www.cardiff.ac.uk/cardiff-university-brain-research-imaging-centre

Catapult Centres / Compound Semiconductor Applications Catapult

A network of world-leading technology and innovation centres which bridge the gap between business, academia, research and government. The Compound Semiconductor Applications Catapult is based in South Wales. www.catapult.innovateuk.org

Centre for Automated Manufacturing and Efficient Operations (CAMEO), UWTSD

CAMEO focuses on projects and research on the digital simulation of manufacturing processes to map, optimise and validate future scenarios such as the introduction of new technologies.

Centre for Batch Manufacturing (CBM), University of South Wales Trinity St David

An industry focused advanced research, product development, and batch manufacturing facility including 3D printing, scanning and low volume manufacturing for sectors including aerospace, automotive, medical and dental. www.cbmwales.co.uk

Centre for Photonics Expertise (CPE), Glyndŵr, Aberystwyth, Bangor University and the University of South Wales

A three-year project to provide innovative solutions to businesses in the West Wales and Valleys region. The intended benefits are to improve to the Welsh economy by providing solutions and improving skills, facilitating growth and improving productivity. www.sewales-ret.co.uk/centre-for-photonics-expertise-cpe

Centre of Excellence in Mobile and Emerging Technology (CEMET), University of South Wales

An initiative which enables SMEs to access funded collaborative research & development via a three-stage process or diagnostic, collaborative R&D and commercialisation. www.cemet.wales

Computational Foundry, Swansea University

This world-class facility will drive research into computational and mathematics sciences aiming to make Wales a global destination for computational scientist and industrial partners. Its initial core research themes include cyber security ('Securing Life'), health technologies ('Sustaining Life') and the increasing pervasiveness of digital in everyday life ('Enhancing Life'). www.swansea.ac.uk/science/computationalfoundry

Data Innovation Accelerator scheme (DIA), Cardiff University

A scheme designed to support the transfer of data science and analytics knowledge from academia to SMEs in Wales through collaborative projects with companies specialising in ICT and cyber security, advanced materials, energy and eco-innovation. www.cardiff.ac.uk/data-innovation-accelerator

Data Innovation Research Institute (DIRI), Cardiff University

DIRI uses big data to provide research-led solutions to real world problems by conducting research into the aspects of managing, analysing and interpreting massive volumes of textual and numerical information. It works with public and private sector organisations. www.cardiff.ac.uk/data-innovation-research-institute

Design4Innovation, Cardiff Metropolitan University

A collaborative project of eight European regions to promote design as a tool for user-centred innovation. It aims to help SMEs create more desirable products and services, be more profitable and grow faster.

Factory of the Future (part of ASTUTE)

The ASTUTE Factory of the Future in Neath Port Talbot will be a Centre of Excellence with state-of-the-art equipment, building on the world class expertise of the College of Engineering at Swansea University. The project will develop, demonstrate and accelerate the uptake of disruptive smart manufacturing technologies.

IMPACT, Swansea University

A £35m research institute specialising in materials, processing and numerical technologies. The aim of IMPACT is to futureproof the advanced engineering and materials industry through collaborations that enhance research capacity and increase competitiveness.
https://www.swansea.ac.uk/engineering/impact/

Manufacture for Advanced Design Engineering (MADE), UWTSD

MADE is a suite of EU-funded projects, being delivered by UWTSD's Centre for Advanced Batch Manufacture (CBM). It is designed to collaborate with SMEs to future-proof their operations, by upskilling and by adopting advanced manufacturing technologies. Projects are split in to three areas Advanced Design Engineering (ADE), Industry 4.0 and International Innovation Masters. These are also listed.
www.made.wales

National Digital Exploitation Centre (NDEC), Thales, University of South Wales and supported by the Welsh Government

The NDEC in Ebbw Vale is a joint project to offer training in digital practices, cyber security and research.
www.ndec.org.uk

National Institute for data science in health, Health Data Research UK (HDR-UK) and Swansea University

Pioneering new techniques combining and analysing patient data for research, public health applications and treatment.
www.hdruk.ac.uk/news/queens-university-belfast-and-swansea-university-join-new-54-million-uk-health-data-science-institute

PDR, Cardiff Metropolitan University

International Design and Research Centre which develops new knowledge in product design and development whilst applying and transferring this knowledge within both academia and industry. PDR covers the full range of design support needed from original research through to design, prototyping and low-volume rapid manufacture.
www.cardiffmet.ac.uk/pdr/Pages/default.aspx

Rensihaw Advanced Metrology Laboratory, Cardiff University

The Rensihaw Advanced Metrology Laboratory is a world-class facility with equipment that can perform 3D scanning, imaging, measuring and reconstruction of objects and complex surfaces. It is part of a suite of additive manufacturing labs in Cardiff University which work in many substrates, such as medical grade materials, enabling innovation in sectors from healthcare, through high value manufacturing, to the creative industries.
www.cardiff.ac.uk/engineering/research/facilities/additive-manufacturing-labs

Solar Photovoltaic Academic Research Consortium (SPARC II), Swansea University in partnership with Aberystwyth and Bangor Universities

Focused on building research capacity in solar photovoltaic technology. The research will seek added value solutions to these technology challenges that will provide new manufacturing and supply opportunities for Welsh industry. www.swansea.ac.uk/sparc-ii/

SPARK (Social Science Research Park), Cardiff University

Focused on developing innovative solutions to societal problems through collaborative research activity.
www.cardiff.ac.uk/social-science-research-park

SPECIFIC, Swansea University

SPECIFIC is a ground-breaking project which is turning buildings into power stations, which is crucial to achieving our decarbonisation targets.
www.specific.eu.com/about-us

AI Wales Masters Programme, Cardiff, Bangor and Swansea Universities

Part of an AI Wales Masters programme, a UK Government Initiative. Tramshed Tech are involved and Amplyfi is one of the industrial sponsors.

