TECHNOLOGY AT WORK v2.0

The Future Is Not What It Used to Be

Citi GPS: Global Perspectives & Solutions

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TECHNOLOGY AT WORK v2.0

The Future Is Not What It Used to Be

It is a pleasure to introduce Technology at Work v2.0: The Future Is Not What It Used To Be. This report is the third in a long-term series of Citi GPS reports co-produced by Citi and the Oxford Martin School at the University of Oxford in order to explore some of the most pressing global challenges of the 21st century. The report further explores the concepts introduced in our February 2015 report, Technology at Work: The Future of Innovation and Employment, which marked the introduction of the Oxford Martin Programme on Technology and Employment, a long-term programme of research at the University of Oxford supported by Citi that will focus on the implications of a rapidly changing technological landscape for economies and societies.

In this new report, Oxford Martin School academics; Dr. Carl Benedikt Frey, Associate Professor Michael Osborne and Dr. Craig Holmes expand their theories on the changing nature of innovation and work and the associated implications for the future of employment and society more widely. Based on their methodology that predicted 47 percent of US jobs were at risk from automation, the authors now look at the probabilities of jobs at risk across the world as well as the disparities of job risk between cities.

To protect against jobs being eliminated due to automation, it is important to recognize which characteristics are most likely to be associated with a given job being automated — perception and manipulation, creative intelligence, and social intelligence are the three bottlenecks to automation. Cities and regions that have invested in skilled industries remain relatively safe from automation and technological dynamism will remain the best way to maximize employment and to benefit positively from new technologies. Education is also a very important tool that policymakers will need to leverage in preparation for the effects of accelerated technological change.

Throughout this report, Citi Research analysts drill deeper into specific industries to highlight a number of sectors already feeling the effects of automation as well as areas where technology is helping to create new jobs. The Citi Research Economics team investigates whether traditional measurement tools are failing to capture the productivity and GDP improvements as well as the subsequent inflation effects that come from accelerated technological change. Finally, we look to identify adequate policy responses for the issues highlighted in this report.

We hope that you enjoy this Citi GPS report. We look forward to sharing the results of the exciting collaboration between Citi and the Oxford Martin School in future reports.

Andrew Pitt
Global Head of Research
Citi

Ian Goldin
Director of the Oxford Martin School
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University of Oxford

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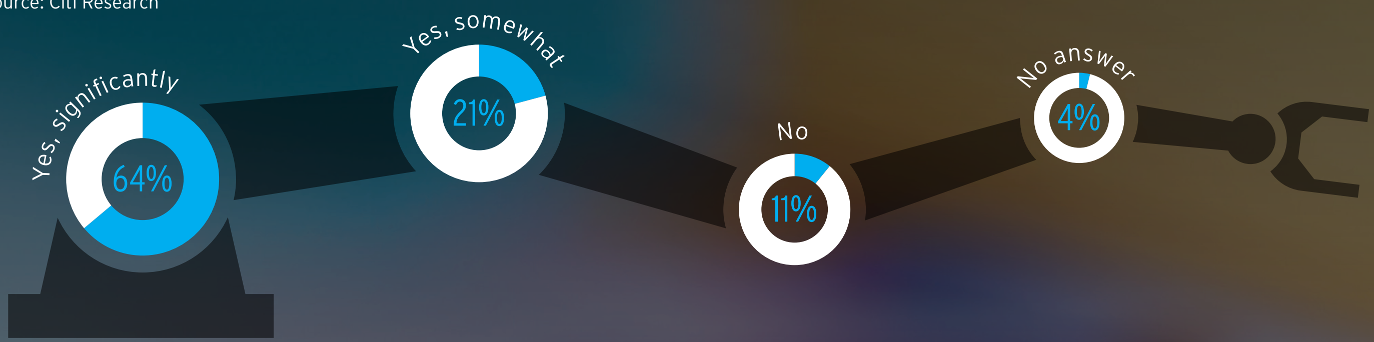
Accelerating technological change

What are the risks and what should we do to address them?

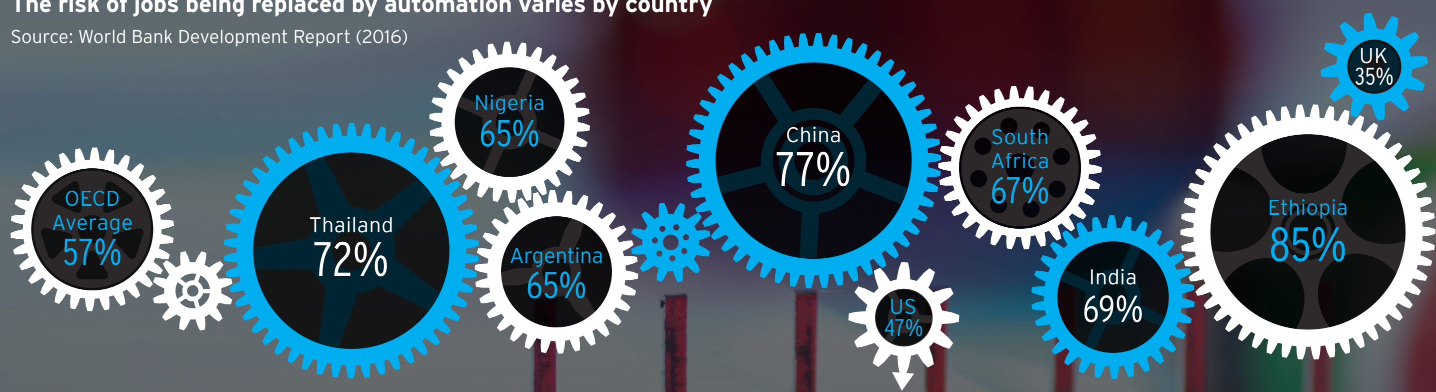
Do you believe that automation will lead to major challenges (e.g. on labour or wealth distribution)?

Source: Citi Research



The risk of jobs being replaced by automation varies by country

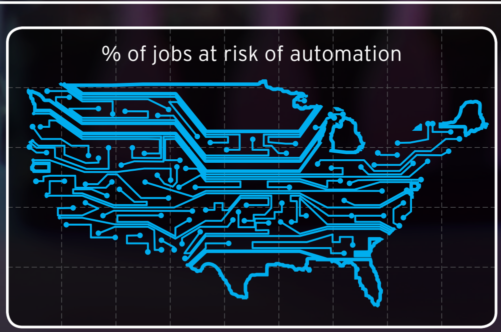
Source: World Bank Development Report (2016)



47% of US jobs are at risk from automation, but not all cities have the same job risk

Source: Berger, Frey and Osborne (2015)

Least at risk			Most at risk
Boston	38.40%	45.80%	Houston
Washington D.C.	38.40%	45.90%	Sacramento
Raleigh	39.70%	46.00%	Dayton
Baltimore	40.40%	47.00%	Los Angeles
New York	40.70%	47.10%	Harrisburg
Bridgeport	41.10%	47.10%	Oklahoma City
Toms River	41.20%	47.90%	Grand Rapids
Richmond	41.40%	48.40%	Reading
Minneapolis	41.40%	48.50%	Greensboro
Denver	41.50%	49.10%	Las Vegas
San Francisco	41.70%	53.80%	Fresno



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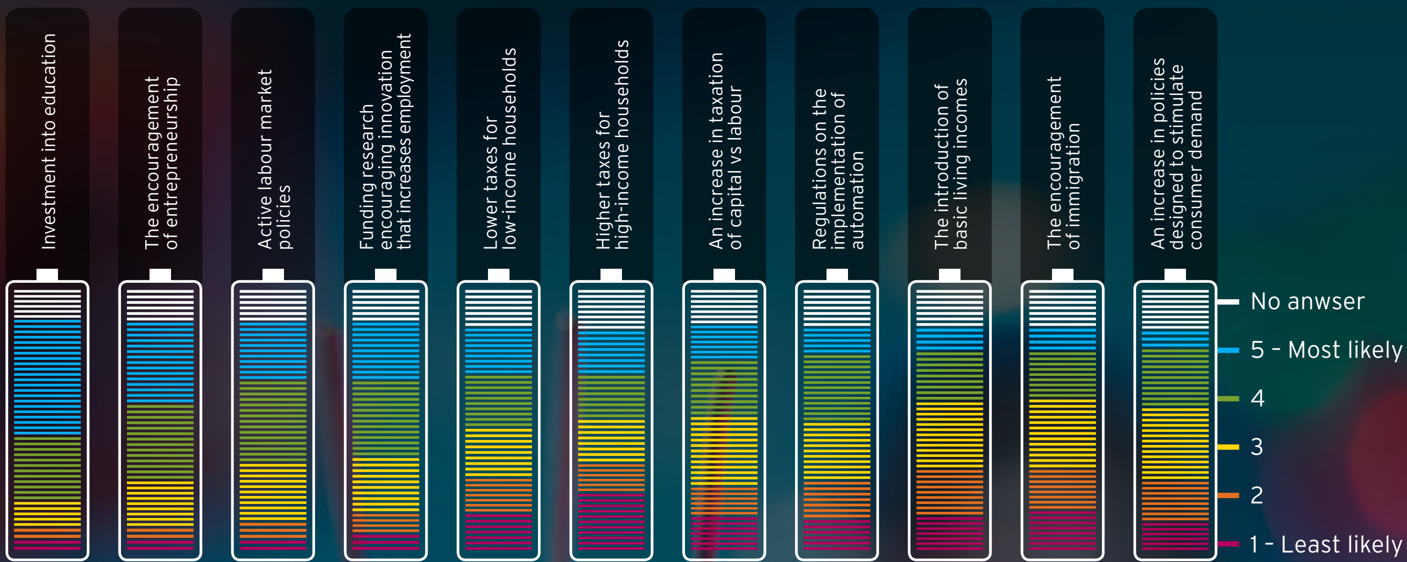
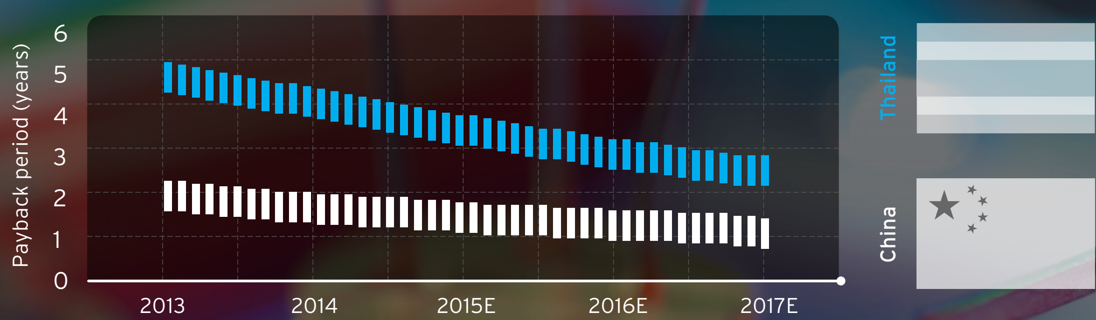
Which policies are likely to be most effective to offset the risks of automation impacting labour and wealth distribution?

Source: Citi Research



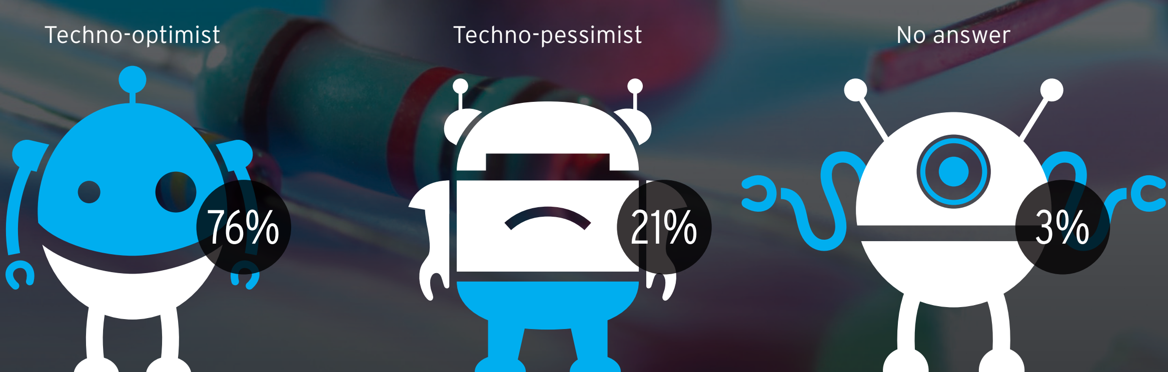
The payback period for robot systems are falling

Source: Citi Research



Boom or doom – techno-optimists vs techno-pessimists

Source: Citi Research



Contents

The Oxford Martin Programme on Technology and Employment is a new research programme established in January 2015 with support from Citi. It has been created to investigate the implications of a rapidly changing technological landscape for economies and societies. The programme will provide an in-depth understanding of how technology is transforming the economy, to help leaders create a successful transition into new ways of working in the 21st century. The programme is part of a wider research partnership between the Oxford Martin School and Citi, analysing some of the most pressing global challenges of the 21st Century.

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Executive Summary[1]

Robert Garlick
Global Equity Product Head, Citi

The debate over the impact of automation has been going on for several centuries, from the Luddites in 1811 to John Maynard Keynes' prediction of technological unemployment in the 1930's, to Stephen Hawking's recent warnings over Artificial Intelligence. Most recently, the topic has been chosen as the primary theme for the 2016 World Economic Forum meeting in Davos and the Financial Times awarded their 2015 Business Book of the Year to Martin Ford's 'The Rise of the Robots'.

In our February 2015 Citi GPS report *Technology At Work* we cited three primary reasons why we believed the impact of technology change on the economy was different this time: (1) the pace of change has accelerated; (2) the scope of technological change is increasing; and (3) unlike innovation in the past, the benefits of technological change are not being widely shared — real median wages have fallen behind growth in productivity and inequality has increased. In the report that follows, Citi again teams up with Carl Benedikt Frey and Michael Osborne from the Oxford Martin School to answer a number of the questions that were generated post the original report – on a range of topics from susceptibility to solutions.

There seems little doubt that the pace of technology change has accelerated. Whereas it took on average 119 years for the spindle to diffuse outside of Europe, the Internet spread across the globe in only 7 years. Going forward, as argued in the Citi GPS Disruptive Innovations III report, the cost of innovation continues to fall as cheaper smartphones will help bring 4 billion more people online. The next stage of connectivity will move from people to 'things' with Cisco estimating 500 billion devices will be connected by 2030, up from 13 billion in 2013. Increasing digital connectivity is fuelling a data boom, with data volume estimated to be doubling every 18 months, and computers are likely far better able to handle this volume than people. In 2015, the Edelman Trust Barometer found that more than half of the global "informed public" believe that the pace of development and change in business today is “too fast" with 70% citing technology as the driver of change. Over 96% of institutional clients who participated in Citi's survey on technology and work believe that automation will accelerate over the next five years vs. the previous five years.

Our work also suggests the scope of technology change is increasing. The big data revolution and improvements in machine learning algorithms means that more occupations can be replaced by technology, including tasks once thought quintessentially human such as navigating a car or deciphering handwriting. Carl Benedikt Frey and Michael Osborne's original study on employment[2] suggested 47% of US jobs were at risk of computerisation. In the chapter 'How Susceptible are Countries Worldwide?', we use data from the World Bank to show that the risks of automation are actually higher in many other countries —- for example in the OECD the data shows on average 57% of jobs are susceptible to automation, this number rises to 69% in India and 77% in China.

[1] The authors are very grateful to Andrew Pitt and Professor Ian Goldin for guidance in framing this report, as well as to Anushya Devendra at the Oxford Martin School for advice and editorial support

[2] Frey, C. B. and Osborne, M. A. (2013). The Future of Employment: How Susceptible are Jobs to Computerisation? Oxford Martin School Working Paper No. 7.

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Increased automation in low-wage countries, which have traditionally attracted manufacturing firms, could see them lose their cost advantage and potentially lose their ability of achieving rapid economic growth by shifting workers to factory jobs. In a survey that we conducted with institutional clients, 70% of our clients also believe that automation and the developments in 3D printing will encourage companies to move their manufacturing process closer to home — with North America gaining the biggest advantage from this development and China having the most to lose. A growing concern of 'premature deindustrialisation' in emerging and developing countries could require new growth models and a need to upskill the workforce.

Historically, new technologies have not only transformed regions, industries and companies, but also cities. In the US, the computer revolution has shifted the fortunes of many cities with some, such as San Francisco, experiencing rapid growth while others spiral towards bankruptcy. Cities that specialised in cognitive work gained a comparative advantage in new job creation, mirroring trends in population and wage growth over the same period. The expanding scope of automation in the 21st century may shift the fortunes of US cities once more, affecting a different set of cities than the ones historically impacted by computerisation and offshoring. Berger, Frey and Osborne in their most recent analysis[3] suggest that the exposure of cities in the US to future automation ranges from 54% in Fresno to 38% in Boston. The best way forward for cities to reduce their exposure to automation is to boost their technological dynamism and attract more skilled workers.

The chapter 'What Jobs do We See Ahead' emphasises the importance of acquiring skills for future employment. The European Centre for the Development of Vocational Training (Cedefop) estimated that in the EU nearly half of the new job opportunities will require highly skilled workers. Today's technology sectors have not provided the same opportunities, particularly for less educated workers, as the industries that preceded them.

This downward trend in new job creation in new technology industries is particularly evident starting in the Computer Revolution of the 1980s. For example, a study by Jeffery Lin[4] suggests that while about 8.2% of the US workforce shifted into new jobs during the 1980s which were associated with new technologies; during the 1990s this figured declined to 4.4%. Estimates by Thor Berger and Carl Benedikt Frey further suggest that less than 0.5% of the US workforce shifted into technology industries that emerged throughout the 2000s, including new industries such as online auctions, video and audio streaming, and web design.[5]

Despite these low numbers to date, a number of forecasts suggest good opportunities for future job creation in the information technology, industrial (i.e. robot engineers and technicians) and green sectors. In addition, the health sector is set to create the largest job openings, estimated at more than 4 million new jobs in the US from 2012 to 2022. This is not surprising given that many people in advanced countries are living for longer. This, together with a reduction in fertility rates, is changing the demographics in many advanced and some emerging nations

[3] Berger, T., Frey, C.B., Osborne, M., "Cities at Risk", Oxford Martin School Working Paper

[4] Lin, Jeffrey, "Technological Adaptation, Cities and New Work", Review of Economics & Statistics, May 2011, Vol. 93, No. 2, pp. 554-574. While the estimates by Lin are not necessarily directly comparable, they speak to further studies showing a downward trend in new job creation.

[5] Berger, T. and Frey, C.B., "Industrial Renewal in the 21st Century: Evidence from U.S. Cities", Regional Studies, forthcoming.

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(e.g. Japan and China) as described in the chapter ‘Demography vs Automation: Will We Run Out of Workers or Out of Jobs?’ In these countries, automation is seen as a possible solution to the changing demographics, however we conclude that automation could pose more risks to jobs than demographic changes.