Cardiff School of Technologies, Cardiff Metropolitan University

With its first intake of student in 2019, the proposed new school is focused on education, research, innovation and higher-level skills in digital media and smart technology, data science and informatics, and systems engineering and design technology.
www.cardiffmet.ac.uk/technologies/Pages/default.aspx

Institute of Coding in Wales, a partnership led by Swansea University which forms part of the National Institute of Coding based in England

The Institute aims to develop specialist skills training in responding to the digital skills gap and create the next generation of digital specialists.
www.instituteofcoding.org

International Innovation Masters (IIM), UWTSD

The programme is available to those in West Wales and Valleys areas and seeks to produce managers with an international perspective who understand how to bring innovative products and services to market, how companies can introduce and exploit innovation, and how new commercial opportunities can be identified and realised. www.made.wales/project/international-innovation-masters/

National Cyber Security Academy (NCSA), USW

Aimed to help address a shortage of cyber security skills and develop the next generation of cyber security experts. The National Cyber Security Academy (NCSA), the first of its kind in Wales and a major UK initiative offers the BSc (Hons) Applied Cyber Security.
www.southwales.ac.uk/courses/bsc-hons-applied-cyber-security/2352/national-cyber-security-academy

National Software Academy, delivered by Cardiff University in partnership with Welsh Government and industry leaders

Primary focus on addressing the national shortage of skilled programming and software engineering graduates.
www.cardiff.ac.uk/software-academy

UKRI Centre for Doctoral Training in Artificial Intelligence, Machine Learning and Advanced Computing

(CDT-AIMLAC), Swansea (lead), Aberystwyth, Cardiff, Bristol, Bangor Universities Initiative providing 4-year, fully funded PhD opportunities across the broad areas of particle physics and astronomy, biological and health, and mathematical and computer sciences.
www.cdt-aimlac.org

Upskilling for Industry 4.0, UWTSD

Providing accredited qualifications particularly within the advanced manufacturing sector.
It aims to support participants to understand and engage with rapid technological change and help drive business growth and adaption.
www.made.wales/project/upskilling-for-industry-4-0wales

FORUMS AND NETWORKS

AISB - Society for the Study of Artificial Intelligence and Simulation of Behaviour

AISB is the largest Artificial Intelligence Society in the United Kingdom. It is chaired by Dr Bertie Müller, Senior Lecturer in Computer Science in the Computational Foundry at Swansea University.
www.aisb.org.uk

ESTnet - Electronic and Software Technologies Network for Wales

Created in 2011, ESTnet is a network of technology organisations whose members design, develop, manufacture or integrate electronic and software technologies.
www.estnet.uk.net/about-the-estnet

FinTech Wales

FinTech Wales was launched in April 2019 as a not-for-profit, sector led organisation to pool together all the resources available in Wales to support and encourage the growth of the Welsh Fintech sector.
www.fintechwales.org

AI Wales

AI Wales was founded last January and has grown to about 600 members. As well as providing a platform for the AI sector in (and out) of Wales there is a learning element to it and they encourage non-tech people to attend who have an interest in learning more about AI.
www.meetup.com/AI-Wales

Digital Tuesdays

Launched by Sir Terry Matthews in 2014, Digital Tuesday is a dynamic networking community driven to discuss digital directions, share knowledge, stimulate ideas and make things happen.
www.digital-tuesday.co.uk

Be the Spark

A movement fostering innovation-driven entrepreneurship in Wales by 'Enabling Welsh businesses to win and grow fast by linking you with the brightest minds in Wales'.
www.bethespark.wales

INDUSTRY CLUSTERS

UK Cyber Security Forum

Welsh Government has supported the establishment of Cyber Security Clusters in North Wales and South Wales, which operate under the umbrella of the UK Cyber Security Forum, to share best practice and build capabilities. The South Wales Cyber Security Cluster is now the largest by membership and meeting attendance in the UK.
www.ukcybersecurityforum.com

Cyber Wales

Cyber Wales are one of the 14 founding members of GlobalEPIC - the Global Ecosystem of Ecosystems Partnership in Innovation and Cybersecurity - bringing together the world's foremost cyber security communities from 10 countries spanning 3 continents.
www.cyberwales.net

Digital Health Ecosystem for Wales (DHEW), Life Sciences Hub Wales and the NHS Wales Informatics Service (NWIS)

A network connecting developers and companies with innovative digital health solutions with the NHS in Wales. www.lshubwales.com/dhew

Appendix C: Proposed activities of the AI Institute for the Future Economy

The overarching aim of the AI Institute for the Future Economy is to become a world leader in the development and application of AI. To achieve this the new institute will need to:

- Build internationally recognised capacity and capability in key areas relevant to the Welsh economy and society.

- Develop new research across Technology Readiness Levels (TRLs) from concept formulation and experimental proof of concept, to prototype demonstration and operational implementation. However, there will be significant focus on building economic capacity to attract business R&D which tends to be more applied.

- Cultivate networks and collaborations with global AI hubs, e.g. Boston, Berlin, Toronto, Bangalore, Beijing, Shenzhen and London.

- Adopt an interdisciplinary approach as ethical questions do not come after research innovation but is integral to its conduct. Given the fundamental economic and social changes anticipated to result of AI there is little sense in drawing shape divisions between STEM and the humanities and arts.

- Establish an innovative portal highlighting the activities of the Institute as well as showcasing the growing range of activities around AI and machine learning, including initiatives already happening in Wales.

- Have links to higher level skills training including the National Software Academy and Institute of Coding so that businesses and other organisations can access capabilities that ensure the benefits of digital change are harnessed for the Welsh economy.