Incremental productivity gains through automation should offset some of the demographic developments; however we are currently also facing a ‘productivity paradox’ as described in more detail in the chapter ‘Impact of Automation on Productivity’. If, as we believe, progress in technology is so rampant, we should see healthy productivity improvements. However across advanced economies, labour productivity growth has slowed from 4% in 1965-75, to about 2% from 1975-2005 and further lower to 1% from 2005-2014. Rather than taking the view that the 'low-hanging fruits' of innovation have been plucked, we see limitations in the current measurement of productivity, a lag effect in measurement and a wider distribution of productivity across firms and workers. We found that institutional clients agree — 95% of clients in our survey expect automation and technology will drive an increase in productivity growth to some degree over time (60% to a significant degree and 35% to a minor degree).

While we are positive on productivity, the chapter ‘Impact of Automation on Inflation’ argues that the rise in automation and technology is likely to reinforce the current low inflation environment due to increased uncertainty and the narrow distribution of productivity gains. There is also good reason to suspect that current price deflators and measures of inflation are overstated. We may already be observing some of these effects given the Phillips curve has flattened. To close output gaps, demand stimulus will continue to be needed, with monetary policy remaining accommodative and more creative in most advanced economies.

Whilst the first half of the report discusses the effect that automation could have on countries and cities and on productivity and inflation, in the second half of the report we look at changes that are already occurring in a number of industries. We highlight a number of sectors such as the food industry, call centres and factories that are already automating a number of different processes which could ultimately affect (or are already affecting) a number of different jobs. In addition, with the cost of robots expected to decrease over time, economic barriers to the expansion of automation in different sectors are expected to fall. This is discussed in detail in the chapter ‘What are the Barriers to Automation?’ which shows that payback periods for some industrial robots would reduce to 1.2 and 2.6 years in China and Thailand respectively by 2017. Barriers still exist for small and medium-sized enterprises (SME’s) however the flexibility and affordability of co-bots could offer appropriate solutions for these companies.

Looking at the macroeconomic and microeconomic effects of technological change, we find further evidence that the pace, scope and benefits of this change will be a challenge to societies. The remainder of the report focuses on potential policy options. The chapter ‘Response: Policy and Job Risk from Automation’ details active labour market policies which could help people find jobs: from training, to earned income tax credits (EITCs) or lowering tax wedges, to incentives to support self-employment. We believe EITCs are more appropriate than current moves to raise minimum wages given the latter could lead to higher unemployment. If self-employment is becoming a new norm, this also has policy implications — 34% of the total US workforce, or 53 million people, are currently freelancers (see Figure 34). Some argue a basic income or benefits (healthcare, housing, pensions) should be provided, yet we fear changes in taxation that may be required to pay for solutions will impede an effective policy response. At the same time, local, regional,

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and state governments could face challenges in maintaining tax revenues from income disparities and from the difficulties in effectively taxing the digital economy.

With technological change a key driver for the demand of both the level and type of skills needed ahead, it is no surprise that the number one policy suggestion in our client survey was for increased investment in education. Although it is clear that more information & communication technology (ICT) skills will be needed, significant differences currently exist in IT skills between countries, with the US and the UK lagging behind other countries on some measures. While many argue science, technology, engineering & math (STEM) skills are needed, intermediate level skills in STEM seem to be a riskier educational investment. Non-cognitive skills can be increasingly important, but malleability of these skills should not be assumed. These factors could complicate the ability of education to adapt to the pace and scope of technological change described above.

With careers likely to be more disrupted than at any other point in the past, individuals should anticipate the need to retrain in the future. A talent mismatch already exists in many countries, with many well-educated workers finding employment in lower-skilled jobs. To combat this, greater coordination will be needed between the educational, training and employment sectors.

One of the paths involving the least commitment for policy makers to adapt to accelerated technological change would be to look to shorter working weeks. This is starting to take place in some countries; for example Sweden is moving to a standard 6 hour week day with the aim of improving productivity. Annual hours worked per person have already fallen by 35% in France from 1950-2014 and by 10% in the US. Leisure time in the US has increased by 6-8 hours per week between 1965-2003 for men and 4-8 hours for women. When we add in longer lives and retirements, cumulative lifetime leisure time has increased 26% from the 1930s. Could automation increase leisure time further whilst also maintaining a good standard of living for everyone? The risk is that this increased leisure time may only become a reality for the under-employed or unemployed.

When we polled opinions on many of these issues in the third quarter of 2015, 85% of respondents felt automation posed a challenge to societies and policymakers, of which 64% said it was a major challenge. However, and encouragingly, 76% also said they were techno-optimists on the outlook for productivity and profits, with policy adapting to share increasing abundance. Only 21% were techno-pessimists on the outlook for growth, employment, inequality, and disruption of company profit pools. We agree with the optimists that the opportunities for increased innovation and productivity can be very beneficial, providing policy, education and workers can adapt to the challenges faced from accelerating technological change.

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How Susceptible are Countries Worldwide? Jobs at Risk of Automation

Highlights

- Advances in technology are now making a broader range of non-routine tasks automatable, with computers mainly substituting for low-income low-skill workers over the next decades.
- Building on Frey and Osborne's original work showing 47% of the US workforce is at risk of automation as a result of these trends, recent data from the World Bank suggests the risks are higher in many other countries. For example, their estimates suggest that the equivalent figures for China and India are 77% and 69%, respectively.
- Although there has been convergence in adoption lags of technology between rich and poor countries, divergence in long-run penetration rates once technologies have been adopted, explain divergent income patterns between the Western and non-Western world since the Industrial Revolution.
- A growing concern of 'premature industrialisation' in emerging and developing countries could require new growth models and a need to upskill workforces.

Carl Benedikt Frey
Co-Director for the Oxford Martin Programme on Technology and Employment and Oxford Martin Citi Fellow

In the past, the comparative advantage of computers relative to human workers has been confined to routine rule-based activities that can easily be specified in computer code. Following recent advances in technology, however, a broader range of non-routine tasks are now equally automatable. The expanding scope of automation mainly relates to advances in Machine Learning technology, including Data Mining, Machine Vision, Computational Statistics and other sub-fields of Artificial Intelligence (AI), turning a wide range of knowledge work into well-defined problems. This is, in turn, made possible by the provision of relevant data. For example, companies such as Work Fusion sell software to automate non-routine tasks, previously performed by office workers. Specifically, the software divides the job into smaller tasks, automates the routine work and then recruits freelance workers through crowdsourcing platforms to perform the non-routine work. As the software monitors the workers it learns from them, meaning that over time it can automate more of the non-routine tasks. In other words, the freelance workers train the system to replace them. Similarly, a growing body of digitalised translated text allows sophisticated software, such as Google Translate, to benchmark and improve the performance of translation algorithms. In healthcare, IBM's Watson computer now provides automated chronic care and cancer treatment diagnostics, drawing upon piles of data that a doctor would not be able to process, including information from more than 1.5 million patient records and clinical trials, as well as 2 million pages of text from medical journals.

Big data is the key driver behind the expanding scope of automation

Connected devices, advances in user interfaces, and cheaper and better sensors are all drivers of the big data revolution. For example, implantable monitors, such as pulmonary artery pressure measurement systems, enable significant reductions in heart failure hospitalisation. These devices rely upon sophisticated machine-to-machine communication to spot and signal potential warning signs. Advances in speech recognition also allow computer-controlled technologies to respond directly to human actions and requests: SmartAction, a provider of call automation services is able to realise cost savings of 60 to 80 percent over a traditional call centre. Thus, in short, machine learning algorithms are now, in many cases, better at basic

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knowledge work than human workers. Although we do not know what the impact on labour markets of these developments will be, some estimates suggest that algorithms could displace around 140 million knowledge workers globally.[6]

The big data provided by improved sensors also allow engineers to overcome a wide range of engineering bottlenecks that have hindered robotic development in the past. Three-dimensional maps of road networks, for example, have been a crucial enabler of autonomous vehicle navigation. This is not least illustrated by Google's use of vast datasets for its driverless cars. Meanwhile, more advanced robots are gaining enhanced sensors and manipulators, allowing them to perform non-routine manual tasks. A well-known example is Baxter — a robot that requires no programming. Instead Baxter is able to memorise new working patterns as a human worker guides the robot arms through the motions needed to complete a task. Its physical flexibility is also enhanced by different attachments that can be installed on its arms, allowing Baxter to perform a much broader scope of work tasks.

Similarly, surgical robots have become significantly more flexible and with a greater range of motion now perform more operations, while commercial service robots are now able to perform more complex tasks in elderly care, food preparation, and cleaning. In Japan, some hotels already use robots for check-in and to guide guests to their rooms. The robotic receptionist can also speak different languages depending on the preferences of the guest. Thus, in short, while sophisticated algorithms for big data can perform more knowledge work, the potential scope for the automation of physical labour is expanding in tandem.

The Engineering Bottlenecks to Automation

As the potential scope of automation is expanding, where will human workers still hold the comparative advantage?

Creative intelligence, social intelligence, and perception and manipulation are three potential bottlenecks to expanding the scope of automation

Importantly, the expanding scope of automation is not suggestive of the end of work, as has been proclaimed by several commentators and scholars. This is because despite significant advances in machine learning and mobile robotics, several engineering bottlenecks to automation remain. Specifically, Frey and Osborne identify three key bottlenecks: creative intelligence, social intelligence, as well as perception and manipulation. In this section, we briefly describe these bottlenecks, each in turn.

Creative work, involving the development of novel ideas and artifacts — requiring the ability to achieve desired goals without explicit instruction — is difficult to automate by definition as computerisation usually requires some explicit instruction. To be sure, there are humanoid robots that can interpret music and make improvisations on the part of other performers, and drawing programs, such as AARON, have generated thousands of drawings being exhibited in galleries worldwide. Nevertheless, human workers still maintain the comparative advantage in creative work as replicating the kind of implicit reservoirs of knowledge and judgment drawn upon by human creators is extremely difficult, largely because we find it difficult to define creativity ourselves. Thus, although it is clearly possible to design an algorithm that can churn out an endless sequence of paintings, it is difficult to teach the algorithm to differentiate between the emotionally powerful and the rest.

[6] MGI (2013), "Disruptive technologies: Advances that will transform life, business, and the global economy", McKinsey Global Institute.

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The reason tasks requiring social intelligence are difficult to automate is largely similar: social intelligence requires a wealth of tacit knowledge, about social and cultural contexts, and thus involve a wider range of subtleties that are difficult to specify and often give rise to misinterpretations, even among humans. The state-of-the-art of automation technology in the context of social interactions is best captured by Eugene Goostman, a software chatterbot, managing to convince a third of judges on a panel that it was human based on five minutes of text communication. Nevertheless, it did so by pretending to be a 13-year old boy using English as a second language. Thus, more challenging forms of social intelligence, including coordination, teaching, negotiation and mentoring, is today far from automatable.

Michael Osborne
Co-Director for the Oxford Martin Programme on Technology and Employment and Associate Professor in Machine Learning at the University of Oxford

Which Skills Are Least Automatable?

Technology is leading to increasing automation, but not all work skills are equally replaceable. In recent work (by Linda Perkio and Michael A Osborne), we make use of advanced machine learning techniques to highlight which job characteristics are most likely to be associated with that job being computerised. Our findings reinforce the conclusions found in the previous work of Frey & Osborne that originality and social intelligence are the most profound bottlenecks to automation.

Our analysis is built on the 2010 edition of O⋆NET, a service developed for the US Department of Labor. O⋆NET provides a "standardised, measurable set of variables", comprising 277 quantitative descriptions of the skill requirements for each of 702 detailed occupations in the US. O⋆NET was originally collected by labour market analysts, but has been subsequently updated and revised with the use of surveys of both incumbent workers and experts, enabling it to reflect the changing nature of job tasks. We consider 67 of the 277 variables: we selected those that provide data for all or most occupations, and excluded other variables with much missing data. These variables capture a diverse range of different skills, and include examples that typify social and creative bottlenecks. We list the names and definitions of some pertinent example variables below.

- Originality: "The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem."
- Service Orientation: "Actively looking for ways to help people."
- Manual Dexterity: "The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects."
- Gross Body Coordination: "The ability to coordinate the movement of your arms, legs, and torso together when the whole body is in motion."

Each variable gives, for each occupation, an integer between 0 and 100, which quantifies the level at which a certain skill or ability is required. For example, for the attribute Manual Dexterity, a low level corresponds to "Screw a light bulb into a light socket"; medium level is exemplified by "Pack oranges in crates as quickly as possible"; high level is described as "Perform open-heart surgery with surgical instruments".

To make the link to automatability, Frey and Osborne (2013) identified a training set of 70 occupations using these O⋆NET variables, along with O⋆NET's open-ended descriptions of the tasks performed by each occupation. This training set described the occupations that were most emblematically either automatable (e.g. Data Entry Keyers) or non-automatable (e.g. Clergy). Specifically, occupations were chosen for which the question: "Can the tasks of this job be sufficiently specified, conditional on the availability of big data, to be performed by state of the art computer-controlled equipment?" could be most confidently answered.

We next proceeded to use a probabilistic classification algorithm to learn the relationships between the labels of automatability and the O⋆NET variables. We additionally performed feature selection to choose the variables that were most informative in predicting the labels. Those labels that were chosen can be thought of as those that are most strongly correlated with automatability: high scores on these variables are likely to render an occupation secure from automation. Crucially, a variable's significance cannot be assessed in isolation: even if poor individually, it may contribute in conjunction with another. For example, it is clear that while Gross Body Coordination is relatively uninformative on its own, it can substantially assist classification if Originality is also available. For this reason, we used a non-linear classifier that is able to benefit from these correlations. Multiple methods of classification and feature selection were trialled: our confidence in our conclusions is reinforced by the consistency in their results.

Firstly, Originality was by some way the most important individual feature. This supports the argument that human creativity is the most difficult human faculty to automate. It is certainly possible to design an algorithm that can churn out an endless sequence of paintings, but it is still difficult to teach such an algorithm the difference between the emotionally powerful and the dreck. In a study with UK charity Nesta, Frey and Osborne (2014) found, for both the UK and the US, that almost 90% of creative jobs are at low or no risk of automation.

Secondly, the best pair of variables was the combination of Originality with Service Orientation. Recall that we listed social intelligence as the second bottleneck to automation. Social intelligence is such a bottleneck because subtle interactions with other people, such as the anticipation of others' needs that Service Orientation embodies, draw upon implicit reservoirs of knowledge and judgement that are difficult to represent explicitly in code. Our conclusion is hence that a job is particularly well-insulated from automation if it combines high originality with a high requirement for active interaction with other people.

The challenge of automating tasks requiring perception and manipulation skills can more fully be described as the challenge of perceiving and interacting with unstructured physical environments. Consider, for example, the task of cleaning a home, and associated sub-tasks such as the identification of dirty objects. Understanding that a plant pot containing a plant is not dirty, while similar dirt on a floor needs to be cleaned is intuitive to most humans, but difficult to grasp for a robot. In addition to the challenge of perceiving and distinguishing between various objects, a generalist robot that is able to manipulate all sorts of irregular objects contained in a home is difficult. For example, manipulating an object with some understanding of its material characteristics, to make sure that it is not damaged in the process, requires a deep understanding which is difficult to reproduce within software. Thus, in time-varying, heterogeneous environments, the tacit knowledge and pliable hands possessed by humans are likely to remain superior to robotic labour for some time.

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Impacts on the US Labour Market

So how significant will these developments be in terms of their employment impact? According to research by Carl Benedikt Frey and Michael Osborne, 47 percent of the US workforce is at risk of automation as a result of these trends.[7] This does not necessarily imply that all of these jobs in fact will be automated. A job is considered to be "exposed to automation" or "automatable" if the tasks it entails allows the work to be performed by a computer, even if a job is not actually automated. Although many cashiers have been displaced by self-service technology, for example, there are still more than 3 million cashiers in employment in the United States.

Jobs in transportation and logistics as well as office and administration support are among the most susceptible to automation

A wide range of jobs are exposed to recent trends in technology. Jobs in transportation, logistics, as well as office and administrative support, are among the most susceptible. As autonomous vehicles are already being developed and augmenting cars with advanced sensors is becoming more cost-effective, this prediction is seemingly accurate. Algorithms for big data are similarly already capable of displacing human workers in most tasks that involve the storing or processing of information, making a substantial share of office and administrative support jobs automatable.

The pace of displacement in service occupations is also expected to increase

In the light of the recent expansion of jobs in non-tradable services, however, the most interesting finding is perhaps that many service occupations, where the most job growth has occurred over the past decades, are now susceptible to computerisation. Yet there is already some evidence that this trend is underway. According to some estimates, the market for personal and household service robots is now experiencing annual growth rates of around 20 percent.[8] As machines will get better at performing tasks involving mobility and dexterity over time, the pace of displacement in service occupations is likely to increase even further.

Low-skilled jobs are the ones that are most susceptible to automation in the future

Nevertheless, around 33% of US employment remains at low risk of automation, while another 19% is categorised at medium risk. Jobs at the low risk of automation consist of generalist occupations requiring knowledge of human heuristics, and occupations involving the development of novel ideas and artifacts. In other words, the common denominator for low risk jobs is that they are intensive in social and creative skills. Most management, business, and finance occupations, which are intensive in work requiring social skills, are largely confined to the low-risk category. This is also true of most occupations in arts and media, as well as jobs in education and healthcare. The low susceptibility of engineering and science occupations to computerisation, on the other hand, is largely due to the high degree of creativity skills they require. Finally, while there is plenty of anecdotal evidence about knowledge work becoming increasingly automated, low- skilled jobs are the ones that are most susceptible to automation. In other words, Frey and Osborne predict a shift from the computerisation of middle-income jobs to computers mainly substituting for low-income, low-skill workers over the next decades.

Developing Countries at Risk

As emerging technologies increasingly substitute for low-skilled workers, what are the impacts on developing economies likely to be?

[7] Frey, C. B. and Osborne, M. A. (2013). The Future of Employment: How Susceptible are Jobs to Computerisation? Oxford Martin School Working Paper No. 7.
[8] MGI (2013), "Disruptive technologies: Advances that will transform life, business, and the global economy", McKinsey Global Institute.

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Throughout the 20th century, the adoption of new technology has been an essential component of countries development strategies. The way the Industrial Revolution provided the foundation of sustained growth in the West, industrialisation has permitted a number of emerging economies to catch up, including Singapore, South Korea and Taiwan. These remarkable growth stories were achieved by shifting workers from labour-intensive production to more capital-intensive products such as motor vehicles, and more recently to human capital-intensive activities such as information and communication technology. China has similarly managed the transition to capital-intensive products, and with a per capita income of about $8,280, it has now become a middle-income country. Sometimes this phase is referred to as a middle-income trap, as history suggests that countries entering the middle-income bracket often come to experience stagnant growth.

The Great Divergence

The divergence in penetration rates of technology adoption can account for 82% of the increase in income gap across the globe

Despite a number of non-Western economies having successfully managed the industrialisation process, income inequalities across the globe have grown significantly since the Industrial Revolution. In 1820, incomes in Western countries were 1.9 times the average of incomes in the non-Western world.[9] Over the course of the next 180 years, the West experienced a "Great Divergence" from the rest: by 2000, their per capita income was 7.2 times the average of non-Western countries. One of the main reasons for this divergence is that while emerging economies have become better at adopting new technologies, they are getting worse at putting them into widespread use. For example, in a recent study, Diego Comin and Martí Mestieri Ferrer asked the question: if technology has arrived everywhere, why has income diverged? Doing so, they show that lags in technology adoption across countries have declined significantly over the past two centuries, and this decline has recently accelerated: while it took 131 years for steam and motor ships to reach Indonesia, after their initial adoption in Britain, it took 11 years for the computer to diffuse from the United States to Vietnam. By contrast, however, the degree to which new technologies diffuse across the population after their initial adoption has widened over the same period. Thus, in short, although there has been convergence in adoption lags between rich and poor countries, there has also been divergence in long-run penetration rates once technologies are adopted, explaining divergent income patterns since the Industrial Revolution: the divergence in penetration rates can account for 82 percent of the increase in the income gap since 1820.[10]

'Premature Deindustrialisation'

Although a number of Asian economies have managed to catch up over recent decades, the developing world as a whole has shown little sign of closing the income gap. One exception, however, is in manufacturing industries, which have experienced unconditional convergence in labour productivity across countries.[11] Because manufacturing companies produce goods that are traded on international markets, and thus operate under constant competitive threat from abroad, these firms constantly need to improve production processes to remain competitive. Furthermore, since manufacturing processes are not subject to external conditions, such as soil and weather, in the same way as agriculture, they are easier to standardise and automate, and therefore more similar across geographies.

[9] Maddison, A. (2004), The World Economy: Historical Statistics, OECD.
[10] Comin, D.A. and Ferrer, M.M. (2013), If Technology Has Arrived Everywhere, Why has Income Diverged? Working Paper No. 19010.
[11] Rodrik, D. (2015), Unconditional Convergence in Manufacturing, Quarterly Journal of Economics, Volume 128, issue 1, pp. 165-204.

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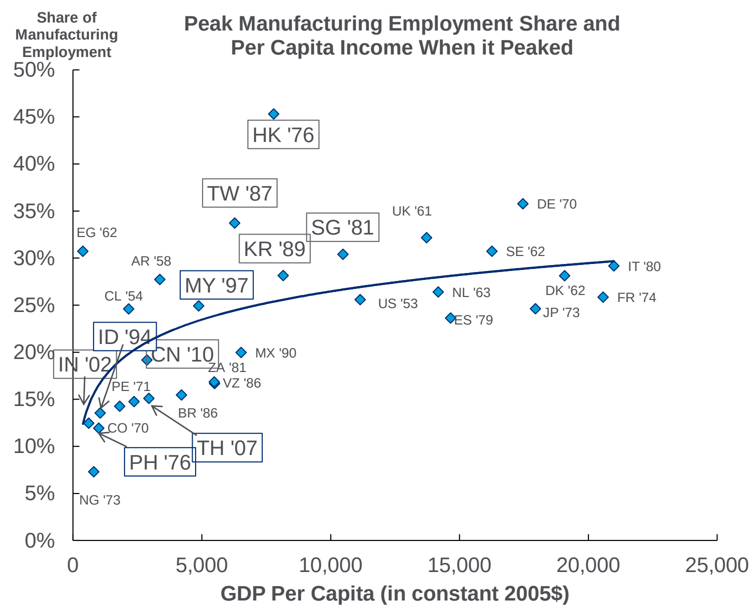
As a result, manufacturing is becoming less labour-intensive in the emerging and developing world also, contributing to a growing concern over "premature deindustrialisation." For example, a recent study by Dani Rodrik has persuasively shown that over the course of the 20th century, peak manufacturing employment has declined among emerging economies.[12] Manufacturing employment in the United Kingdom, for example, peaked at 45% of total employment just before World War I. Today's emerging economies, in contrast, including Brazil and India, have already seen manufacturing employment peak at no more than 15% (See Figure 1). Furthermore, in Africa, a recent report by the UN's Economic Commission for Africa (UNECA) estimates that between 1980 and 2013 the manufacturing sector's contribution to total economic activity on the continent declined from 12% to 11%. In most of sub-Saharan Africa, the manufacturing share of output has persistently declined over the past 25 years. The share of jobs in manufacturing is even smaller: just over 6% of all jobs. This figure barely changed over the course of the three decades leading up to 2008, while manufacturing employment in Asia grew from 11% to 16% over the same period.

Figure 1. Peak Manufacturing Employment Share and GDP per Capita When It Peaked



Source: GGDC-10 Sector database, World Bank Development Indicators, Citi Research

Manufacturing processes are more automated today than in past

The reason for this is that manufacturing processes, also in low- and middle-income countries, are more automated today than in the past. A recent report by Citi and the Oxford Martin School shows that China, has already replaced the US as the largest market for industrial automation. This is indeed part of the country's development strategy: in China's 12th Five Year Plan, workforce automation recently emerged as a strategic area, seen as essential to maintain the country's competitiveness in manufacturing, and potentially prevent production from shifting to low-income destinations where labour is cheaper.

Some emerging economies have, however, also experienced declines in manufacturing output which cannot be explained by production processes being increasingly automated. Rodrik (2015) thus argues that globalisation provides an alternative, albeit complementary, explanation for countries experiencing premature

[12] Rodrick, D. (2013), "Premature Deindustrialization", NBER Working Papers 20935, National Bureau of Economic Research, Inc.

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deindustrialisation: as countries with a comparative disadvantage in manufacturing become exposed to international trade they start to import deindustrialisation. Crucially, while many 20th century technologies, including the telephone, the container ship, and the computer, contributed to the surge in international trade by allowing companies to shift production to locations with an abundance of cheap labour, recent developments in robotics and additive manufacturing now allow firms in advanced economies to locate production closer to domestic markets in automated factories. For example, despite a secular decline in its share of manufacturing employment, the US manufacturing output share has remained roughly constant. In other words, although the US has not produced many new jobs in production, as computer technologies provide an increasingly cheap substitute for workers, it remains a competitive manufacturing location. Even in middle-income countries, such as China, industrial automation provides an increasingly cheap substitute for labour. Recent estimates by Citi Research shows the payback period for industrial robots in China is now less than two years. (This is discussed in more detail in the chapter on barriers to automation.)

Due to an increase in automation in manufacturing, low income countries will not achieve rapid growth by shifting workers from agriculture to factory jobs

In the light of these technological developments, industrialisation is likely to yield substantially less manufacturing employment in the next generation of emerging economies than in the countries preceding them. Hence, it will be increasingly difficult for African and South American manufacturing firms to create jobs in the same numbers that Asian companies have done. In other words, today's low-income countries will not have the same possibility of achieving rapid growth by shifting workers from farms to higher-paying factory jobs.

The susceptibility to automation across developing countries ranges from 55% in Uzbekistan to 85% in Ethiopia

In the absence of export-led manufacturing growth as a path to prosperity, developing countries will need to search for new growth models. Service-led growth constitutes one option, but many low-skill services are now becoming equally automatable. Building on the work of Frey and Osborne, a recent World Bank Report shows that developing countries are highly susceptible to the expanding scope of automation, even relative to advanced economies where labour costs are high. As shown in Figure 2, the susceptibility to automation across the developing world ranges from 55% in Uzbekistan, to 85% in Ethiopia, with a substantial share of the workforce being at high risk of automation in countries such as China and India (77 percent and 69 percent, respectively). These figures, in turn, can be compared to the OECD average, which the World Bank estimates at 57 percent. Furthermore, countries with a higher share of their workforce "at risk" typically exhibit lower levels of GDP per capita, as highlighted by Figure 3. Thus, there are reasons to be concerned about the future of income convergence, as low-income countries are relatively vulnerable to automation.

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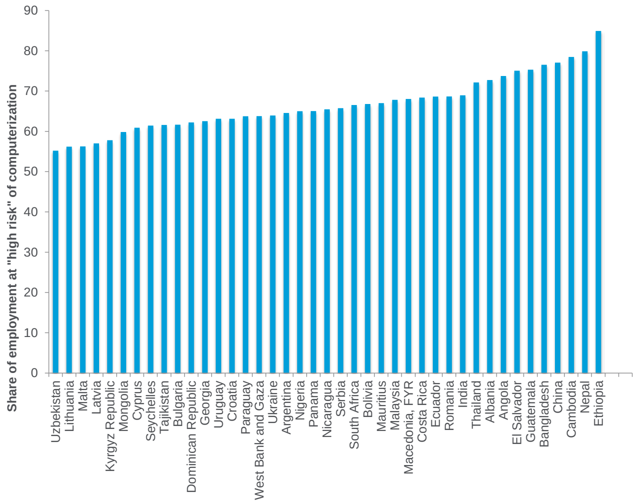
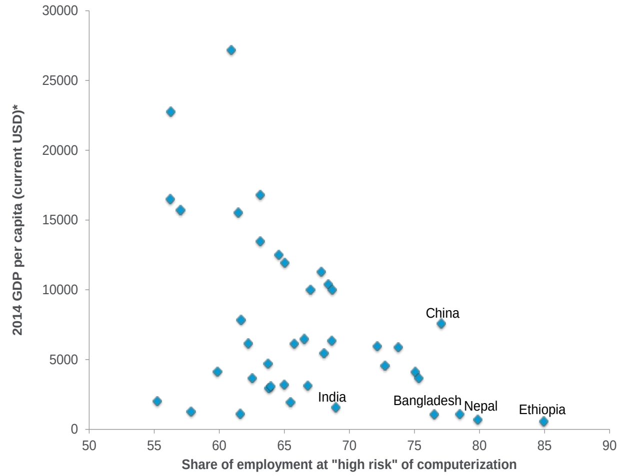
Figure 2. Developing Countries Susceptibility to Automation



Source: World Bank Development Report 2016; based on Frey and Osborne (2013) methodology, Citi Research

Figure 3. Countries Susceptibility to Automation is Negatively Associated with their GDP per Capita



Source: World Bank Development Report 2016; World Bank national accounts data. Note: For Angola and Malta 2013 GDP per capita figures were used, Citi Research

A crucial reason why developing countries are more susceptible to automation relative to high-income countries however is that while many jobs are "automatable" in the developing world, automating them is not yet economically feasible due to the abundance of cheap labour. As shown by a number of studies, labour-saving inventions may only be adopted if the access to cheap labour is scarce or prices of capital are relatively high.[13] For example, case study evidence suggests that mechanisation in 18th century cotton production initially only occurred in Britain because wage levels were much higher relative to prices of capital than in other countries.[14] In addition, recent empirical research reveals a causal relationship between the access to cheap labour and mechanisation in agricultural production, in terms of sustained economic transition towards increased mechanisation in areas characterised by low-wage worker out-migration.

The best hope for developing and emerging nations is to upskill their workforce

Thus, in essence, while the potential labour market disruption associated with the expanding scope of automation is likely to affect the developing world later than advanced economies, it may be potentially more disruptive in countries with little consumer demand and limited social safety nets. Developing countries would thus do well to plan ahead of such an event. This means investing more in education and boosting domestic demand. Because skilled jobs are substantially less susceptible to automation, the best hope for developing and emerging economies alike is to upskill their workforce. That has indeed also been the lesson from regional development patterns in advanced economies. For example, while Ford and General Motors have some of the most advanced production facilities in the world, the city of Detroit has failed to create employment opportunities in new occupations and industries. By contrast, the cities that have successfully managed the renewal process, including New York, Boston and San Francisco, have done so by educating and attracting pools of talent. We examine the implications of the expanding scope of automation for regional development in a later chapter but first we look at how automation is changing the trend of offshoring to low cost regions.

[13] Habakkuk, Hrothgar John (1962), American and British technology in the nineteenth century: The search for labour-saving inventions, Cambridge University Press.
[14] Allen, Robert C. (2009b), "The Industrial Revolution in Miniature: The Spinning Jenny in Britain, France and India", The Journal of Economic History, 63(04): 901-927.

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Does Automation Change the Trend of Offshoring to Low Cost Regions?

Highlights

- After a period of Global Value Chain proliferation, there are clear signs that the pace of goods production fragmentation across borders is slowing.
- Seventy percent of clients surveyed believe automation and the developments in 3D printing will encourage companies to move their manufacturing closer to home. North America is seen as having the most to gain from this trend, while China has the most to lose.
- As technology advances, emerging market (EM) countries need to diversify and find ways to move up the value-added chain to stay competitive. They must also boost service productivity growth.

ICT Revolution and 'Second Unbundling' in Global Value Chains

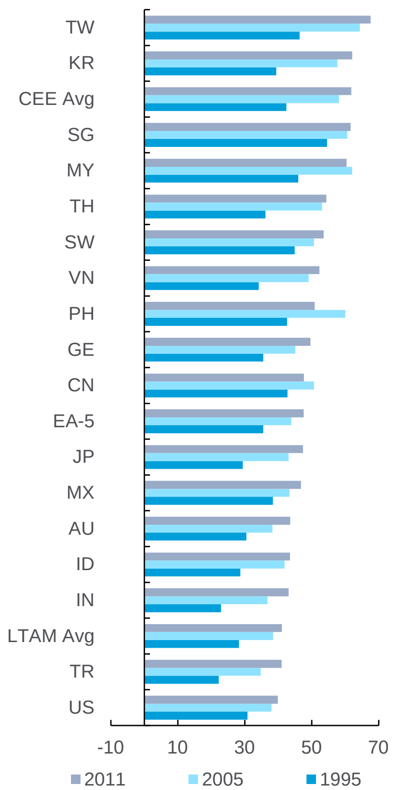
Johanna Chua
Head of Asia Pacific Economics and Market Analysis, Citi

The scope and nature of globalisation have changed dramatically over human history. The first major wave of globalisation starting in the latter half of the 19th century was triggered by significant reduction in transportation costs (steam engine, railroads, 'industrial revolution'), which facilitated the geographic separation between where goods are produced and where they are consumed, alongside the transfer of ideas. Further technological advancements in transport in the last century, including containerisation and air cargo, plus the entry of major economies like China and India into the global trading system, allowed this process to accelerate. This is what Baldwin (2006) calls the 'first unbundling'.[15]

However, a second and different type of 'unbundling' (overlapping with the first one) took place in recent decades with the ICT revolution that helped pave the way for proliferation of Global Value Chains (GVC), or the fragmentation of production across borders**.** Rapidly declining cost and increased power of computing and advances in communication technology have made it increasingly economical to unbundle various tasks depending on comparative advantages, with much improved ability to coordinate and monitor production across large distances. Goods production became increasingly fragmented into stages spread out across borders — but beyond this, even the ability to offshore services has risen rapidly over the last two decades. Global value chain linkages can be decomposed into two types: (1) '*backward linkages'*, wherein domestic firms use foreign intermediate value added as inputs for its exports; and,(2) '*forward linkages'*, wherein a country's exports are inputs to other countries' exports, the sum of which we use as a measure of GVC participation rate, shown on Figure 4.

[15] Baldwin, Richard, (2006), "Globalisation: The Great Unbundling(s)". *Economic Council of Finland,* 2006.

Figure 4. GVC Participation Rate (%)



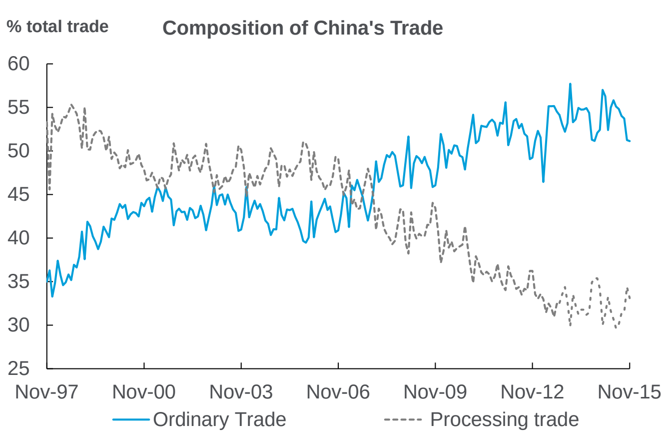
Source: Source: OECD TiVA, Citi Research

Note: *EA5- Average of France, Germany, Italy, Netherlands & Spain

GVC trade expanded significantly since the 1990s and we think advancing technology, plus trade and foreign direct investment (FDI) liberalisation and improved logistics infrastructure, facilitated this. Supply chain fragmentation will mean goods will cross borders many times to undergo various phases of 'processing' until they reach their final destination. This helps explain why, in previous decades, (goods) trade elasticity was very high relative to income. East Asia as well as parts of Europe were very active in the global supply chain, as can be seen by their relatively high and rapidly increasing GVC participation rates from 1995 to 2005 (Figure 4). We believe such trade engagement was a significant driver of productivity-driven growth, generating technology/knowledge transfer, employment and higher incomes in East Asia.

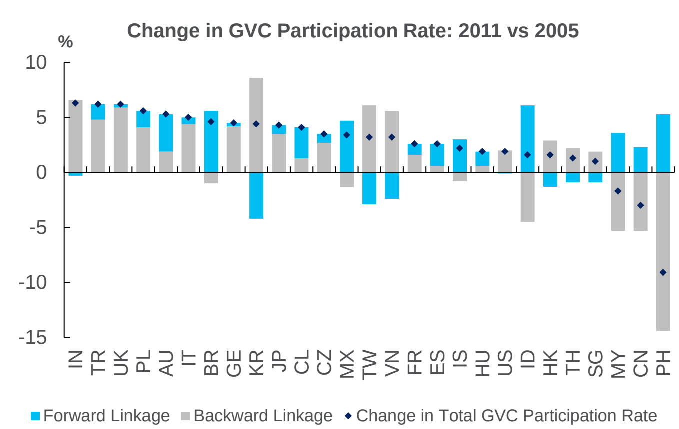
However, there are now clear signs that the pace of goods production fragmentation across borders is slowing, a trend even preceding the Great Financial Crisis (GFC). We view this as an important structural factor compounded by cyclical weakness that explains why global trade growth has been so subdued relative to GDP growth. Constantinescu et al. (2015) estimate that the elasticity of trade to income in the 2000s halved relative to the 1990s.[16] We think China is at the forefront of this dynamic, given that more of its supply chain is shifting domestically as seen by the declining share of processing trade to global trade (Figure 5). China's growing market size, technology upgrading, and more recently, significant excess capacity in many upstream industries, has enabled it to source more of its intermediate inputs onshore (i.e. 'backward linkages' has fallen more over the years and likely continues to do so; see Figure 6).

Figure 5. China- Share of Processing Trade has been Coming Off



Source: Citi Research

Figure 6. China is Sourcing Less of its Imported Upstream Inputs into its Production (i.e. decline in 'backward linkages')



Source: Citi Research

[16] Constantinescu, C. et al. (2015),"The Global Trade Slowdown: Cyclical or Structural?" *IMF, No. 15/6,* 2015.