- Enable Welsh Universities and businesses to bid for additional R&D resources in the UK and beyond and help to 'crowd in' business investment in R&D towards a formal 2.4 per cent GDP (OECD average and existing UK ambition) target for Wales.

- Directly linked with the Lab for Work@Wales[4.0], proposed within the recommendations of this review.

- Be based on a hub and spoke model of national and international collaboration. Direct links to other 'innovation hubs' and R&D ventures in Wales including those identified and supported via the Development Bank of Wales.

- Be run by an independent board but with key representation from Welsh Universities, businesses and government, similar to existing Catapult Centres.

Appendix D: Example output from Amplyfi surface and deep web analytics

This example demonstrates how the surface and deep web data which Amplyfi is able to capture through its DataVoyantTM software to visualise today's drivers of manufacturing production. The charts reveal a current focus on the industrial internet of things and additive manufacturing (3D printing), but it also uses predictive analytics to identify technologies that are likely to impact on the future of manufacturing such as manufacturing execution systems (MES) and robotic process automation (RPA).

This is just a small snapshot of the initiative data visualisations which Amplyfi is able to produce using their combination of AI and web harvesting.

Drivers of change influencing manufacturing today

Machine analysis delivers unbiased trend analysis of every topic

● Cyber Physical Systems (CPS)	● Manufacturing Execution Systems (MES)	● Additive Manufacturing
● Robotic Process Automation (RPA)	● Industrial Internet of Things (IIoT)	
● Smart Factory	● Predictive Maintenance (PDM)	
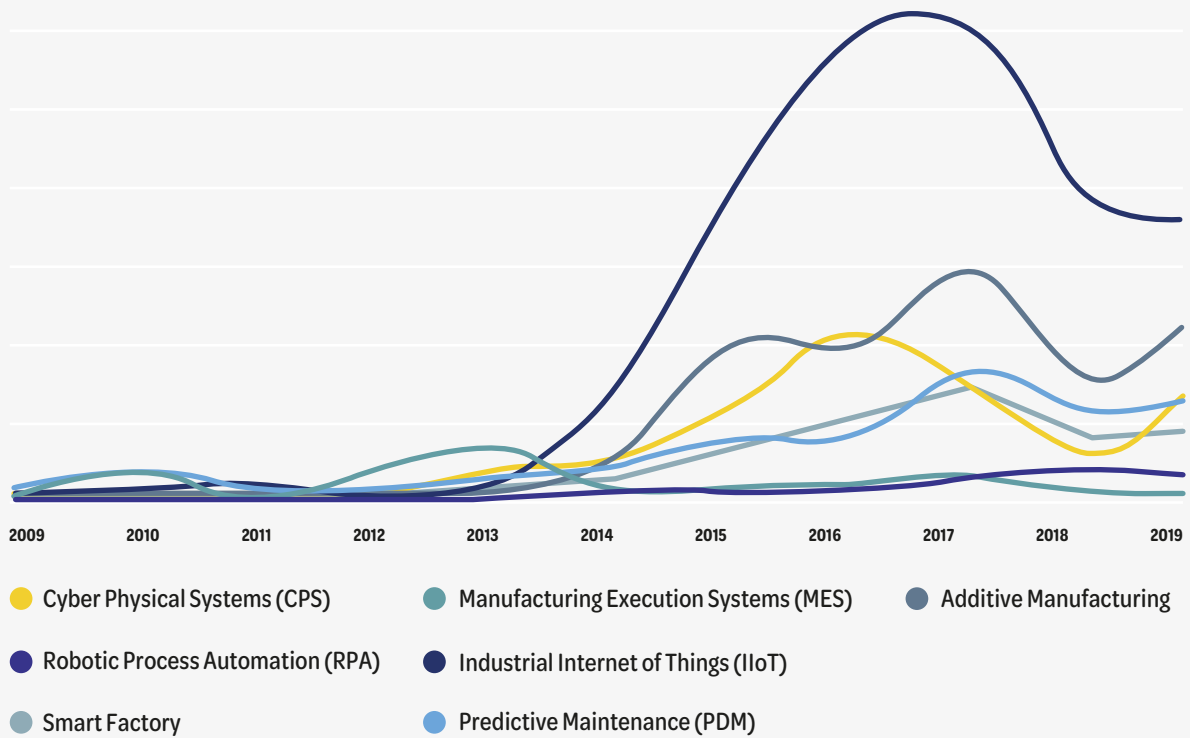
Key drivers of tomorrow's manufacturing

Machine analysis delivers unbiased view of the future and infers maturity peaks
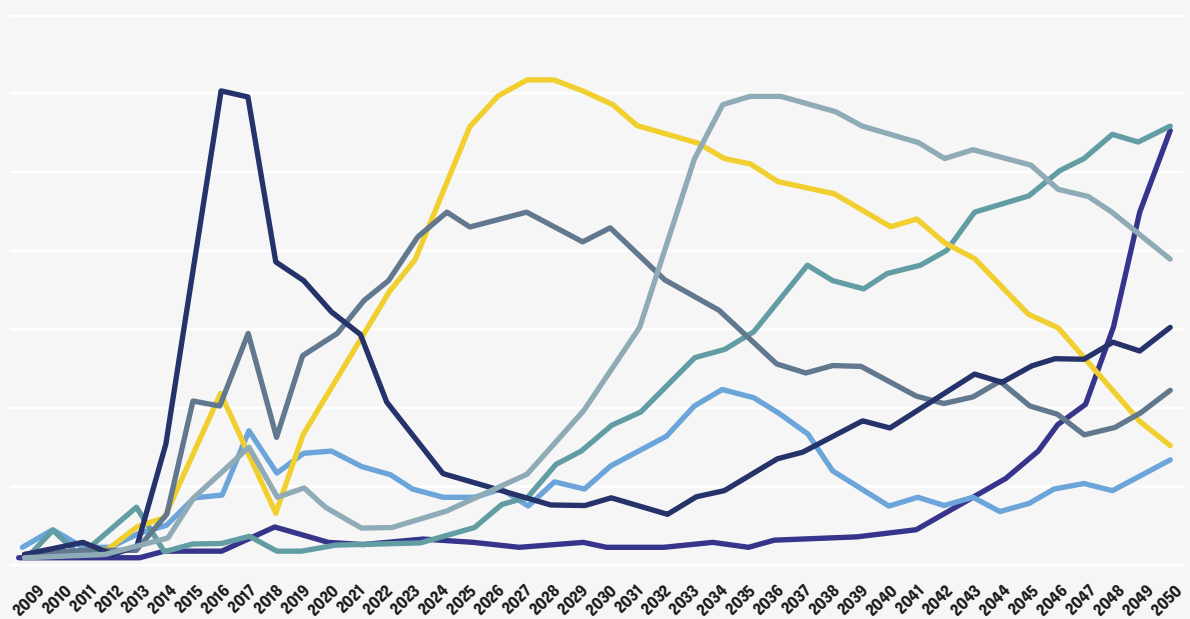
Source: Analysis by Amplyfi

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See also Keynes, J.M. ([1930] 2008) Economic Possibilities for Our Grandchildren, in Pecchi, L. and Piga, G. (2008) Revisiting Keynes: Economic Possibilities for our Grandchildren, London: MIT Press.

[2] Fair Work Commission (2019) Fair Work Wales, Welsh Government. [Online]. Available at: https://gov.wales/sites/default/files/publications/2019-05/fair-work-wales.pdf

[3] YouGov survey commissioned by the Commission on Workers and Technology https://fabians.org.uk/workers-and-technology-our-hopes-and-fears/

[4] Some manufacturing companies in Wales are adopting the principles of Industry 4.0, which is the part of the fourth industrial revolution relating to industrial production. The aim of Industry 4.0 is to support businesses who are typically in manufacturing to make their production processes 'smarter'. See also Made Smart Review (2017) chaired by Professor Juergen Maier. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf

[5] The Well-being of Future Generations Act requires public bodies in Wales to think about the long-term impact of their decisions, to work better with people, communities and each other, and to prevent persistent problems such as poverty, health inequalities and climate change. It is supported by seven Well-being Goals and Five Ways of Work. See https://futuregenerations.wales/about-us/future-generations-act/

[6] www.bbc.co.uk/news/uk-wales-43712829, see also Mathew Lawrence, Carys Roberts and Loren King (2017) Managing Automation: Employment, Inequality and Ethics in the Digital Age, IPPR. [Online]. Available at: https://www.ippr.org/publications/managing-automation

[7] See Terms of Reference for the Review of Digital Innovation for the Economy and the Future of Work in Wales. https://gov.wales/review-digital-innovation-economy-and-future-work-wales/terms-reference

[8] See Robert J. Gordon (2016) The Rise and Fall of American Growth, Oxford: Princeton University Press; Thomas Picketty (2013) Capital in the Twenty-First Century, Boston: Harvard University Press. For a discussion on the changing relationship between education, jobs and incomes, see Phillip Brown, Hugh Lauder and David Ashton (2011) The Global Auction: The Broken Promises of Education, Jobs and Incomes, New York: Oxford University Press.

[9] Figures from the OECD indicate that in 2018 the average worker in Germany worked 1,363 hours. https://data.oecd.org/emp/hours-worked.htm#indicator-chart

[10] See HSBC (2018) The World in 2030, https://www.hsbc.com/news-and-insight/2018/the-world-in-2030

[11] Ibid. HSBC (2018).

[12] Based on Q1 2019 data from the OECD on Employment rates by specific age groups. https://data.oecd.org/emp/employment-rate-by-age-group.htm#indicator-chart

[13] Klaus Schwab (2016) The Fourth Industrial Revolution, Geneva: World Economic Forum. Others have also argued that the technological innovations of today fail to match those driving economic growth in the post world war II era. See Robert J. Gordon (2016) The Rise and Fall of American Growth, Princeton NJ: Princeton University Press.

[14] Klaus Schwab (2016) The Fourth Industrial Revolution, Geneva: World Economic Forum, p.1.

[15] See Now and Then – The Process of Invention, Economist, April 25, 2015, and Hyejin Youn, Deborah Strumsky, Luis M. A. Bettencourt and Jose Lobo, 2015 Invention as a Combinatorial Process: Evidence from US Patents', Interface, 12, pp.1-8. (available online)

[16] Phillip Toner (2011) Workforce Skills and Innovation: An Overview of Major Themes in the Literature, OECD Science, Technology and Industry Working Paper, https://search.oecd.org/innovation/inno/46970941.pdf

[17] Kevin Morgan, Adrian Healy, Robert Huggins and Meirion Thomas (2017) Growing the Value of University-Business Interactions in Wales, National Centre for Universities and Business. [Online]. Available at: http://www.ncub.co.uk/reports/growing-value-wales-full-report

[18] David Ricardo (1821) Principles, Chapter 31. [Online]. Available at: https://economistsview.typepad.com/economistsview/2012/09/david-ricardo-on-machinery.html

[19] Keynes, ibid. p20-21. For a modern discussion of this debate see Brown, P., Lloyd, C. and Souto-Otero, M. (2018) *The Prospects for Skills and Employment in an Age of Digital Disruption*: *A Cautionary Note*, Centre on Skills, Knowledge and Organisational Performance, SKOPE Research Paper No.127, November 2018, http://www.skope.ox.ac.uk/?person=the-prospects-for-skills-and-employment-in-an-age-of-digital-disruption-a-cautionary-note

[20] Maggie Tillman and Adrian Willings (2019) Real-life robots that will make you think the future is now. [Online]. Available at: https://www.pocket-lint.com/gadgets/news/134820-real-life-robots-that-will-make-you-think-the-future-is-now