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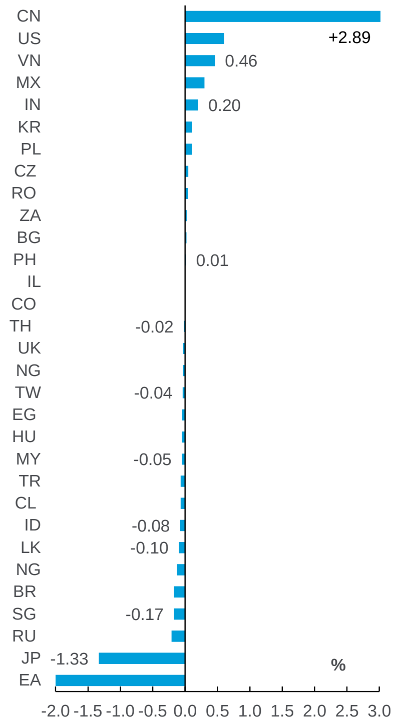
Figure 7. Change in Export Market in Latest 12 months up to May 2015 vs. 2010



Source: IMF Direction of Trade, Haver, Citi Research

Thus, even if we see some global cyclical recovery, world trade growth may remain more subdued than previously. We look closely at how domestic value added (DVA) in '*manufactured goods*' exports (to remove distortions from the commodities trade) have evolved in Figure 11. Unfortunately, data are released with a significant lag.[17] In the last several years, DVA of manufactured goods exports have grown in China, the Philippines, Singapore, and Malaysia. For parts of industrialised Asia (KR, TW, JP), sadly even for mid-income Thailand, and parts of EM (Turkey), they are not only losing goods export market share (except for Korea) but also face diminishing DVA, which could be signs of growing competitiveness challenges.

Figure 8. Manufactured Goods Exports – Estimation of Domestic Value Added (DVA)

Source: OECD TiVA, Citi Research

[17] Detailed OECD TiVA (Trade in Value Added) data for 2011 was only released in Oct 2015.

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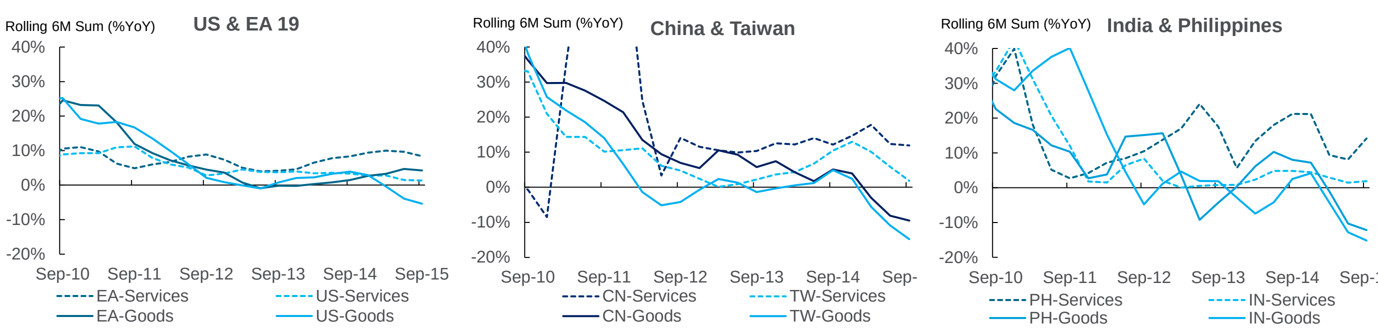
Figure 9. Global Ranking of Service Offshoring or Outsourcing Destinations

	Tholons Top Outsourcing Destination (2015)	Towers Watson Services Offshore Ranking (2014)	AT Kearney Global Services Location Index (2014)	Average Rank
India	1	2	1	1.33
China	4	1	2	2.33
Philippines	2	4	7	4.33
Malaysia	10	9	3	7.33
Vietnam	9	3	12	8.00
Brazil	12	5	8	8.33
Poland	3	16	11	10.00
Mexico	21	11	4	12.00
Sri Lanka	8	**	16	12.00
Indonesia	30	6	5	13.67
Chile	15	19	13	15.67
Czech	7	8	33	16.00
Lithuania	**	17	15	16.00
Costa Rica	5	21	24	16.67
Russia	18	14	21	17.67
Hungary	13	12	31	18.67
Thailand	44	7	6	19.00
Bulgaria	27	22	9	19.33
Estonia	28	13	22	21.00
Egypt	39	18	10	22.33
Taiwan	37	10	**	23.50
South Africa	11	20	47	26.00
Ukraine	**	15	41	28.00
Singapore	14	**	48	31.00

Source: Tholons, Towers Watson, AT Kearney, Citi Research; Note: **Not mentioned in the ranking

Figure 10. Comparing Trade Growth in Goods & Services — Diverging in Some vs. Others



Source: Haver, CEIC, Citi Research; Note: Trade growth calculated in US$ terms, *Countries included are ID, KR, MY, SG and TH

We think it is also important to distinguish the supply chain dynamics of trade in goods vs. trade in services. While demand for goods and services should be correlated, we find that services trade growth has diverged relative to goods trade in some areas over the last few years (Figure 10). Perhaps the digital world may have shifted the trade in value added from physical to virtual goods over time, which may to a degree explain the weakness in goods trade. Or perhaps productivity gains from GVC trade in services has not yet reached its peak the way it has for goods, and improving technology plus growing efficiencies from 'economies of scale' remain conducive to further service offshoring. We think this will continue to benefit more the populous low-income English-speaking economies (notably India and Philippines), which look relatively competitive (Figure 9).

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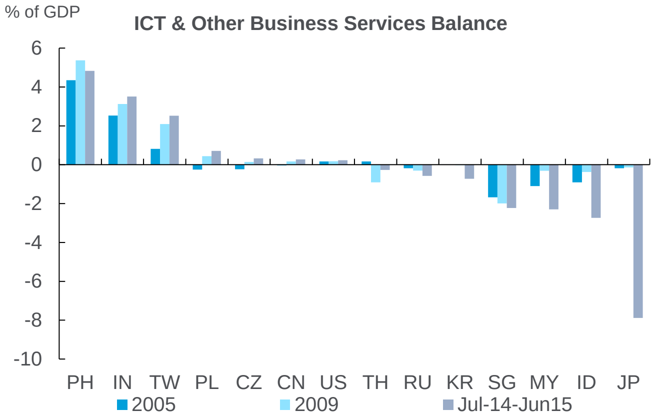
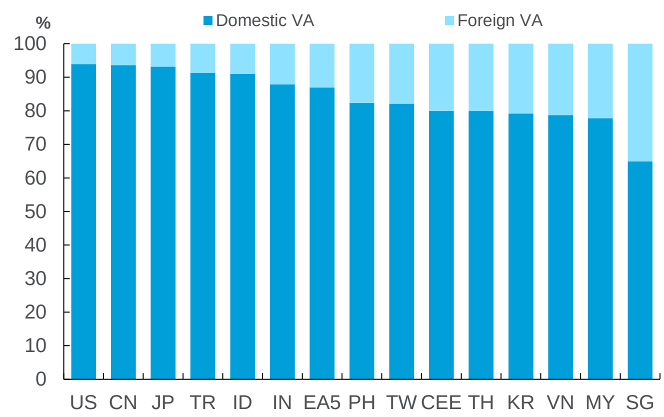
These rankings would also suggest China, Malaysia, and Vietnam could also benefit but, on net service trade balance of what we believe to be the more technology-induced tradable services — ICT and 'Other Business Services' — only the Philippines, India, Taiwan (though small relative to its weak goods trade), some Eastern European countries and marginally China (small relative to its GDP) seem to be making inroads (Figure 11). Meanwhile, Japan, Korea and others in ASEAN (except we have no data to validate Vietnam) look increasingly uncompetitive.

Figure 11. Net ICT and Business Services Exports (% of GDP)



Source: CEIC, Haver, Citi Research

Figure 12. Domestic Value Added of Service Exports is Very High



Source: OECD Tiva, Citi Research

While the value of service trade is much smaller than goods trade for EM Asia, accounting for only an average of ~ 25% of its annual nominal value (China and Indonesia being low at 17% of goods trade, and the Philippines and India being high at 45% and 37% of goods trade, respectively), **the domestic value added is so much higher in services** (Figure 12) – averaging 82% versus 65% for manufactured goods. Thus, we should not underestimate the spillover impact of tradable services on the domestic economy and, among other things, this helps explain why India and Philippines growth have outperformed the region. Meanwhile, with relatively weak goods trade performance on top of already-weak services sector productivity and competitiveness, the growth prognosis remains more challenging for industrialised Asia, especially Singapore and Korea where services productivity growth is low,[18] and even Thailand seems to have limited dynamism in services trade outside of tourism.

Industrial Robotics Revolution – Conducive to 'Re-bundling'?

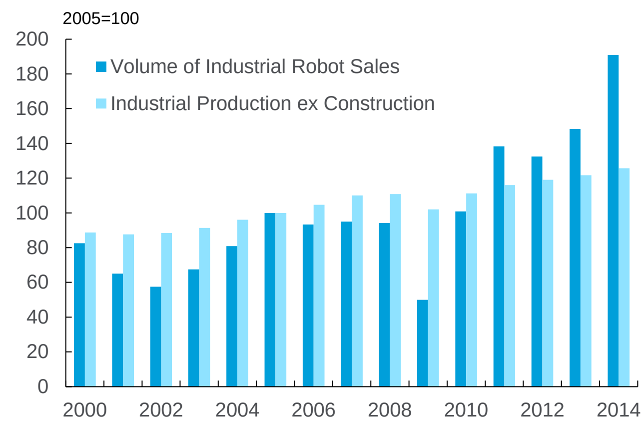
Automation and industrial robots could also have a significant impact on global supply chains

Beyond advances in ICT, we think significant advances in the use of automation and industrial robotics to aid manufacturing processes in recent years will also have a significant impact on global supply chains. The use of robotics is at least a four-decade phenomenon, but the process appears to have accelerated since the global financial crisis, seeing average robot sales rise on a compound average growth rate (CAGR) of 17% per year in 2010-14 (in fact, up almost 29% year-over-year in 2014 alone!) versus only average CAGR 3% per year in 2004-08. This comes even while global growth, especially industrial production growth, had actually *decelerated* in recent years versus the pre-GFC period (Figure 13). We think there are three main

[18] For an earlier discussion, see [Asia Macro and Strategy Outlook - Dematerialized World]() (March 2015)

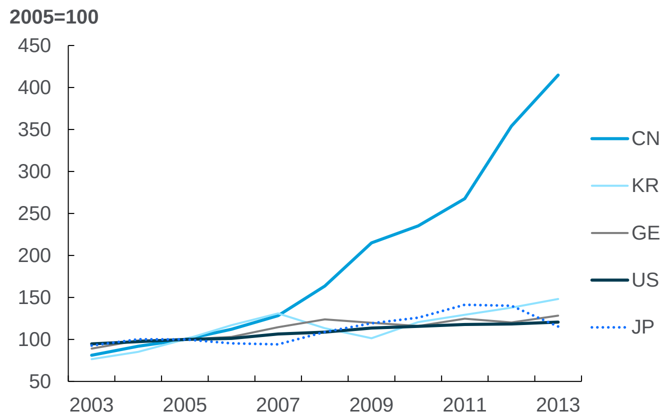
drivers of this record acceleration of robotic use. First, rapid wage gains (plus aging populations) in large manufacturing-producing countries – especially China – have induced demand for automation.[19] Second, the prices of hardware and 'enabling' software have declined markedly, making it an increasingly attractive investment; and third, technological advances (everything from vision sensors, gripping systems, etc.) have increased the scope and usability of robotics, not only making robots smarter, safer and more applicable across a broader range of processes, but also delivering more consistent and better product quality. Thus, even relatively low-wage countries, India and Indonesia, for example, have seen brisk robotic sales.

Figure 13. World – Industrial Robot Sales have Outpaced IP



Source: World Robotics, CPB Netherlands, Citi Research

Figure 14. Trends in Manufacturing Compensation Costs (2003=100)*



Source: Conference Board, Research; Note: In US$, also includes benefits

Figure 15. Comparing Robot Density

	Number of multi-purpose Industrial Robots per 10,000 employed in manufacturing
Korea	478
Japan	314
Germany	292
US	164
Global Ave	66
Europe	85
Americas	79
Asia	54
China	36

Source: IFR World Robotics 2015

Nonetheless, not all industries can benefit equally from the developments of robotics. International Federation of Robotics (IFR) data shows that **robotic usage is *highly concentrated* in three major industry groupings** (all under SITC code 7) — vehicles & transportation equipment, electronics & electrical equipment, and machinery (Figure 16). Interestingly, **these are also the same industries that historically had been very susceptible to production fragmentation via GVC given the complexity of products and processes involved**. Thus, rapid growth of automation/robotics will likely have significant implication on GVC trade in the future, on top of ability of other countries to benefit from participating in this GVC.

[19] While hourly manufacturing compensation costs in China are only estimated to be 8% that of the US in 2013, it was only 2% of the US a decade earlier.

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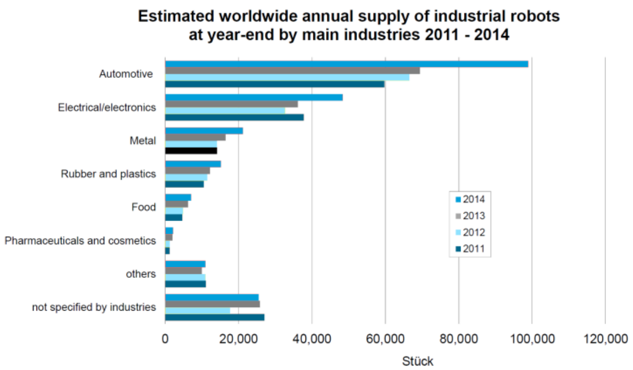
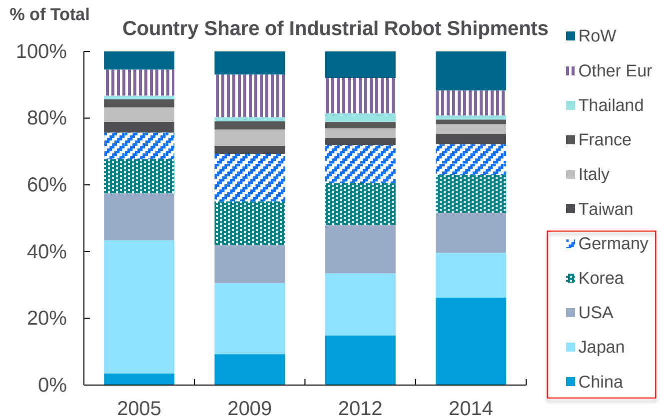
Figure 16. Automobiles & Electronics/Machinery Dominate the Usage…



Source: IFR World Robotics 2015, Citi Research (Note: In Units)

Figure 17. ...and Five Countries Dominate Robotic Use



Source: IFR World Robotics, Citi Research

China, Germany, Japan, Korea, and the US have 75% of the industrial robots

Given that robotics are historically expensive and more efficient when used at a large scale, robotic installations are very geographically concentrated — about 75% of industrial robots globally go to five countries — China, Germany, Japan, Korea, and the US. China is, by far, the fastest growing market (Figure 17) and its still relatively low robot density relative to peers leaves significant room for future growth (Figure 15).

Robots are estimated to perform about 40-45% of production tasks

According to Boston Consulting Group projections, at least 85% of the production tasks in these robotic-intensive industries (under SITC code 7) can be automated. With wages in these industries also higher than the average for manufacturing given its higher skill requirements, they are ripe for continued automation over time. The impact on relative cost saving from automation is expected to be higher among those with relatively high labour costs to begin with. For example, BCG estimates that, as robotics systems cost around $10-$20 per hour, on average, to own and operate in the US in these sectors — already lower than US manufacturing wages — and are projected to decline further such that, in ten years, robots are estimated to eventually perform about 40-45% of production tasks versus <10% today. [20] The top suppliers for industrial robotics who can benefit from this growth are concentrated in developed markets — Japan (Yaskawa, Fanuc and Kawasaki), Germany (Kuka) and Switzerland (ABB) — though there are new entrants from China with government also backing the industry through its "Made in 2025" program, though for now, China is still, technology-wise, lagging significantly behind. [21]

[20] For a comprehensive discussion, please see Sirkin, H. et al. "The Robotics Revolution - The Next Great Leap in Manufacturing" Boston Consulting Group (September 2015).
[21] Bryant, C., (2015), "Robot makers turn to technology industry as next world to conquer." FT, (June 4, 2014); Shih, G. "Technology gap gives foreign firms the edge in China robot wars." Reuters, (Sep 20, 2015)

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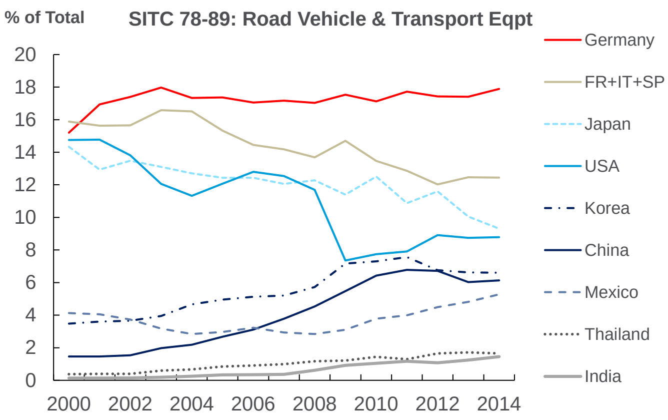
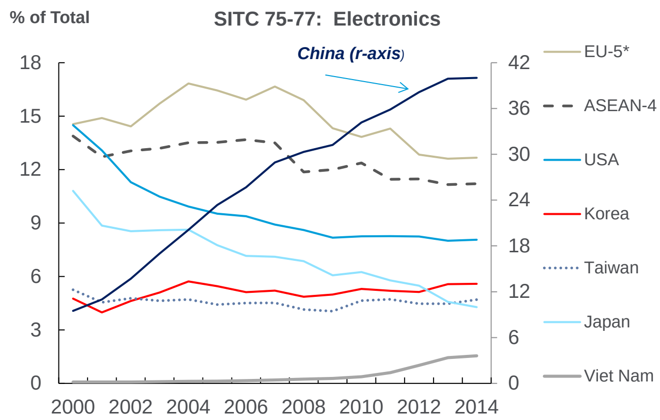
Figure 18. Export Market Share for Road Vehicles & Transport Eqpt



Source: UN Comtrade, Citi Research

Figure 19. Export Market Share for Electronics & Electrical Equipment



Source: UN Comtrade, Citi Research; Note: For China, we add shipments from HK.

We can tangentially analyse this by looking at the export market share of the most robot-intensive industry, Road Vehicles & Transport Equipment — Germany continues to dominate, but even the US (alongside Mexico) is gaining ground (Figure 18). In the electronics/ electrical equipment industry where there are likely to be more diverse tasks (in some cases, dealing with very small components that can still be more cheaply handled by hand), East Asia continues to do well but, interestingly, production is increasingly concentrated in a few countries, notably China but, more recently, we see a catch-up in Vietnam (Figure 19).