[21] Frey, C.B. and Osborne, M.A. (2014) London Futures - *Agiletown: the relentless march of technology and London's response*. [Online]. Available at: https://www2.deloitte.com/uk/en/pages/growth/articles/agiletown-the-relentless-march-of-technology-and-londons-response.html See also *'The Future of Employment: How Susceptible are Jobs to Computerisation?*, Carl Benedikt Frey and Michael A. Osborne. https://www.oxfordmartin.ox.ac.uk/publications/the-future-of-employment/

[22] Frey and Osborne used an online database of US jobs descriptions O*NET, to estimate the "probability of automatable or non-automatable" of different occupations. They manually labelled 70 out of 702 occupations based on 'eye-balling' the job descriptions assigning 1 if automatable and 0 if not. Then objectively assign scores corresponding to their probabilistic model based on the levels of "engineering bottlenecks" (a) perception and manipulation; b) creative intelligence, and; c) social intelligence, which they consider difficult to be automated.
However, the work of Frey and Osborne has been criticised for failing to consider the variations of heterogeneous tasks within occupations. These critics suggest only some tasks are automatable and the composition of each job can vary from one person to another while having the same occupation. Focusing on more granular data Arntz et al. take a task-based approach uses the OECD's Survey of Adults Skills (PIAAC) to predict impact of automation across and within occupation. See Brown, P., Lloyd, C. and Souto-Otero, M. (2018) *The Prospects for Skills and Employment in an Age of Digital Disruption: A Cautionary Note*, Centre on Skills, Knowledge and Organisational Performance, SKOPE Research Paper No.127, November 2018, http://www.skope.ox.ac.uk/?person=the-prospects-for-skills-and-employment-in-an-age-of-digital-disruption-a-cautionary-note

[23] Mathew Lawrence, Carys Roberts and Loren King (2017) *Managing automation: Employment, Inequality and Ethics in the Digital Age*, IPPR. [Online]. Available at: https://www.ippr.org/publications/managing-automation

[24] Joseph A. Schumpeter, (1976) 'The Process of Creative Destruction' in Capitalism, Socialism and Democracy, London: George Allen and Unwin, p.84.

[25] For a discussion of digital Taylorism, see Phillip Brown, Hugh Lauder, and David Ashton (2011) The Global Auction, New York: Oxford University Press.

[26] Deloitte (2015) *Technology and people: the great job creating machine*. [Online]. Available at: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/finance/deloitte-uk-technology-and-people.pdf. See also Autor, D. H. (2015) Why are there still so many jobs? The history and future of workplace automation, The Journal of Economic Perspectives, 29,3, 3-30.

27 PwC (2017) *UK Economic Outlook*, March 2017, p. 44 www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf

28 World Economic Forum (2018) *The future of jobs 2018*. [Online]. Available at: http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf; McKinsey (2017) *Jobs lost, jobs gained: workforce transitions in a time of automation*. [Online]. Available at: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/what%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/mgi-jobs-lost-jobs-gained-report-december-6-2017.ashx

29 The definition of employment used by the Labour Force Survey (LFS) in the UK, is the number of people aged 16 years and over who do one hour or more of paid work per week. It also includes those who had a job that they were temporarily away from (for example, because they were on holiday or off sick). This is an extremely low benchmark of employment as someone may only work an average of four hours a month yet qualify as employed.

30 Guy Standing (2011) The Precariat: The New Dangerous Class, New York: Bloomsbury.

31 Klaus Schwab (2016, p.20.) Much is made of freelance professions selling their services on a global basis no longer requiring them to conform to traditional models of employment. Apple app developers are an example.

32 Fair Work Commission (2019) *Fair Work Wales*, Welsh Government. [Online]. Available at: https://gov.wales/sites/default/files/publications/2019-05/fair-work-wales.pdf

33 See https://futureadvocacy.com/wp-content/uploads/2018/04/FutureAdvocacy-GeographicalAI.pdf and https://futuregenerations.wales/news/the-impact-of-ai-in-welsh-constituencies/

34 Nesta (2017) *Future of Skills: Employment in 2030*. [Online] Available: https://www.nesta.org.uk/report/the-future-of-skills-employment-in-2030/

35 See ONS *Regional and sub-regional productivity in the UK*: February 2019 https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/articles/regionalandsubregionalproductivityintheuk/february2019

36 Welsh Government (2019) *Level of Highest Qualification held by Working Age Adults*, 2018, April 2019. [Online]. Available at: https://gov.wales/sites/default/files/statistics-and-research/2019-04/levels-of-highest-qualification-held-by-working-age-adults-2018-731.pdf Working age adults are defined as males and females aged 18-64.

37 Michaela Brockmann, Linda Clarke and Christopher Winch (2011) Knowledge, Skills and Competence in the European Labour Market: What is a Vocational Qualification? London: Routledge. In 2017, 15.2 per cent of individuals aged 25-64 years old attained a Bachelor's or equivalent tertiary education degree in Germany, substantially lower than the UK figure of 22.6 per cent and also lower than the OECD average of 17.0 per cent. See OECD Education GPs http://gpseducation.oecd.org/CountryProfile?primaryCountry=DEU&treshold=10&topic=EO

38 Wilkinson, R. & Pickett, K. (2009) The Spirit Level: Why more equal societies almost always do better. London: Allen Lane/Penguin; OECD (2018) *A Broken Social Elevator? How to promote social mobility*. Paris: OECD Publishing - DOI https://doi.org/10.1787/9789264301085-en; Social Mobility Commission (2017) *The State of the Nation 2017: Social Mobility in Great Britain*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662744/State_of_the_Nation_2017_-_Social_Mobility_in_Great_Britain.pdf

39 Alan Felstead and Rhys Davies (2019) *Work in Wales, 2006-2017, Evidence from the Skills and Employment Survey*. Welsh Government. Available at: https://gov.wales/sites/default/files/statistics-and-research/2019-04/work-in-wales-2006-2017.pdf

40 Referring to the departure of educated or professional people from one country, economic sector, or field for another usually for better pay or living conditions. The implication being the loss of talent and skills.