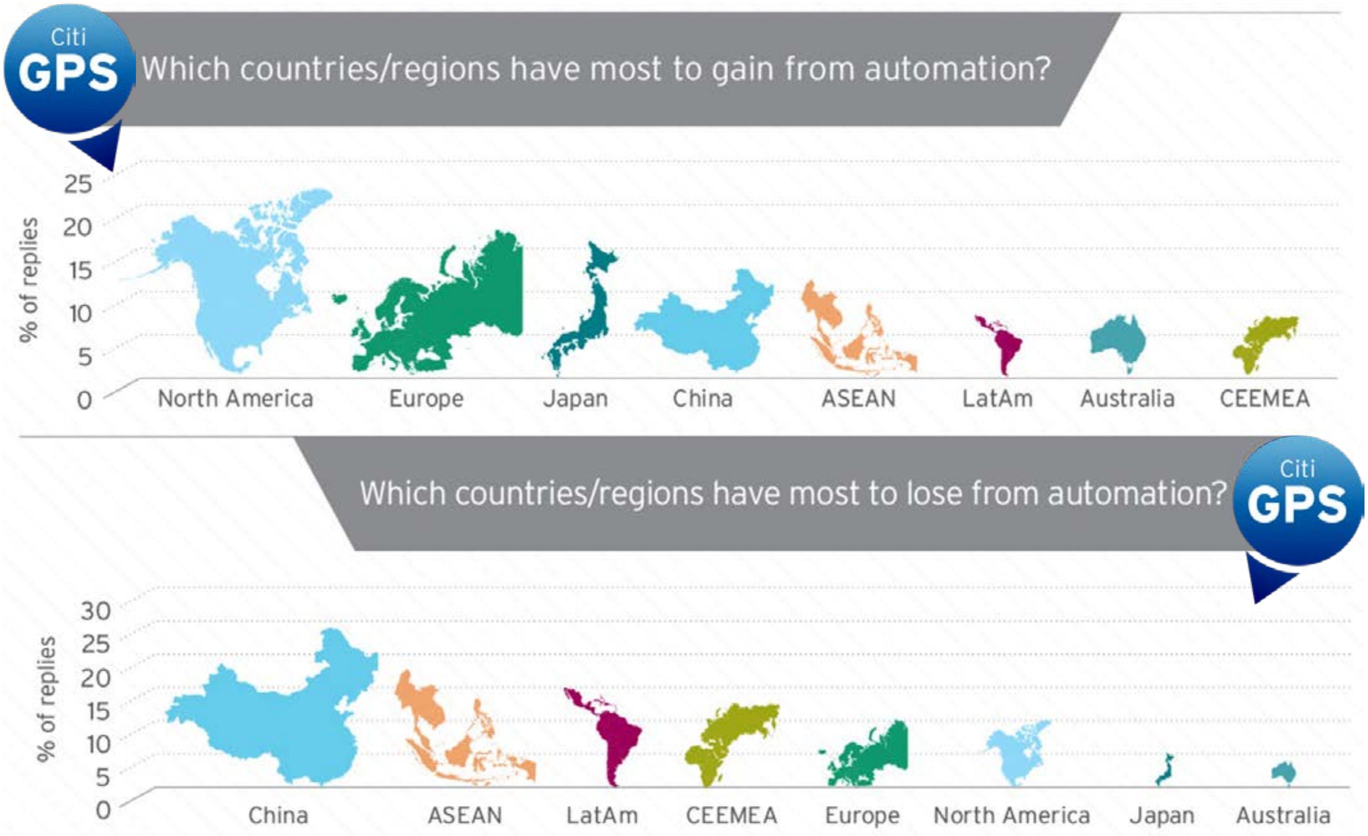
Scope for automation and industrial robotics will likely significantly alter manufacturing competitiveness, and we think could lead to some 'rebundling' or 'reshoring' of some manufacturing supply chains in critical geographical hubs. Will automation and developments in 3D printing encourage companies to move their manufacturing closer to home? In a survey of 238 Citi institutional clients, 70% believe that this would actually happen with 20% believing it would be to a significant degree and 52% responding it would be to a minor degree (see Figure 20 below).

Figure 20. Over 70% of Clients Surveyed Believe Automation and Developments in 3D Printing Would Lead to Reshoring in Some Degree

Source: Citi Research

If this is the case, then which countries/regions would have the most to gain or lose from automation? 22% of survey respondents stated that North America has the most to gain from automation, followed by Europe (17%) and Japan (16%). On the other hand the majority of the respondents stated that China (24% of replies), ASEAN (18%), and LatAm (15%) have the most to lose from automation (see Figure 21).

Figure 21. 22% of Respondents Believe that North America Has Most to Gain, While 24% Believe China Has the Most to Lose



Source: Citi Research

How is Global Competitiveness Going to Evolve with Greater Automation?

Korea, Germany, China, Japan, and the US are expected to obtain large competitive gains from the use of robotics

Based on pace of robotic adoption (high in parts of East Asia and the Czech Republic, slower in Brazil and even higher wage economies like Australia or Spain) relative to trends in wage costs (low wage countries like Indonesia and India will see less impact on reducing costs), BCG estimates that manufacturing cost competitiveness by 2025 from robotics could tilt in favour of the existing industrial powerhouses. Sirkin et al (2015)[22] estimate that Korea, Germany, China, Japan, and US are expected to be in a stronger position via larger cost competitiveness gains in the coming decade from the use of robotics, while select EM countries including Indonesia, India, and Mexico will be less so. EM economies could more than compensate for any robotic cost disadvantage via other means, such as improved logistics infrastructure. Nonetheless, depending on the speed at which robotic technology progresses, what may look like a small impact now could snowball to larger cost competitiveness shifts over time, and could disadvantage EM economies that do not keep up from a manufacturing cost-competitiveness standpoint.

[22] For a comprehensive discussion, please see Sirkin, H. et al. "The Robotics Revolution - The Next Great Leap in Manufacturing" Boston Consulting Group (September 2015).

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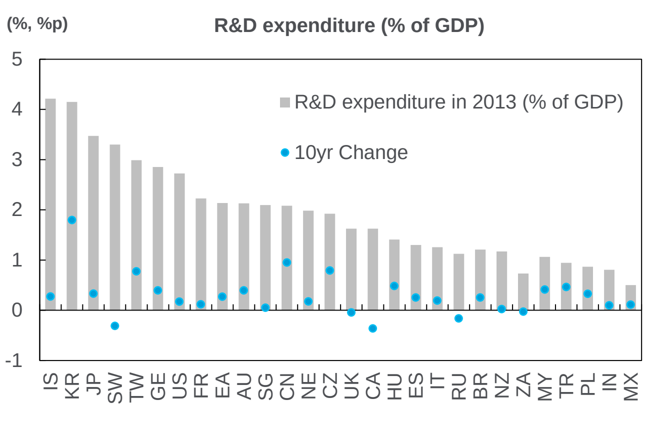
Financial and technological hurdles for robotic/automation adoption are expected to decline over time, and more sectors could enter a “turning point” wherein adoption could accelerate in nonlinear ways. For now, a lot of the scope for automation and robotic use is relatively more limited in other industries and services, especially in EM where labour costs are still low and humans are still the most cost-efficient means for assembly. In the case of robots used for services, annual sales are only about 11% of those used for industry, according to the International Federation of Robotics, the bulk of which – 45% of total –are used in defence applications (e.g. drones). Nonetheless, with the rapid developments in big data analytics, advances in artificial intelligence and autonomous machines (e.g. self-driving cars, self-service kiosks), the scope for labour displacement would grow such that even many ‘outsourced’ labour intensive-professional services, like data entry and medical transcription, could become increasingly automated. Thus, Asia needs to continue to find ways to move up the value-added chain to stay competitive, not just with other EM economies, but with advanced economies that may be increasingly equipped with technology.

China’s R&D expenditure as a % of GDP has increased fourfold

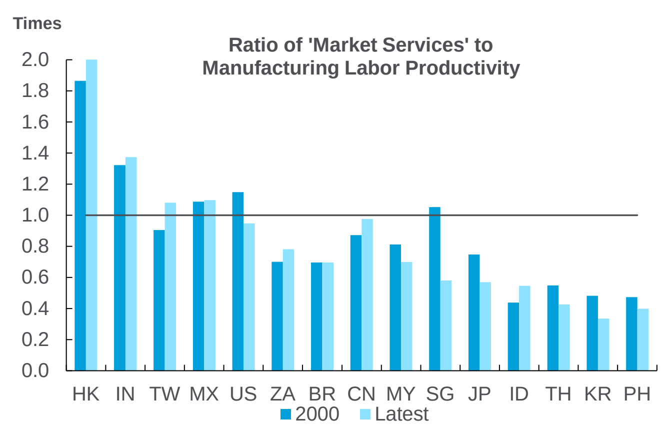
China seems to be following in the footsteps of other industrialised Asian economies in terms of spending more on R&D to upgrade technology, and we think they are in a relatively strong position to catch up in manufacturing from more advanced peers. A recent report from Citi Strategy highlighted that China’s R&D expenditure ranks globally at No.2, and R&D as a % of GDP has jumped fourfold in 20 years to 2.1%.[23] However, in a world where labour-substituting technology continues to expand, this means employment among EM economies, as in developed markets (DM), will remain highly skewed to the services sector, which may be less productive and, in the EM context, mired in informality and small-scale enterprises. The extent to which countries can boost service productivity growth comparable to manufacturing will be important and will depend on the ability to upgrade skills, provide a conducive regulatory environment, harness technology and tap into widely disseminated ‘global knowledge’ to catch up with the frontier. This is easier said than done. We next look at the susceptibility of automation within countries, focusing on US cities.

Figure 22. R&D Expenditures (% of GDP) – 2013 and 10-yr Change



Source: World Bank, OECD, Haver, Citi Research

Figure 23. Productivity in ‘Market Services’ is Comparable or High Relative to Manufacturing in Some versus Others



Source: World Bank, OECD, Haver, Citi Research GGDC-10 Sector database, Citi Research; Note: We define “market services” to exclude construction, government and community services

[23] Jason Sun, Manufacturing Champions 2025: Not Just “made in China” but Increasingly “Innovated in China.” 29 October 2015, Citi Research

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How Does Susceptibility Vary Within Countries? Cities at Risk

Highlights

- Historically, new technologies have not only transformed companies and industries, but cities and regions. The expanding scope of automation to low end service jobs may shift the fortunes of US cities once more, affecting a different set of cities than those impacted by offshoring.
- Recent work by Berger, Frey and Osborne suggests major US cities exposure to future automation ranges from 54% in Fresno to 38% in Boston.
- New jobs have emerged in locations different from the ones where old jobs are likely to disappear, potentially exacerbating income disparities between US cities.

Carl Benedikt Frey
Co-Director for the Oxford Martin Programme on Technology and Employment and Oxford Martin Citi Fellow

Why Have Some Cities and Regions Been Better Able to Adapt to the Arrival of New Computer Technologies than Others?

Historically, new technologies have significantly transformed companies and industries. For example, Clayton Christensen has shown in some detail how disruptive technologies have reshaped a wide range of industries, from computer hardware to retail, causing leading companies to fail in the process.[24] Notably, out of the 17 companies populating the disk drive industry in 1976, only IBM's disk drive business had not failed or been acquired by 1995. Rapid technological progress had even caused the demise of relatively large, diversified corporations such as Ampex, Control Data, Diablo, EMM, and Memorex. Similarly, by the turn of the 20th century, rail transport and the mail order catalogue fundamentally changed the retailing business, making it possible for companies like Sears Roebuck to compete in local markets across the United States. Following this disruption, Sears was regarded as the leading retailing corporation in the world for decades. Yet, the emergence of the online retail market changed the nature of the retailing business once more, causing Sears to lose market share as they lagged behind more adaptive companies such as Amazon.

Such technological upheaval can sometimes shift the fortunes of entire cities, causing some to prosper and others to decay. For example in 1879, when George Eastman invented the emulsion-coating machine in Rochester, New York City was the centre of the photographic industry. The Eastman Kodak company soon took over the market for photographic film and Rochester replaced New York as the leading city in film production. In the 1960s, Kodak was still the largest employer in Rochester with over 60,000 employees. Yet, as with many other companies, Kodak did not manage the transition to digital photography. When the company finally shut down its largest research and production facility in Rochester, known as Kodak Park, the population of Rochester had not just witnessed the decline of an industrial giant, but the decline of an entire city. As Kodak's workforce dropped by almost 80 percent between 1993 and 2006, Rochester rapidly lost population. Similarly, the arrival of steel mini mills did not only result in a restructuring of the steel industry, but significantly contributed to the decline of leading steel cities, such as Pittsburgh and Youngstown.[25] In other words, cities that have remained locked into old jobs,

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[24] Christensen, C. (1997), The innovator's dilemma: when new technologies cause great firms to fail. Harvard Business Review Press.
[25] Brezis, E.S. and Krugman, P.R., (1997), Technolgoy and the life cycle of cities, Journal of Economic Growth, 2(4), 369-383.

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that are gradually made redundant by a new technology, have eventually become subject to urban decline.

The Computer Revolution and the Shifting Fortunes of US Cities

The arrival of the PC changed the types of jobs that were created in the US, affecting the fortunes of UScities

The Computer Revolution has perhaps shifted the fortunes of US cities even more significantly than technologies of the past. Indeed, although computers have arrived everywhere, US cities have fared very differently over recent decades — while some cities have experienced rapid growth, others have virtually disappeared. In a recent study, Thor Berger and Carl Benedikt Frey show how the arrival of the personal computer (PC) in the early 1980s changed the types of jobs that were created in the US labour market, in turn leading to a shift in the fortunes of US cities. Throughout the 1970s, when technological change mainly created routine jobs, human capital abundant cities had a comparative disadvantage in new job creation, as these jobs mainly emerged in routine task-intensive industries — jobs that have since been automated away. By contrast, since the Computer Revolution of the 1980s, cities specialised in cognitive work, gained a comparative advantage in new job creation that has persisted since, mirroring trends in population and wage growth across cities over the same period.

Cities have adjusted differently to the Computer Revolution where places like New York have become a primary example of how to adapt to technological innovation

Thus, in tandem with the US labour market experiencing a secular decline in jobs intensive in routine tasks, which can easily be expressed in computer code and readily automated, cities have adjusted differently to the Computer Revolution of the 1980s. While places historically specialised in routine work have adopted computers to substitute for labour, human capital abundant cities that have a comparative advantage in using skill-intensive computer technologies have created new types of jobs. This is indeed also consistent with popular perceptions of urban success and decline in the US, emphasising the relative decline of old manufacturing cities such as Buffalo, Cleveland or Detroit — cities that all historically specialised in routine work. At the heart of the decline of these cities was their failure to create new employment opportunities as old ones were being eroded. Having nearly filed for bankruptcy in 1975, New York has become a primary example of how to adapt to technological change. While average wages in Detroit were slightly higher than in New York in 1977, they are now less than 60 percent of average New York incomes.[26] At a time when Detroit successfully adopted computers and industrial robots to substitute for labour, New York adapted by creating new employment opportunities in professional services, computer programming and software engineering.

Emerging Technologies and their Impacts on Cities

Cities with low exposure to automation of routine work will for the first time find that a significant share of their workforce is exposed to computerisation

The expanding scope of automation may shift the fortunes of US cities once more. Recent developments in Data Mining, Machine Vision, Computational Statistics and other sub-fields of AI, are widely being regarded as the beginning of a 'Second Machine Age'. In a recent study, Thor Berger, Carl Benedikt Frey, and Michael Osborne, analysed how these technologies may impact on US cities, relative to computer technologies of the past. Importantly, they find that cities with a low exposure to the automation of routine work will for the first time find a significant share of their workforce exposed to computerisation. The potential impact of future automation is also distinct from the labour market impacts of globalisation, suggested by the fact that there is no significant overlap with the susceptibility of

[26] Glaeser, E.L., and Ponzetto, G. (2007), Did the Death of Distance Hurt Detroit and Help New York? NBER Working Papers 13710, National Bureau of Economic Research, Inc.

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cities to offshoring. In other words, workforce automation in the 21st century will potentially affect a different set of cities than the ones that have historically seen workers made redundant by computerisation and offshoring.

Fresno and Las Vegas are the most exposed to automation, whilst Boston and Washington D.C. are the least exposed

The exposure of US cities to future automation ranges from 54% in Fresno, to 38% percent in Boston (see Figure 24). Notably, the cities with the highest share of their workforce exposed to automation (with the exception of Grand Rapids), do not include any Rust Belt manufacturing cities, such as Buffalo, Cleveland, and Detroit. Instead, some of the cities most at risk, include places in the Sun Belt that have recently faded: both Fresno and Las Vegas suffered some of the steepest drops in housing prices during the Great Financial Crisis, becoming plentiful in empty homes and office buildings. The cities that are least susceptible to automation, in contrast, include well-known examples of skilled cities, such as Boston, New York, San Francisco and Washington D.C.

Figure 24. Cities at Most and Least Risk of Automation

Least at Risk			Most at Risk
City	% of Jobs at 'High Risk' of Automation	City	% of Jobs at 'High Risk' of Automation
Boston	38.4%	Houston	45.8%
Washington D.C.	38.4%	Sacramento	45.9%
Raleigh	39.7%	Dayton	46.0%
Baltimore	40.4%	Los Angeles	47.0%
New York	40.7%	Harrisburg	47.1%
Bridgeport	41.1%	Oklahoma City	47.1%
Toms River	41.2%	Grand Rapids	47.9%
Richmond	41.4%	Reading	48.4%
Minneapolis	41.4%	Greensboro	48.5%
Denver	41.5%	Las Vegas	49.1%
San Francisco	41.7%	Fresno	53.8%

Source: Berger, Frey and Osborne (2015) Note: Cities are defined on the basis of commuting patterns. If people are willing to commute between various towns those towns together constitute a local labour market. For example Toms River is the largest of many towns that people commute between.

Explaining the Exposure of Cities to Automation

Specialised cities have a larger exposure to automation

The variation in the exposure of cities to the expanding scope of automation can at least partly be explained by industry specialisation patterns. In general, more specialised cities have a larger share of jobs at 'high risk' of automation, while diversified cities are more resilient to the expanding scope of automation. In other words, industrial diversification can make cities more resilient to negative demand shocks in any specific industry.