41 Some manufacturing companies in Wales are adopting the principles of called Industry 4.0, which is the part of the fourth industrial revolution relating to industrial production. The aim of Industry 4.0 is to support those businesses who are typically in manufacturing to make their production processes 'smarter'. https://assets.publishing.service.gov.uk/government/uploads/system/

uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf Wales 4.0 goes much further to embed the principles of the Wellbeing of Future Generations (Wales) Act and holistically grow our economic, social, environmental and cultural wealth in this new digital age.

[42] Employment prospects are not only determined through individual effort or ability but by the structure of opportunity over which individuals have limited control. For a recent discussion of 'job scarcity' versus 'labour scarcity' see Brown, P., Lauder, H. and Cheung, S.Y. (Jan. 2020) The Death of Human Capital?, New York: Oxford University Press.

[43] There are different definitions of a universal basic income and significant differences of opinion in terms of its affordability and effectiveness. See Philippe Van Paris and Yannick Vanderborght (2017) Basic Income: A Radical Proposal for a Free Society and a Sane Economy, Boston, Mass.: Harvard University Press; Rutger Bregman (2016) Utopia for Realists: The Case for a Universal Basic Income, London: Bloomsbury; Anthony B. Atkinson Inequality: What Can Be Done?, Cambridge, Mass.: Harvard University Press, 2015. Atkinson argues for a universal child benefit (allowance) to be paid for all children at a substantial rate and should be taxed as income, pp.216-18. Estimates in Britain suggest that a UBI to cover social security would also need a top up in terms of housing benefit, see Luke Martinelli, The Fiscal and Distributional Implications of Alternative Universal Basic Income Schemes, The Institute for Policy Research, Working Paper, March, 2017, University of Bath.

[44] It also requires a review of key performance indicators (KPIs) used by Welsh Government to define and justify its delivery activities, given a danger of putting effort into things that are inconsistent with the ambition for Wales 4.0. Some KPIs are relatively easy to identify such as eliminating the median income gap with England and Scotland or increasing R&D expenditure to the OECD average of 2.4 per cent as an indicator of innovation. But more work is required to link KPIs to the Government's industrial transformation policy.

[45] See a *Mission-Oriented Innovation Policy*, Mariana Mazzucato (2017). She highlights the fact that economic growth has not only a rate but also a direction; that innovation requires investments and risk taking by both private and public actors; that the state has a role in not only fixing markets but also in co-creating and shaping them; that successful innovation policy combines the need to set directions from above with the ability to enable bottom up experimenta-tion and learning; and to be successful missions may require consensus building in civil society. https://www.ucl.ac.uk/bartlett/public-purpose/publications/2018/jan/mission-oriented-innovation-policy-challenges-and-opportunities

[46] Sen, A (2001) Development as Freedom, Oxford: Oxford University Press.

[47] In a number of cases these initiatives have been born from current and emergent areas of industrial collaboration between research institutions and businesses in Wales. In others their intention is to stimulate new industrial clusters aligned to emerging technology trends. https://www.cardiff.ac.uk/__data/assets/pdf_file/0005/794030/Growing-the-Value-of-University-Business-Interactions-in-Wales-Summary-Report.pdf

[48] Informed by briefing material provided by Professor Johnny Sung, Centre Director for Skills, Performance and Productivity, Institute for Adult Learning Singapore. See also the Report of the Committee on the Future Economy: Pioneering the Next Generation, 2016. https://www.mti.gov.sg/Resources/publications/Report-of-the-Committee-on-the-Future-Economy https://www.mti.gov.sg/-/media/MTI/ITM/General/Fact-sheet-on-Industry-Transformation-Maps---revised-as-of-31-Mar-17.pdf

[49] Further background to the Singaporean Industrial Transformation Maps can be found online at https://www.mti.gov.sg/ITMs/Overview

[50] Graeme Reid (2018) *Review of Government Funded Research and Innovation in Wales*, Welsh Government. [Online] Available at: https://gweddill.gov.wales/docs/det/publications/reid-review-en.pdf

[51] Gross Domestic Product Expenditure on Research & Development, UK, 2017 – ONS - https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2017

52 *The UK is a State of Inequality* Rhun ap Iorwerth 2019 https://www.iwa.wales/click/2019/04/the-uk-is-a-state-of-inequality/. Similarly if we consider the Gross Domestic Expenditure on R&D (GERD), which involves a portfolio of sources from business, higher education, government and research councils, and private not for profit organisations, the ratio and volume of these sources differs greatly between different areas of the UK, and generally show that investment in Wales is much lower. *Gross Domestic Product Expenditure on Research & Development, UK, 2017* – ONS - https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2017 The figure of HE R&D spend per head in Wales was just £86, compared to £275 in London and the home counties. *The UK is a State of Inequality* Rhun ap Iorwerth 2019 https://www.iwa.wales/click/2019/04/the-uk-is-a-state-of-inequality/ It should be noted though that Wales has been successfully awarded a large proportion of European funding. During the current Programme funding period (2014-2020), the Welsh Government has invested £340m in Research and Innovation priorities. *Wales: Protecting research and innovation after EU exit* – Welsh Government 2019 - https://gov.wales/sites/default/files/publications/2019-03/wales-protecting-research-innovation-after-eu-exit.pdf

53 Welsh Government. 2019. *Wales: Protecting research and innovation after EU exit*. [Online]. Available at: https://gov.wales/sites/default/files/publications/2019-03/wales-protecting-research-innovation-after-eu-exit.pdf