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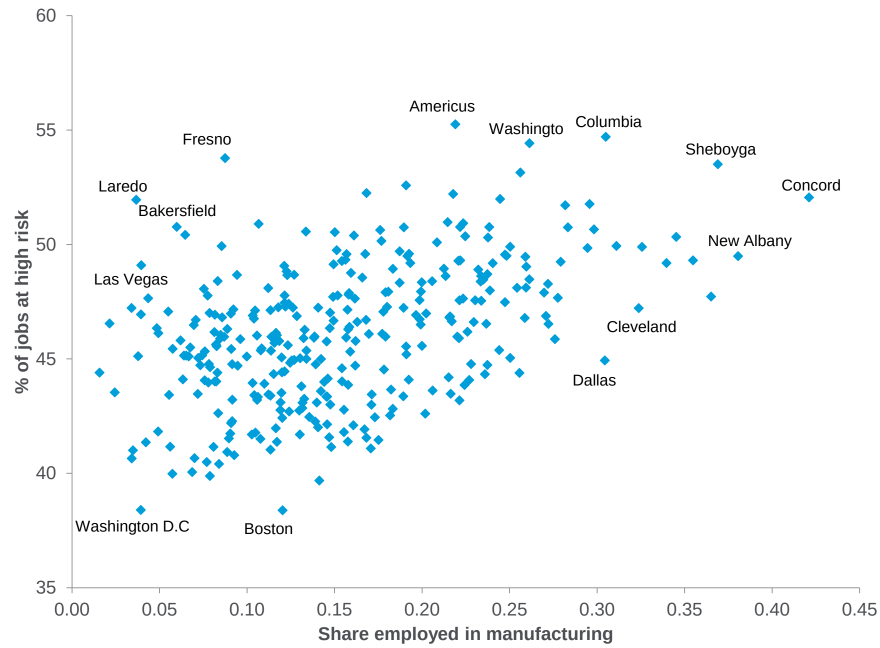
Figure 25. Manufacturing Cities Remain More Susceptible to Automation



Source: Berger, Frey and Osborne (2015)

Cities that specialise in skilled industries remain relatively safe from automation

The type of industries cities have specialised in also matter. For example, cities specialised in manufacturing continue to be relatively exposed to automation, and without efforts to create new industries, manufacturing cities are likely to experience continued decline. In addition, cities specialised in service jobs are now, for the first time, exposed to automation. This contrasts with the experience of the past decades, when most US job growth occurred in service occupations.[27] Cities that remain relatively safe from automation are the ones that have specialised in relatively skilled industries, including information, finance, insurance & real estate (FIRE), education, and professional services, or creative industries, such as the arts.

[27] Autor, D. and Dorn, D., (2013), The Growth of low skill service jobs and polarization of the US labour market, American Economic Review, Vol. 103(5), pp. 1553-97.

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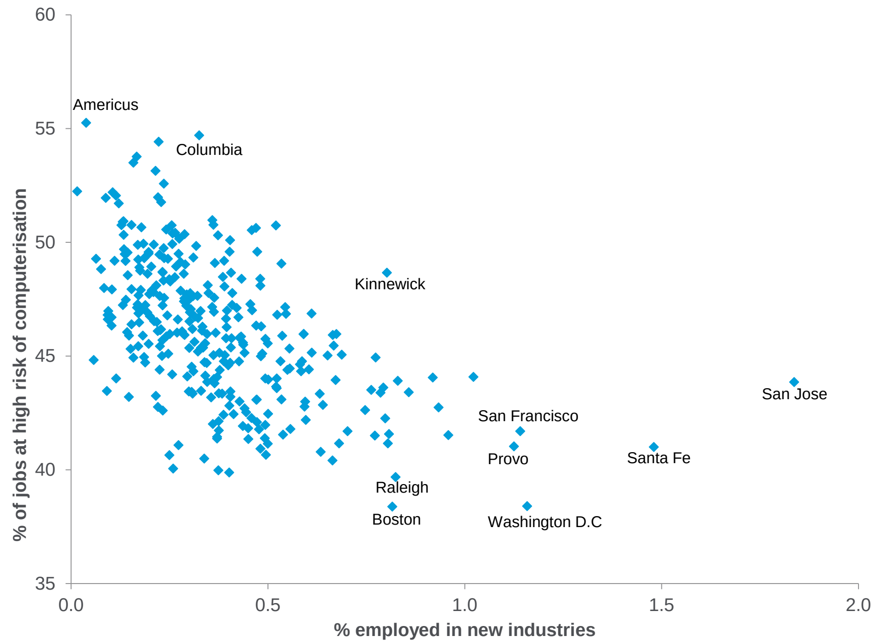
Figure 26. Cities with New Industries are Less Susceptible to Automation



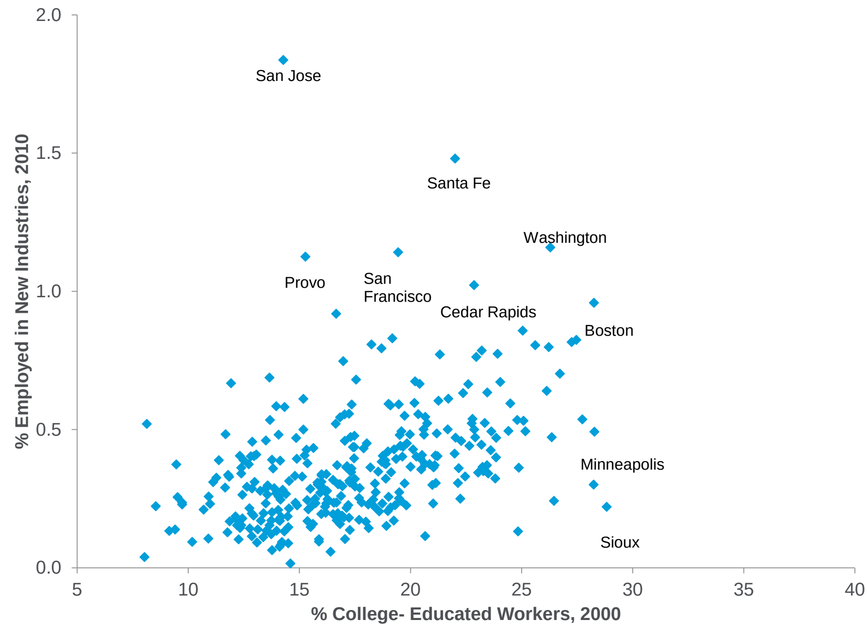
Source: Berger, Frey and Osborne (2015)

Cities least exposed to automation have been substantially more innovative in terms of patent output

The research by Berger, Frey, and Osborne further suggests that the best way forward for cities looking to reduce their exposure to automation is to boost their technological dynamism and attract more skilled workers. The cities that are least exposed to automation have been substantially more innovative in terms of patent output, have created more new businesses and managed to shift their workforce into new and emerging industries, over the past decade. Examples of such industries include video and audio streaming, online auctions and web design. Because technological change has recently been skill-biased, attracting skilled workers is also increasingly crucial. As shown by Berger and Frey, new industries that emerged throughout the 2000s are substantially more skill-intensive than other industries. Furthermore, workers in industries that experienced rapid technological change earn much higher wages: the average wage for workers in new industries is more than twice the US median wage. In other words, initially skilled cities have created even more jobs for skilled workers.

Crucially, these new industries have mainly appeared in urban locations. In particular, cities that were already dense in college-educated workers experienced substantially more additions of new industries (Figure 27). It is also noteworthy that many cities with high fractions of new industries are well-known for their specialisation in information technology. The highest employment shares in new industries, for example, are exhibited by San Jose and Santa Fe, incorporating Silicon Valley and the Info Mesa cluster respectively. Other cities where new industries are prominent include Washington, D.C. and San Francisco, where Instagram, Dropbox, Uber, Internet Archive and Twitter are all located or began.

Figure 27. Cities With Higher Share of College Educated Workers Have Created More Jobs in New Industries



Source: Berger and Frey (2015)

The Great Divergence of US Cities

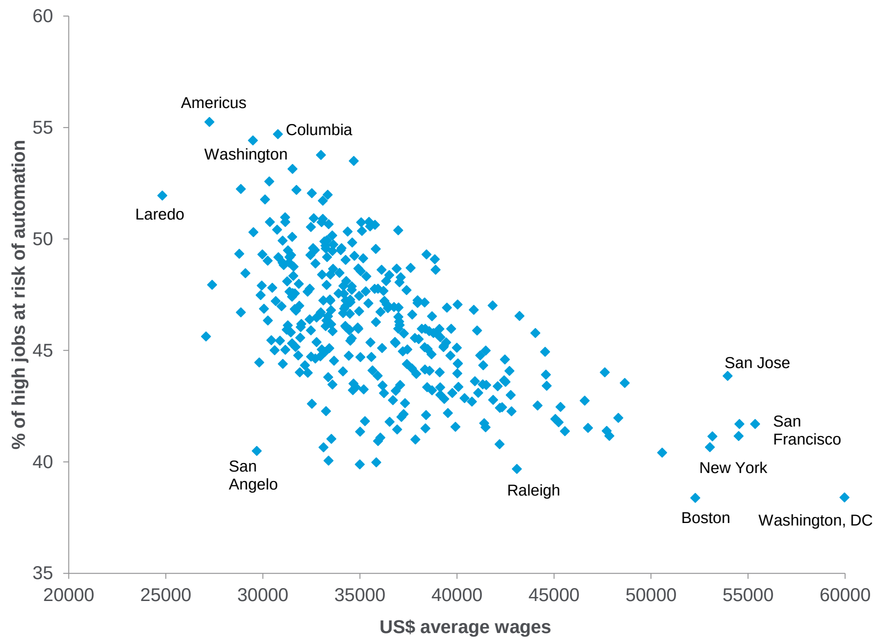
In tandem with the polarisation of labour markets, prosperity has already become increasingly unevenly distributed across locations within the United States. According to Enrico Moretti the Great Divergence of cities in the United States has its origins in the 1980s, when skills started to dictate the fortunes of US cities. Thor Berger and Carl Benedikt Frey further show that this tendency is intimately associated with the Computer Revolution of the 1980s, as new computer-related jobs overwhelmingly concentrated to initially human capital abundant cities. Over the forthcoming decades this trend is likely to continue. As shown by Thor Berger, Carl Benedikt Frey, and Michael Osborne, over the course of the 2000s, new jobs have emerged in places that are relatively safe from automation, while cities with a larger share of their workforce exposed to the expanding scope of automation have failed to create new jobs.

The expanding scope of automation could increase income disparities between US cities even further

The expanding scope of automation is likely to further exacerbate income disparities between US cities. Cities that exhibited both higher average levels of income in 2000 as well as the average income growth between 2000 and 2010, are less exposed to recent trends in automation. Thus, cities with higher incomes, and the ones experiencing more rapid income growth, have fewer jobs that are amenable to automation. Similarly, cities with a higher share of top-1% income earners are less susceptible to automation, implying that inequality between the 1 percent and the 99 percent may widen as workforce automation continues. In contrast, cities with a larger share of middle class workers also are more at risk of computerisation.

Hence, new jobs have emerged in different locations from the ones where old jobs are likely to disappear, potentially exacerbating the ongoing divergence between US cities. Looking forward, this trend will require workers to relocate from contracting to expanding cities. Supporting such relocation is particularly important since the arrival of new technology jobs creates additional demand for local services. For example, Enrico Moretti has estimated that one additional job in the technology sector — including Machinery and Computing Equipment, Electrical Machinery and Professional Equipment — generates about 4.9 new jobs in the same city as new jobs create additional demand for local services. Thus, while technology does perhaps not create as many jobs directly as in the past, its indirect impact on service employment is substantial. Nevertheless, because new technology jobs overwhelmingly cluster in highly skilled cities, low skilled workers will inevitably have to follow, making economic activity even more concentrated.

Figure 28. Richer Cities Are Less Susceptible to Automation



Source: Berger, Frey and Osborne (2015)

What New Jobs do We See Ahead? New Jobs in a New Economy

Highlights

- This chapter highlights the new and emerging job openings over the next decade in a number of different sectors.
- In the EU, it is estimated that there will be job openings in all sectors with additional jobs estimated at over 9.5 million and replacement jobs at 98 million between 2013 and 2025.
- In the US the largest number of job openings is predicted to be in the health sector (> 4 million). New jobs are also needed in the green sector and industrial sector.
- The IT sector should continue to create new employment opportunities including: security analysts; data scientists; cloud architects; and the implementation and analysis of the Internet of Things. Robots will replace jobs but also generate new jobs for engineers and technicians.
- The new types of jobs that will be created will require people to be highly skilled; in fact it is forecasted that nearly half of the new opportunities in the EU will require high skilled workers.

Elizabeth Curmi
Thematic Analyst, Citi

In 1961, Time magazine published a story called "The Automation Jobless" which stated that "The number of jobs lost to more efficient machines is only part of the problem. What worries many job experts more is that automation may prevent the economy from creating enough jobs."

Two years later Life Magazine held up a picture of a device called the Milwaukee-Matic, an innovative industrial machining tool, surrounded by the 18 workers that it could replace. Automation and joblessness became such a huge issue that President Lyndon established the 'Blue-Ribbon National Commission on Technology, Automation and Economic Progress'. The Commission studied the effects on productivity, labour, and automation and concluded that automation did not as such threaten employment and there were more important factors at stake: "Thus technological change (along with other forms of economic change) is an important determinant of the precise places, industries, and people affected by unemployment. But the general level of demand for goods and services is by far the most important factor determining how many are affected, how long they stay unemployed, and how hard it is for new entrants to the labour market to find jobs. The basic fact is that technology eliminates jobs, not work".[28]

Clearly in the past, automation and technological progress have not made human labour obsolete, in fact we have managed to adapt by creating new jobs to compensate for the loss of labour. In 1900, 41% of the US workforce was employed in agriculture; however by the year 2000, that share had fallen to 2%, mostly due to mechanisation of the sector. In the developed world, industrialisation moved people into factories and then moved them out again into services. Throughout these changes the number of jobs has always increased. US employment increased from 1950 to 2014, and the unemployment rate in 2015 (5%) is returning back to its average after the financial recession of 2008/2009 (Figure 30 below).

[28] Autor D.H., (2015), Why are there still so many jobs? The History and Future of Workplace Automation, Journal of Economic Perspectives, Vol. 29, No. 3 pp 3-30.

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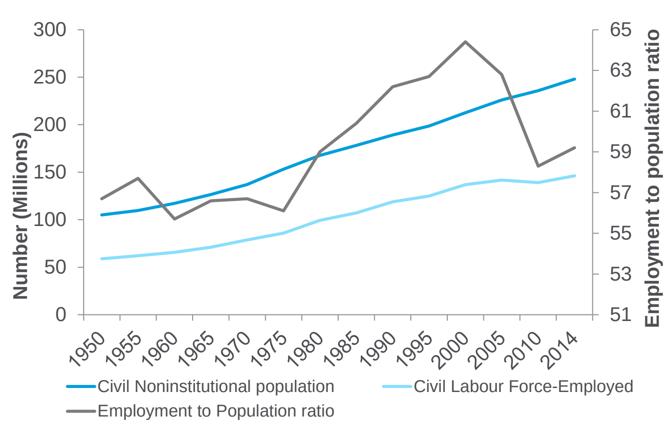
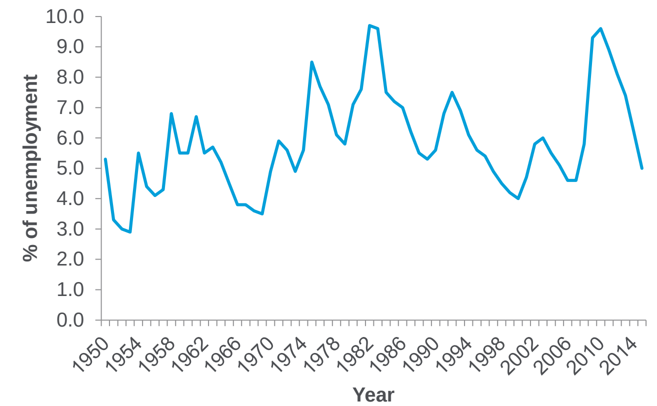
Meanwhile, today's newer technology sectors have not provided the same opportunities, particularly for less educated workers, as the industries that preceded them. This downward trend in new job creation in technology industries is particularly evident since the Computer Revolution of the 1980s. A study by Jeffery Lin suggests that while about 8.2% of the US workforce shifted into new jobs — associated with the arrival of new technologies throughout the 1980s — the equivalent number for the 1990s was 4.4%. Using updates of official industry classifications, Thor Berger and Carl Benedikt Frey further document that less than 0.5% of the US workforce shifted into technology industries that emerged throughout the 2000s, including digital industries such as online auctions, video and audio streaming, and web design. Fifty-one of the 71 new industries that emerged during this period were directly related to digital technologies.[29]

Figure 29. Labour Force in the US (1950-2014)



Source: US Bureau of Labor Statistics, Citi Research

Figure 30. Unemployment Rate in the US (1950-2015)



Source: US Bureau of Labor, Citi Research

What is clear is that technology has already changed the way we work and will continue to do so. Whether it will create more jobs than it will replace is another question in itself. What we are interested in answering in this chapter is the following question: 'What types of new jobs are emerging and will be created over time?' What we find is that is that there are a number of new and emerging job openings in different sectors including the IT, industrial, and health sector. At all skill levels, most jobs in demand will be characterised by non-routine tasks which are not easily replaced by technology or organisational change. Nearly half of the new job opportunities in the EU are estimated to require highly skilled workers, therefore acquiring these skills is extremely important for future employment and could affect the susceptibility of automation at both a country and city level.

Jobs of the Future

Estimates are for 9.5 million new jobs to be created in the EU over the next 10 years

Predicting the types of jobs and skills that will be in demand in the future is challenging and often uncertain, but various detailed data sets are helping us observe such evolving trends. The European Centre for the Development of Vocational Training (Cedefop) estimates that in the EU there will be job openings in all sectors with additional jobs estimated at over 9.5 million and replacement jobs estimated at 98 million from 2013 to 2025. However their results indicate some risk of job polarisation as the new jobs (replacement and expansion) will be created on the top or the bottom of the job sector. At all skill levels, most jobs in demand will be

[29] Berger, T. and Frey, C.B., "Industrial Renewal in the 21st Century: Evidence from U.S. Cities:, Regional Studies, forthcoming.

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characterised by non-routine tasks which are not easily replaced by technology or organisational change. As Figure 31 shows many traditional routine jobs such as clerical jobs and craft-related trade will decline.