54 See also Welsh Government (2019) *Wales: Protecting Research and Innovation After EU Exit*, Appendix 2 p.46, Chief Scientific Advisor, https://gov.wales/sites/default/files/publications/2019-03/wales-protecting-research-innovation-after-eu-exit.pdf

55 PwC (2017) *The economic impact of artificial intelligence on the UK economy*. [Online]. Available at: https://www.pwc.co.uk/economic-services/assets/ai-uk-report-v2.pdf

56 Drakeford, M. and Davies, D. (2018) Labour Leadership Manifesto: 21st Century Socialism.

57 House of Commons Treasury Committee (2019) Consumers' access to financial services, Twenty-Ninth Report of Session 2017–19. [Online] Available at: https://www.parliament.uk/business/committees/committees-a-z/commons-select/treasury-committee/news-parliament-2017/connsumers-access-to-financial-services-report-published-17-19/

58 Universities Wales (2019) *Solving future skills challenges in Wales*. [Online]. Available at: https://uniswales.ac.uk/media/Solving-Future-Skills-Challenges-in-Wales.pdf

59 Some manufacturing companies in Wales are adopting the principles of Industry 4.0, which is the part of the fourth industrial revolution relating to industrial production. The aim of Industry 4.0 is to support those business who are typically in manufacturing to make their production processes 'smarter'. See also *Made Smart Review* (2017) chaired by Professor Juergen Maier. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf

60 Fair Work Commission (2019) *Fair Work Wales*, Welsh Government. [Online]. Available at: https://gov.wales/sites/default/files/publications/2019-05/fair-work-wales.pdf

61 Superfast Broadband Business Exploitation Project (2019) *Digital Maturity Survey for Wales 2018*. [Online]. Available at: https://www.cardiff.ac.uk/__data/assets/pdf_file/0008/1483685/dms-report-2018-v1-5.pdf

62 Department for Education (2017) *Employer skills survey 2017*: Wales slide pack. [Online] Available at: https://www.gov.uk/government/publications/employer-skills-survey-2017-wales-toolkit Also informed by briefing material provided by Professor Ewart Keep, Oxford University.

63 Tech Nation (2018) *Report 2018: Connection and collaboration: powering UK tech and driving the economy*. [Online]. Available at: https://technation.io/insights/report-2018/

64 Kevin Morgan, Professor of Governance and Development at Cardiff University, See https://www.walesonline.co.uk/business/business-opinion/40m-project-create-400-jobs-11063721 and, Kevin Morgan, Adrian Healy, Robert Huggins and Meirion

Thomas (2017) Growing the Value of University-Business Interactions in Wales, National Centre for Universities and Business, August http://www.ncub.co.uk/reports/growing-value-wales-full-report

[65] The Masters in Skills and Workforce Development taught in Singapore by Cardiff University faculty is an example of how this is closely connected to a range of research activities resulting in funded research projects.

[66] Donaldson, G. 2015. *Successful futures: Independent review of curriculum and assessment arrangements in Wales*. [Online]. Available at: http://dera.ioe.ac.uk/22165/2/150225-successful-futures-en_Redacted.pdf

[67] In this regard, the principles of curriculum reform identified by Professor Graham Donaldson are to be welcomed, including six areas of learning and experience with more of a focus on the learning needs of the individual, and all areas contributing to the development of literacy, numeracy and digital competence. Here, further consideration needs to be given to the resource implications of student-centred reforms which are more resource intensive in terms of time, effort and money. See also *Digital 2030: a strategic framework for post-16 digital learning in Wales* https://gov.wales/sites/default/files/publications/2019-06/digital-2030-a-strategic-framework-for-post-16-digital-learning-in-wales.pdf and proposals for a Tertiary Education and Research Commission https://gov.wales/tertiary-education-and-research-commission

[68] See James, D. (2019) Learning in and learning from FE and skills policy in Wales: a relational approach. Journal of Education and Work 32(3), pp. 251-265.

[69] Ellen Hazelkorn (2016) *Towards 2030: A framework for building a world-class post-compulsory education system for Wales*. Available at: https://gov.wales/sites/default/files/publications/2018-02/towards-2030-a-framework-for-building-a-world-class-post-compulsory-education-system-for-wales.pdf

[70] Andrew Haldane, A (2018) *Ideas and Institutions – A Growth Story*, Speech to The Guild Society, University of Oxford, 23 May. p.17. Available at: https://www.bankofengland.co.uk/-/media/boe/files/speech/2018/ideas-and-institutions-a-growth-story-speech-by-andy-haldane

The classic statement on the idea of a 'multiversity' remains Clark Kerr's (1963) The Uses of the University, Cambridge, Mass: Harvard University Press., which he wrote as President of the University of California. For a recent discussion see Claire Donovan (2016) From Multiversity to Postmodern University, in James Cote and Andy Furlong (Eds.) Routledge Handbook of the Sociology of Higher Education, London: Routledge.

[71] Augur, P. (2019) *The Post-18 Education Review (the Augar Review) recommendations*. [Online]. Available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-8577

[72] The Augar Review recommends 'a stronger technical and vocational education system at sub-degree levels to meet structural skills shortages', believing that this is the layer of higher education that is key to addressing 'the UK's weak productivity performance' and that it is a better policy intervention than further expansion of full-time students studying degrees. The OECD (2017) agrees, pointing to the UK's 'longstanding problems in technical education, especially at 'higher' levels (level 4 and above), and an over-reliance on graduate education, often leading to 'non-graduate' work'.

[73] Nesta (2017) *Future of Skills: Employment in 2030*. [Online] Available at: https://www.nesta.org.uk/report/the-future-of-skills-employment-in-2030/

[74] This is different from the T-levels proposed in England from 2020 which will follow GCSEs and will be equivalent to 3 A Levels. These 2-year courses are intended to more direct relevance to employment than more academic A level subjects.

[75] House of Lords (2015) *Make or break: the UK's digital future*. [Online]. Available at: https://publications.parliament.uk/pa/ld201415/ldselect/lddigital/111/111.pdf Also see Qualifications Wales (2018) *Delivering Digital*, esp. Chapter Two Tom Crick, 'The Information and Communication Technology Sector in Context https://www.qualificationswales.org/english/publications/delivering-digital-review-of-qualifications-in-the-ict-sector-2018/

[76] See StatsWales https://statswales.gov.wales/Catalogue/Education-and-Skills/Post-16-Education-and-Training/Further-Education-and-Work-Based-Learning/Lifelong-Learning-Wales-Record/learningprogrammesapprenticeships

[77] Lloyds Banking Group (2019) *UK Consumer Digital Index 2018, Benchmarking the digital and financial capability of people in the UK*. [Online]. Available at: https://www.lloydsbank.com/assets/media/pdfs/banking_with_us/whats-happening/LB-Consumer-Digital-Index-2018-Report.pdf
The Basic Digital Skills fall into five broad areas: (1) managing information; (2) communicating; (3) transacting; (4) problem solving; and, (5) creating.

[78] Waters, L. (2019) *Written Statement: Foundational Economy*. [Online]. Available at: https://gov.wales/written-statement-foundational-economy

[79] See RiverSimple which is developing hydrogen powered vehicles from its headquarters in Llandrindod Wells, Powys, https://www.riversimple.com/ For a discussion of what amounts to a transformation of the means of production, see Jeremy Rifkin, (2014) The Zero Marginal Cost Society, New York: Palgrave Macmillan; and Paul Mason (2015) Postcapitalism: A Guide to the Future, London: Allen Lane;

[80] See for example Robert Chapman (2018) '*Co-Working and the Man from Machynlleth*', https://www.iwa.wales/click/2018/03/co-working-man-machynlleth/ Companies including Stride Treglown '*Variety and Vibrancy: Evolving the Retail Experience*, https://stridetreglown.com/evolving-retail/ and Savills '*Repurposing Shopping Centres*', https://www.savills.co.uk/research_articles/229130/220539-0 are looking way to reimagine town centres and retail outlets. The Chair of the Review is also grateful to Jamie Griffith, a final year student in architecture at Sheffield University who posed the question of how derelict spaces in deprived neighbours could be repurposed in ways that utilised digital technologies to improve the quality of life for local residence.

[81] 'A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.' http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy

[82] Kevin Morgan (2019) 'The future of place based innovation policy (as if 'lagging regions' really mattered)', in Mariachiara Barzotto, Carlo Corrandini, Felicia M Fai, Sandrine Labory and Philip R Tomlinson (Eds.), Revitalising Lagging Regions: Smart Specialisation and Industry 4.0, London: Routledge.

[83] For Local Broadband Information see http://labs.thinkbroadband.com/local/wales

[84] Our ideas on mainstreaming digital infrastructure are informed by currently thinking on the foundational economy and the idea of a universal basic infrastructure, as part of the Industrial Strategy Commission's report, November 2017 http://industrialstrategycommission.org.uk/2017/11/01/the-final-report-of-the-industrial-strategy-commission/

[85] Drakeford, M. and Davies, D. (2018) Labour Leadership Manifesto: 21st Century Socialism.

[86] This is a point made by the OECD in their most recent Employment Outlook report: 'Many people and communities have been left behind by globalisation and a digital divide persists in access to new technologies – resulting in inequalities along age, gender, and socio-economic lines.' See OECD (2019) *The Future of Work: Employment Outlook 2019*. [Online] Available at: https://read.oecd-ilibrary.org/employment/oecd-employment-outlook-2019_9ee00155-en#page1

[87] This takes advantage of reduced latency as data would potentially travel through Wales a fraction of a second before London or New York.

[88] See Regional Labour Market Intelligence Reports produced to support the work of the three Regional Skills Partnerships. https://businesswales.gov.wales/skillsgateway/skills-development/regional-skills-partnerships

[89] There is also significant benefit to be gained by using data analytics to understanding learners' engagement with education, use of educational spaces and devices, sense of wellbeing, and factors affecting retention and achievement. See for example the work of JISC. https://www.jisc.ac.uk/

[90] OECD (2017) *Pro-Productivity Institutions: Learning from National Experience*. [Online] Available at: https://www.oecd-ilibrary.org/docserver/d1615666-en.pdf?expires=1561131945&id=id&accname=guest&checksum=A9A3BA55CA7CCD491EEF067A3AD01FC2

[91] The Well-being of Future Generations Act requires public bodies in Wales to think about the long-term impact of their decisions, to work better with people, communities and each other, and to prevent persistent problems such as poverty, health inequalities and climate change. It is supported by seven Well-being Goals and Five Ways of Working.

[92] The final report of the national conversation on The Wales We Want was published in 2015. Five years on, the Future Generations Commissioner is due to report on progress in June 2020. This provides a great opportunity for synergy as we review the aspirations of 2015 and consider the Wales We Want Now and in the future within the context of the digital age.

[93] Waters, L. (2018) *System Reboot: Transforming public services through better use of digital*: An expert panel report for the Welsh Government. [Online] Available at: https://gov.wales/digital-solutions-expert-panel-report

[94] For example, as part of the approach to Industry 4.0 in the context of MANUMIX Interreg Europe project which Welsh Government is a partner alongside the Basque region of Spain. https://www.interregeurope.eu/manumix/news/news-article/4880/welsh-visit-on-basque-industry-4-0-approach/

Notes

Wales 4.0   Delivering economic transformation for a better future of work

Notes