Figure 31. Total Replacement Demand and Expansion in Job Opportunities in the EU in 2025 (net change)

Source: Cedefop, Citi Research

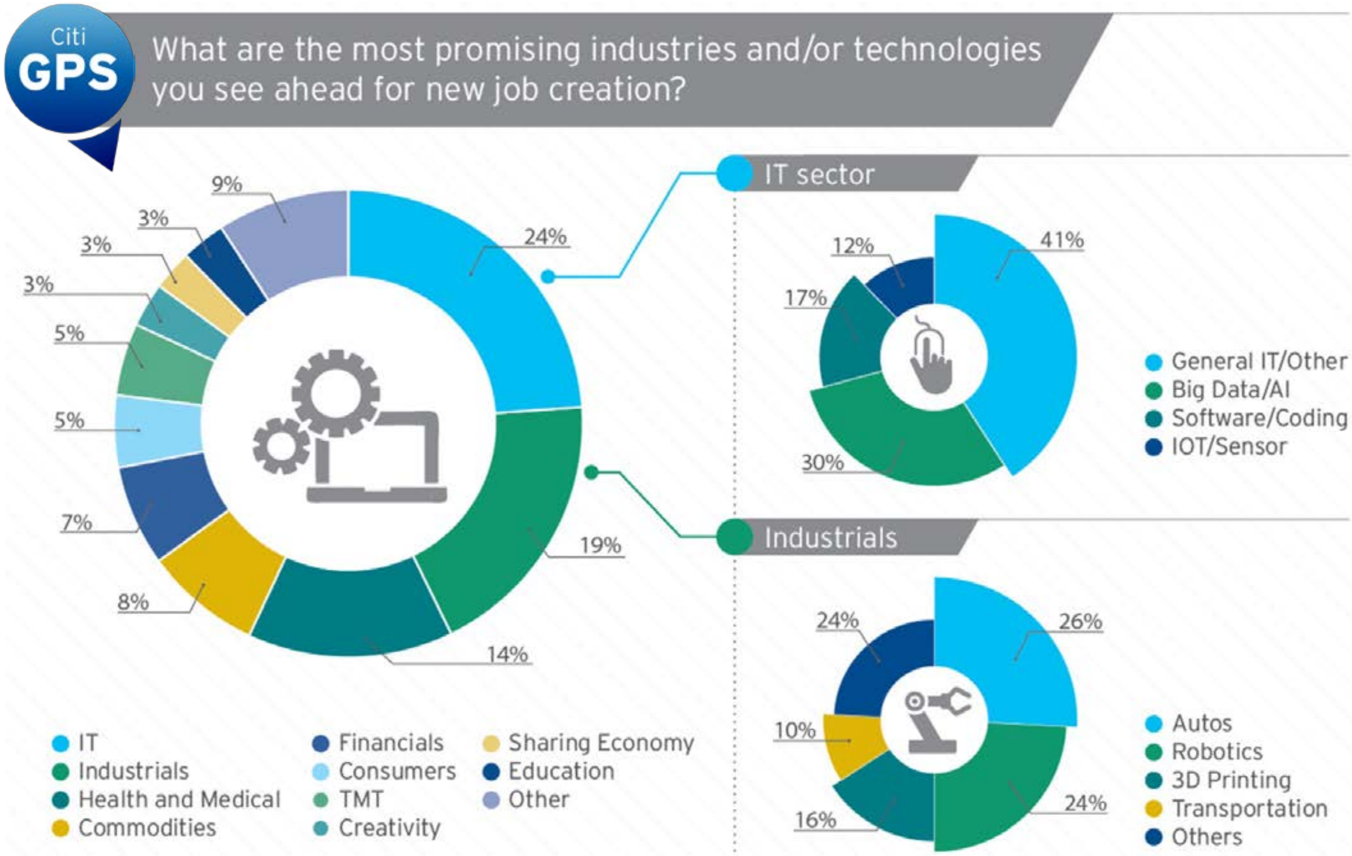
The largest number of job opportunities in the US is expected to be in the health sector

24% of the respondents to Citi's survey stated that the IT sector was the most promising sector for jobs

The O⋆NET programme collects information on 974 different occupations in the US. One key feature that it has is the compilation of a list of 'bright outlook' occupations, where new job opportunities are likely to be in the future or at least until 2022. It categorises these occupations as: (1) those that are projected to grow much faster than the average (employment increase of 22% or more); (2) those that are projected to have a large number of openings; and (3) new and emerging occupations which include new workforce requirements, including changes in technology, society, law or business practices and are leading to new and emerging occupations in the US.[30] The data show that the information technology career cluster has the highest percentage of occupations (62%) considered to have a 'bright outlook', followed by marketing, sales, and service (50%) and health science (45%).[31] If we just look at the new and emerging occupations, the largest number of job opportunities in the US are estimated to be in the health sector (>4 million job openings). Other new and emerging occupations with large job opportunities include green jobs such as wind energy operations managers, automotive engineers and others. (For a full list of bright outlook jobs refer to the O⋆NET website).

[30] http://www.onetcenter.org/bright.html
[31] OECD

Figure 32. Results of Survey- Promising Industries/Technologies for New Job Creation



Source: Citi Research

The Digital Economy: New Jobs Created by the IT Sector

Over the years, computers and their applications have changed the way businesses function and the way we work. The Internet today is considered a fundamental infrastructure in most countries and has over the years and it has created jobs either directly related to technology such as Internet engineers and hardware specialists or jobs directly related to its eco-system — such as the creation of apps and the analysis of data.

Technology job openings have increased by 8% in the US

Employment in the computer and IT sector is expected to increase as applications such as the Internet of Things, Big Data, AI and others expand over time. In fact the top job trends on indeed.com's website are all related to the computer and IT sector including HTML5 Developer jobs which grew by over 350,000 % from January 2010 to January 2015, MongoDB specialists (database technology), IOS, Android, Hadoop (open software that enables distributed processing of large data sets), cloud architects and others.[32] According to Indeed's industry employment trends, information technology job postings have increased by 8% in the US since September 2014 with a total of 329,244 job postings during this period.

LinkedIn's job site has nearly 39,000 data scientist job openings

According to Cisco, by 2020 there will be a staggering 50 billion devices around the globe connected to the Internet and collecting data, and as the number of connected devices explodes, the number of developers around the world contributing to the Internet of Things (IoT) would increase from 500,000 to 4.5

[32] http://www.indeed.com/jobtrends

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million people.[33] In this expanded digital economy, private enterprises connected to the Internet of Things can use Big Data and analytics to develop algorithms and speed up efficiency, productivity, and lower the marginal cost of producing and distributing products.[34] Big Data is also being used in a number of other applications from e-commerce, marketing, medical, AI, and others. For every Big Data problem, the solution often rests with a data scientist. The Harvard Business Review dubbed Data Scientist as the 'sexiest job of the 21st century.' According to Dr. Tara Sinclair, Indeed.com's Chief Economist, the number of job openings for Data Scientists grew 73.5% in the first quarter of 2015.[35] As of January 2016 there are currently over 30,000 Data Specialist job openings on LinkedIn's job site in the US alone.[36]

650,000 jobs are estimated to open in the IT sector

The US Bureau of Labor Statistics has made forecasts of future job opportunities in 2022 for IT and computer-related work (Figure 33 below). It is difficult to divide these jobs into the different applications, however it is interesting to see that the largest percent increase between 2012 and 2022 is in Information Security Analysts (37% increase), Computer System Analysts (25%) and Software Development (22%) with total job openings in the IT sector estimated at 650,000 in the same period. However, this seems to be quite low when compared to Indeed's analysis where over 329,000 jobs in IT have opened from September 2014 to present. The difference could be in definition: the Bureau of Labor Statistics defines occupations differently than job websites, and therefore IT jobs required in certain sectors such as Data Scientists in the healthcare and medical sectors could be counted within the health sector occupational analysis. Even though IT jobs are estimated to grow over almost 18% to 2022, they only form a small part (<3%) of the overall employment in the US, estimated at 160 million in 2022.

Figure 33. Employment in the IT Sector in the US in 2012 and Expected in 2022

Title	Employment in 2012	Employment in 2022	Change % in 2012-2022
Information Security Analyst	75,100	102,000	37%
Computer System Analysts	520,600	648,400	25%
Software Developers	1,018,000	1,240,600	22%
Web Developers	141,400	169,900	20%
Computer Support Specialists	722,400	845,300	17%
Database Administrators	118,700	136,600	15%
Computer & Info Research Scientists	26,700	30,800	15%
Computer Network Architects	143,400	164,300	15%
Network Computer Systems Admin	366,400	409,400	12%
Computer Programmers	343,700	372,100	8%
Computer occupations (all other)	205,800	213,600	4%
Total	3,682,200	4,333,000	18%

Source: US Bureau of Labour Statistics, Citi Research

The Digital Economy: New Jobs for SMEs

The digital economy and the Internet are also helping small and medium sized firms (SMEs) grow their businesses more effectively by procuring inputs and selling globally directly over the Internet, often resulting in the demand for more workers. The Internet has also helped open up markets for home-based business; in fact

[33] Cisco, How many jobs will IoT create by 2020? https://www.netacadadvantage.com/experience-skills/experience-skills-blog/-/blogs/how-many-jobs-will-iot-create-by-2020-

[34] The Office of Jeremy Rifkin, A Smart Green Third Industrial Revolution 2015-2020.

[35] http://fortune.com/2015/05/21/data-science-white-hot/

[36] https://www.linkedin.com/job/data-scientist-jobs/

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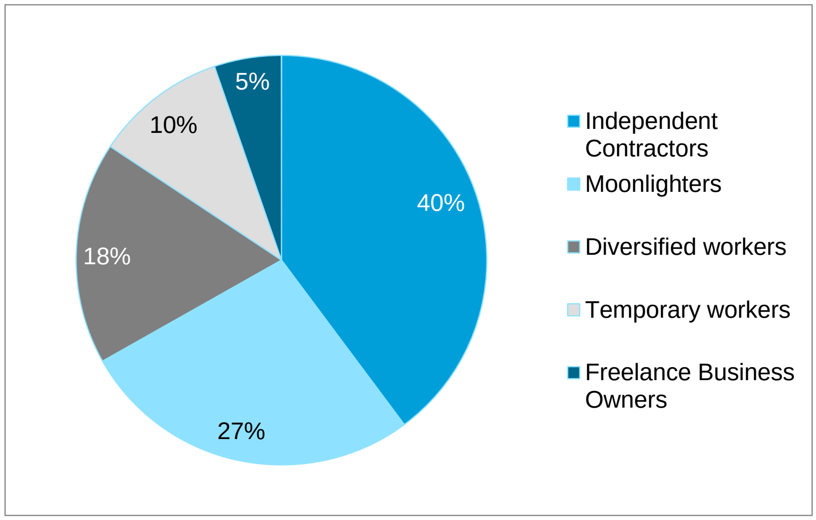
there are currently 53 million Americans that are working as freelancers, equivalent to approximately 34% of the total US workforce. Forty percent of these freelancers are independent contractors, 27% are moonlighters —professionals who have a traditional job but also freelance — and 18% are people with multiple sources of income (see Figure 34).

Figure 34. Types of Freelancers (53 Million Freelancers in the US)



Source: Freelancers Union & Elance-oDesk[37], Citi Research

New infrastructure such as freelancer support and communication platforms are enabling people to move into self-employment

In the UK there has also been a sharp increase in self-employment, accounting for two-thirds of the job growth since 2008. Self-employed individuals now account for one in seven of the British workforce.[38] This increase is driven by new infrastructure such as freelancer support, plus good communication platforms such as Skype, and an increase in available funds through schemes such as peer-to-peer lending and through start-ups such as Uber, Task Rabbit and Handy (part of the sharing economy), which are transforming the way consumers access goods and services.

The sharing economy is providing a number of jobs and opportunities to freelancers

While we lack the data to examine the net employment effects of the sharing economy, it is clear that it facilitates a new range of jobs. The sharing economy allows individuals to share products and services such as renting a room in one's house (Airbnb), driving passengers to destinations (Lyft), and finding a number of tasks that one can do through apps such as Task Rabbit or Handy. The industry is growing and providing a number of jobs to freelancers and other individuals. For example Handy, which is a market for online and mobile cleaning and home repair booking services, has received over $1 million in bookings per week in the last year. Lyft, an app which matches drivers with passengers who request rides, states that some drivers can make more than $800 just driving weekends. Task Rabbit- a web based platform that allows you to outsource errands that you don't want to do and connects you with qualified people who are available to help, has over 30,000 people signed up. Taskers set their own rates and according to Jamie Viggiano, vice president of marketing for the company, 10-15% of the subscribers can earn $6,000 to $7,000 a month.[39]

[37] Freelancers Union & Elance-oDesk, Freelancing in America: A national survey of the new workforce.
[38] ONS, 2015.
[39] http://time.com/money/3714829/working-for-taskrabbit/

Could the future of work lie in self-employment, multiple job holdings, short duration and temporary employees? This theory has been questioned as today the majority of workers have full time jobs and full time jobs bring stability and other perks such as private pensions etc. However as stated in our previously Citi GPS report Technology at Work, as the economy becomes even more digitised, self-employment may become the new norm. The sharing economy is expected to grow over time; with PwC estimating that the five main sharing sectors (peer-to-peer financing, online staffing, peer-to-peer accommodation, car sharing and music video sharing) have the potential to increase global revenues from around $15 billion to $335 billion by 2025.[40]

Is Technology Creating New Jobs in the Industrial Sector?

As robots become smarter, faster and cheaper they will be doing tasks that go beyond repetitive, dull, and dangerous and will be used in other industrial sectors besides the auto industry (where today's majority of industrial robots are used).[41] Although robots will replace a number of jobs, they will also generate a number of new job positions. The International Federation of Robotics (IFR) estimate that growth in robot use over the next five years would result in the creation of one million high quality jobs.

In the US robot engineer jobs are expected to increase by 30,000 over a 10 year period

In 2012, there were 133,000 robot engineers who research, design, develop, and test robotic applications and 17,000 robotics technicians that build, install, test or maintain robot equipment or related automated production systems in the US.[42] The numbers for these jobs are expected to increase by an estimated 30,000 for robot engineers and over 4,000 for robot technicians from 2012 to 2022 in the US. Figure 35 below shows the estimated direct jobs that are related to the increase in robotics including computer controlled machine operators and mechanical engineering technicians. There are also indirect jobs that could be created through the expansion of robotics including software programmers and data analysts; these are discussed in more detail in the section on information technology.

[40] http://www.pwc.co.uk/issues/megatrends/collisions/sharingeconomy.html
[41] Auschitzky et al. (2014), How Big Data can improve manufacturing, McKinsey Global Institute.
[42] https://www.onetonline.org/find/bright?b=3&g=Go

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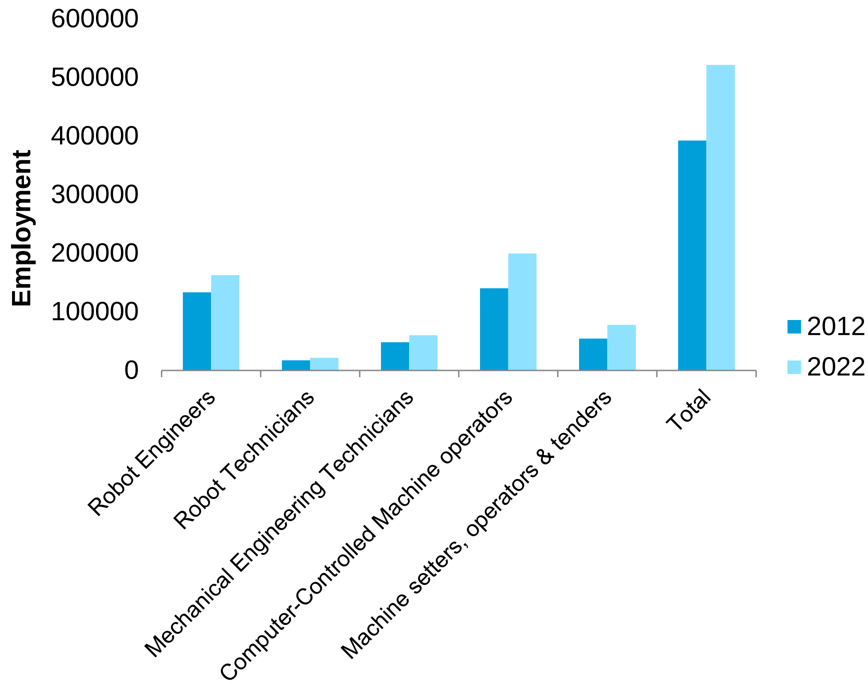
Figure 35. Estimated Direct Jobs Related to Robotics in the US



Source: O*NET, Citi Research

Skills required in the auto industry have changed over time. New jobs for automotive engineers estimated at nearly 100,000

The auto industry has been using industrial robots in its manufacturing process for many years. However, job opportunities in the auto sector are expected to increase over time and new jobs are also emerging in this sector because of new technologies that are available. Automotive engineers who develop new or improved designs for vehicles and automotive engineer technicians who assist engineers in determining the practicality of the proposed design are both new job types in the auto industry and are expected to grow on average between 3% and 7% in the US from 2012 to 2022, with new job openings estimated at nearly 100,000 and 12,000, respectively. The skills required for these jobs have changed over time and now include analytical software design, computer aided manufacturing, development of environmental software, and others which reflect the effect that technology and regulation is having on the auto sector.

Autonomous vehicles could indirectly create new jobs as users can now spend time working, relaxing or accessing entertainment via mobile Internet instead of driving

Driverless cars, directly or indirectly can also create new jobs (even though they would definitely replace others). These cars could free up as much as 50 minutes a day for users, who instead of driving will be able to spend time working, relaxing or accessing entertainment. According to McKinsey, driverless cars could generate global digital-media revenues of €5 billion ($5.5bn) per year for every additional minute people spend on mobile Internet while in a car.[43] This will undoubtedly create some jobs, in fact KPMG estimate that connected and autonomous vehicles could create an additional 320,000 jobs in the UK by 2030, 25,000 of which would be in automotive manufacturing.[44] Most of the job creation would occur indirectly because of improvements to productivity and greater mobility of workers and in adjacent sectors such as telecoms and digital media as new markets will be created by connected and autonomous vehicles.

[43] Bertoncello M, Wee D, (2015), Ten ways autonomous driving could redefine the automotive world, McKinsey & Company.

[44] KPMG (2015), Connected and autonomous vehicles-The UK Economic Opportunity.

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Drones could potentially replace jobs in delivery services and agriculture but will also create manufacturing jobs as drone demand increases

The use of drones and/or unmanned aircraft systems (UAS) is expected to increase over the years. In fact a company called Measure has just recently been given permission for 324 commercial drones to be used for a number of applications. The Association for Unmanned Vehicle Systems International has stated that precision agriculture and public safety are the most promising commercial and civil markets for drones. They estimate that the economic impact of the integration of UAS into the National Airspace System will total more than $13.6 billion in 2017 and will create more than 34,000 and 50,000 new manufacturing jobs in 2017 and 2025 respectively with a total job creation estimated at 103,776 by 2025 (this includes both direct and indirect jobs). However unmanned aircraft systems will replace other jobs such as some farming jobs (even though the agriculture sector in the US has automated the majority of its processes), surveillance of oil and gas pipelines, construction site monitoring etc. and if Amazon succeeds in using drones for its delivery services, some delivery driver jobs could also be lost.

New Jobs that are ‘Needed’ in Society

There are many other new and emerging jobs that are being created and will continue to be created over time. In this section we focus on two particular industries which are growing — the health sector and the environmental/green sector. Both industries are experiencing growth because there is a particular need or ‘requirement’ for them in today’s society.

The health sector is expected to add more than 4 million new jobs in the US from 2012 to 2022 and is projected to become one of the fastest growing industries in the US economy (Figure 36). Health care job openings in the US have increased by 23% from September 2014 to September 2015, reaching a staggering 852,200 job openings in that time period.[45] In the EU it is estimated that the health care sector accounts for about 17 million of all jobs and is predicted to continue growing with an estimate of 8 million openings between 2010 and 2020.[46] A number of factors are expected to lead to the growth in this sector and therefore job opportunities including: (1) a growing population; (2) an increase in life expectancy; (3) chronic conditions such as obesity and diabetes which increase the demand for health care to prevent, manage and/or treat such conditions; (4) improvement in medicine and technology which is expected to increase the demand for health care services; and (5) more people getting health care insurance (especially in the US).

[45] http://www.indeed.com/jobtrends/healthcare-industry

[46] The European Observatory on Health Systems and Polices, (2014) “Health Professional Mobility in a Changing Europe”, edited by James Buchan, Matthias Wismar, Irene A. Glinos & Jeni Bremner, World Health Organization.

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Figure 36. New Projected Jobs in the US Health Care Sector

Industry sector	New Jobs (projected 2012-22)
Offices of health practitioners	1,226,000
Hospitals - private, state & local	826,000
Nursing and residential care	761,000
Home health care services	716,000
Outpatient, laboratory, and other ambulatory care services	522,000
Total	4,051,000

Source: Torpey (2014)[47], Citi Research

According to the World Health Organization there is currently a global health workforce shortage estimated at 7.2 million professionals and forecast to increase to 12.9 million people by 2035.[48] In the US it is predicted that there will be a shortage of at least 124,000 physicians and 500,000 nurses by 2025.[49] The health systems in most EU Member States are also coming under pressure as a result of people living longer, while its health workforce itself is aging. The European Commission projects a shortage of around 1 million health professionals in the EU in 2020 (590,000 nurses, 230,000 medical doctors and 150,000 dentists, pharmacists and physiotherapists), if no measures are taken to encourage people to work in this sector. In Japan the situation is not much better; it is estimated that an additional 800,000 more health workers would be needed in nursing care in the coming decade, with a shortage of workers estimated at 380,000.[50] The Japanese government is taking steps to secure enough nursing care workers to meet this growing demand, including increasing compensation, providing incentives to lure back staff who have left the industry, and encouraging robot technology to be developed to assist the elderly.

Digital healthcare is increasing the demand for specialised skills

The increase in digital healthcare is also fuelling demand for specialised skills which range from managing electronic records to analysing the data generated by remote patient monitoring devices. For example doctors can now remotely monitor one's heart beat or levels of sugar for diabetes. This generates a mountain of data that needs to be analysed, stored, and acted upon. Technological changes will call for a different type of healthcare worker. In fact the O⋆NET have identified a number of new and emerging jobs in this sector, including bioinformatic technicians, informatic nurse specialists and clinical data managers, which are all estimated to grow well above average.

[47] Torpey, E., (2014), Healthcare: Millions of jobs now and in the future, Office of Occupational Statistics and Employment, Spring 2014.
48 The European Observatory on Health Systems and Polices, (2014) – see footnote above.
49http://assets1.csc.com/health_services/downloads/CSC_US_Healthcare_Workforce_Shortages_Caregivers.pdf
50 http://www.japantimes.co.jp/opinion/2015/07/07/editorials/shortage-of-nursing-care-workers-2/#.VhJO9vlVgXs

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The Green Economy: The Creation and Expansion of Jobs in this Sector

The Green economy is also expected to generate new jobs.

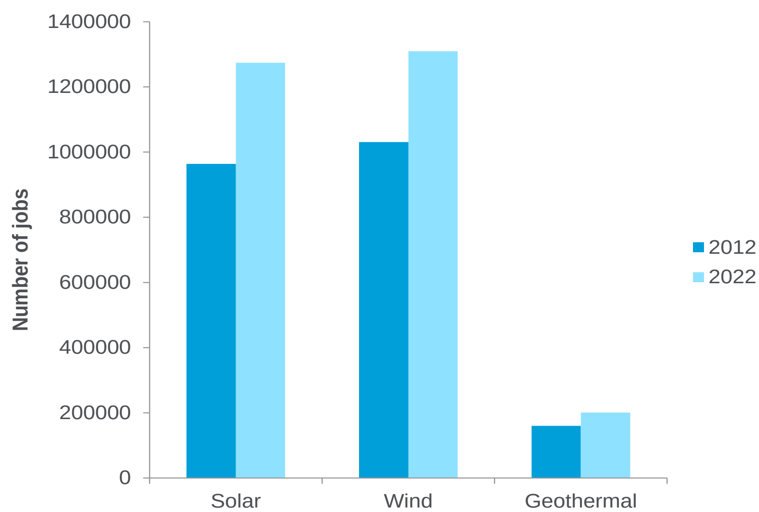
Over the years the 'green movement' has gained public support and new markets and opportunities have opened up in this sector. In the UK, the Office for National Statistics estimated that in 2012 the green economy added £26.3 billion ($37.5 billion) to the UK economy and contributed 357,200 full time equivalent jobs, an increase of 5.3% since 2010. Wastewater and waste management services contributed to the largest value added and employment at £9.4 billion ($13.4 billion) and over 120,000 full time jobs. However other sectors such as renewable energy are also growing.

According to the International Renewable Energy Agency (IRENA), global renewable energy jobs reached an estimated 7.7 million globally in 2014 (excluding large hydropower), which is an 18% increase from the previous year[51] with the majority of the jobs (over 3 million) found in China. The Citi GPS report Energy Darwinism II estimated that the use of renewable energy in the power sector under Citi's 'Action' scenario would increase from 6% in 2012 to 34% by 2040 which will undoubtedly create new jobs in this sector.

700,000 new jobs are estimated in the renewable sector in the US

In the US, there are currently 2.1 million people working in the renewable sector (solar, wind and geothermal). This is number is estimated to increase to 2.8 million by 2022 (Figure 37). These figures could increase even further following the deal being reached on climate change at the UN COP21 meeting in Paris at the end of 2015.

Figure 37. Solar and Wind Jobs



Source: US Bureau of Labor Statistics, Citi Research

It is not just wind turbine engineers and solar panel installers who can look forward to more work, new careers in this sector will spring up across many areas. Most companies today are either measuring or thinking about measuring their greenhouse gas emissions, their water use, and how to make their supply chains more sustainable. Other new and emerging jobs in the US mentioned on the O*NET website include energy auditors (+202,000 jobs in 2022), climate change analysts (+39,700 jobs in 2022), and fuel cell technicians (+99,700 jobs in 2022).

[51] http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2015.pdf

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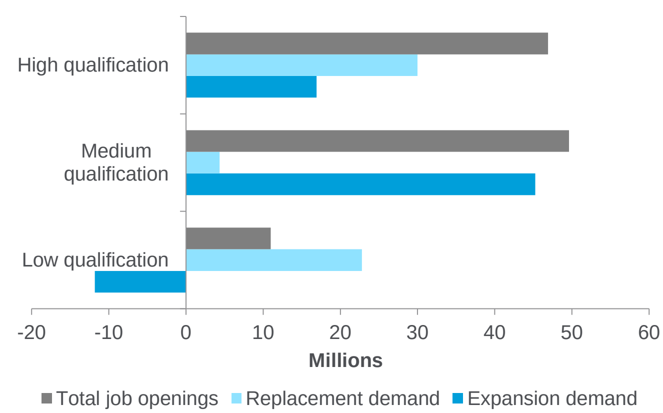
Skills and Qualifications Needed: The Knowledge Driven Economy

“Technology seems to be changing life in a fundamental way and what it’s leaving people thinking is ‘where will I be in 30 years?’ Look how fast everything is changing now. Where will my children be? I want to leave something for them because they could be in terrible straits”. This quote by economics professor and Nobel Laureate Robert Shiller sums up the fears that people are having on the advancement and acceleration of technology, be it at work, in everyday life, or in the choices that they make.

The new types of jobs forecast for the future will require people to be highly skilled — i.e. 46 million job openings in the EU will be for jobs requiring high-level qualifications

How can we better prepare ourselves for such a change and ensure that we have the adequate skills to ensure future employment? The new types of jobs that are being created over the next decade will require people to be highly skilled with the know-how required to create the next generation of products and services. The increasing use of technology and the drive for productivity will raise the demand for high skilled workers, while in some cases depressing growth for low skilled workers. Cedefop estimate that of the 107 million job opportunities in the EU projected from 2013-2025, about 46 million will be for jobs requiring high-level qualifications, 43 million for medium-level qualifications and 10 million for low- or no-level qualifications- mostly due to replacement demands (refer to Figure 38). In terms of absolute numbers, in 2025 the proportion of people with high, medium and low qualifications is forecast to be 39%, 44%, and 15%, respectively (Figure 39). The US shows a similar picture with occupations that typically require a Master’s degree for entry predicted to grow the fastest (18.4%) from 2012 to 2022, however the majority of the job openings from 2012 to 2022 are projected to be in occupations that typically can be entered with a high school diploma (4.6 million jobs). These occupations include retail salespersons, combined food preparation and serving workers, and secretaries and administration assistants. If economists and IT experts are correct some of these jobs and others could be automated.

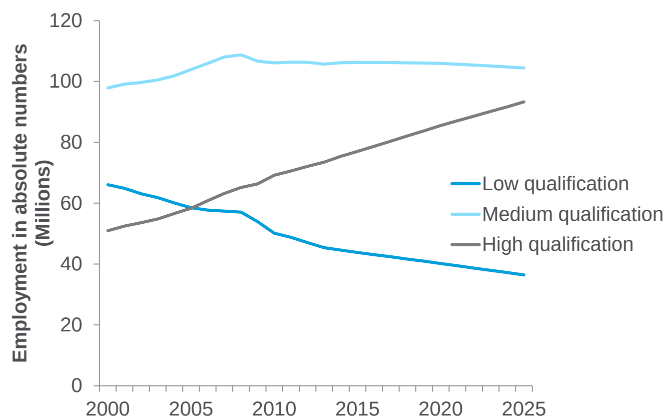
Figure 38. Total Job Openings in the EU by Qualification (2013-2025)



Source: Cedefop, Citi Research

** High level qualification refers to tertiary education, medium level refers to upper and post-secondary education and low is (pre) primary and lower secondary education

Figure 39. Employment in the EU (absolute numbers) by Qualification



Source: Cedefop, Citi Research

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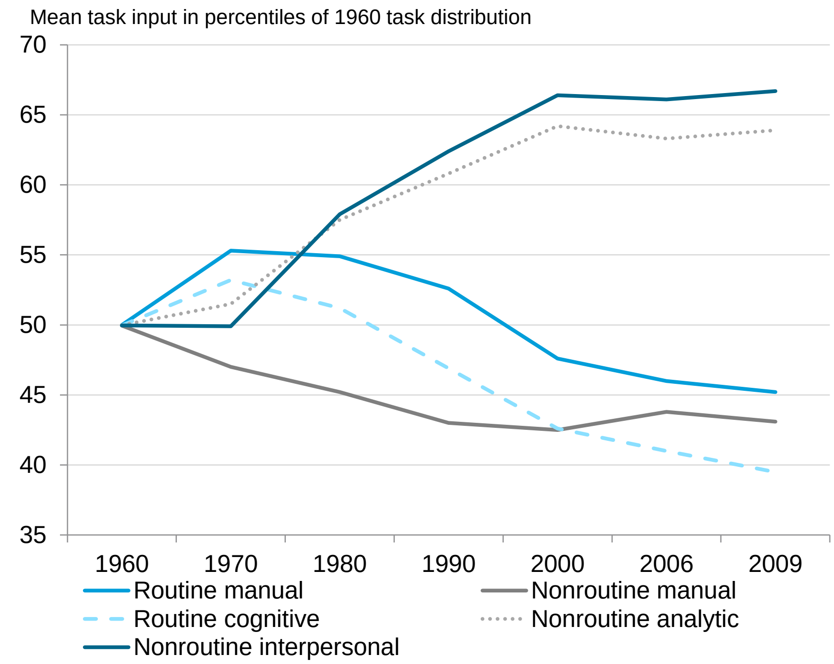
There is a skills mismatch between current worker skills and future job skill requirements

Are we prepared for such a change? A charity called Go.On.UK has stated that currently in the UK, over 12 million people and a million small businesses do not have the skills to prosper in the digital era. The organisation produced a digital exclusion heat map showing the areas in the UK that are most likely to miss out on the digital revolution. McKinsey estimate that by 2020, there will likely be a shortage globally of 40 million high skilled workers unless adequate training and education is given.[52] They state that technological innovation will demand a new set of skills in the workforce; it will change work tasks, automate jobs and also increase the skills gap for the jobs that remain.

This skills mismatch gap has occurred in the past and we got past it

However, this is not something new. We have already seen this happen and we have managed to cope with such changes even though our work and skills have changed. Autor and Price (2013) analysed the change in job tasks in the US from 1960 to 2009 (Figure 40). They argue that the share of non-routine analytical and interactive job tasks (tasks that require expert thinking and complex communication skills) performed by American workers has increased steadily since 1960, whilst the share of routine cognitive and manual tasks began to decline in the early 1970's and 1980's — coinciding with the introduction of computers and automated production processes. The share of non-routine tasks also declined over the years but stabilised in the 1990's, possibly due to the fact that some of these tasks could not be computerised.

Figure 40. Trends in Routine and Non-Routine Tasks in Occupations (US, 1960 to 2009)



Source: Source: Autor and Price (2013)[53], Citi Research

** Routine cognitive tasks such as book keeping and data entry; Routine manual tasks such as repetitive production and monitoring jobs performed on an assembly line; Non-routine analytical- requires analytical skills such as engineering and science, Non-routine interpersonal involving managerial and interpersonal skills, Non-routine manual which demand situational adaptability, visual and language recognition and in-person interaction

[52] Dobbs, R., Manyika, J. and Woetze,l J., (2015), How US Companies Can Fill the Skills Gap, McKinsey Global Institute.
[53] Autor, D.H., & Price, B., (2013), The Changing Task Composition of the US Labor Market: An update of Autor, Levy and Murname (2013).

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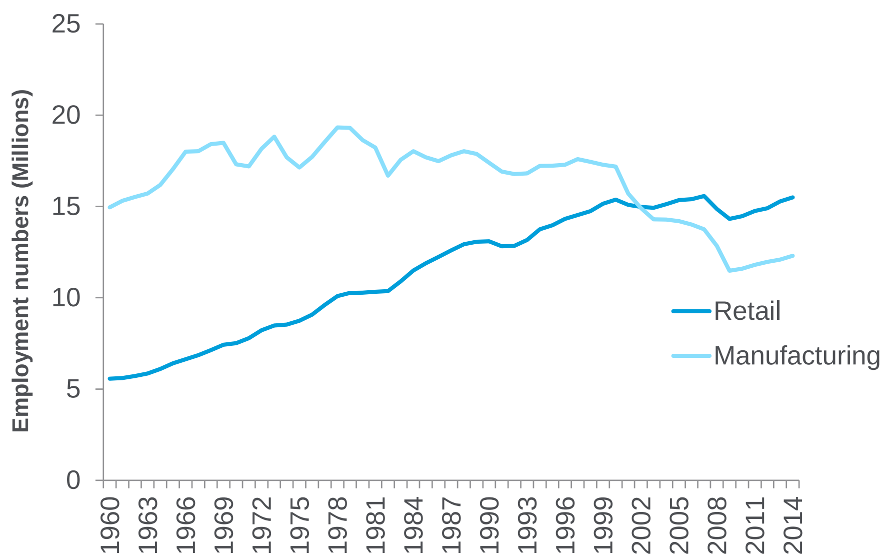
As manufacturing jobs declined in the US, retail jobs increased, skill sets adapted to this change

During this period the US economy changed from a manufacturing to a service economy. Beginning in the 1970s and continuing to pick up speed in the 1990s with the opening up of trade with China, India and Eastern Europe, competition from foreign imports forced US firms to outsource or automate their manufacturing process. This led to a reduction in manufacturing jobs in the US, estimated at 2.6 million between 1960 and 2013 and 7 million between 1978 (when manufacturing was at its highest) and 2014.[54] However, during this period the unemployment rate in the US remained at an average level, even though different US states were affected by this change. As manufacturing jobs declined, retail jobs took over, increasing from 5.5 million in 1960 to 15.5 million in 2014 (Figure 41 below). This parallel shift from manufacturing to a service economy also led to the parallel shift from a high school to a college economy. This prepared the workforce for an attainment of higher skills and enabled other industries to expand, such as business and financial services. Skill sets did change over time with highly analytical and managerial skills increasing over this period but the US workforce had time to prepare and was ready for such changes.

Figure 41. US Employment in Manufacturing and Retail Industry, 1960-2014



Source: US Bureau Labor Statistics, Citi Research

The difference between now and then is the speed of change, meaning we need to enhance current skills to adapt quickly

So is it different this time? One of the differences lies in the speed of change, with technology already affecting the type of tasks that we are required to do in today's workplace. This means that we have to adapt quickly and enhance our current skills to reflect what is needed; not a simple task. In the past moving from a manufacturing job to a retail sales job demanded a change in skills, albeit a set of skills — interpersonal skills, customer services and sales skills — that could be easily obtained through training. This training was usually provided on site and could last from a few days to a few months depending on the type of business. However, training to become, for example, a data scientist requires an advanced quantitative degree in mathematics and statistics, computer science or engineering (88% of the people applying for data scientist roles have at least a Master's degree and 46% have a PhD).[55] Acquiring such high skills is not an easy task, and requires an investment in education and training for a number of years.

[54] US Bureau of Labor Statistics.

[55] Burtch Works, 'The must have skills you need to become a data scientist'.

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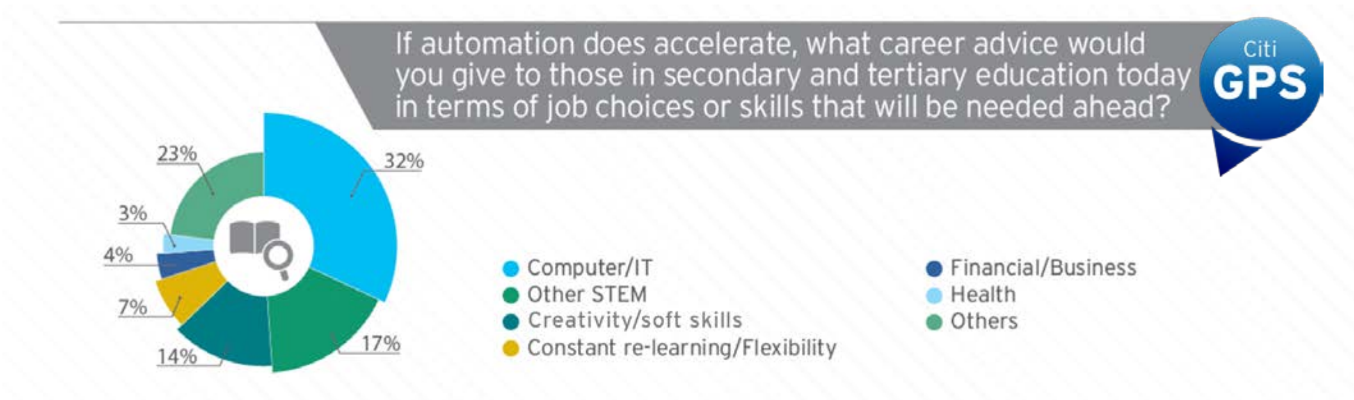
The respondents to our survey believe that IT skills and STEM subjects are important for future work

Outside of skills related to data scientists, what skills should individuals obtain to ensure that they have a good job in the future? Citi asked its institutional clients this question, and over 52% of the respondents thought that one should definitely have some sort of IT/computer skills, whilst 17% mentioned other STEM subjects such as mathematics and physics (Figure 42 below). Surprisingly (or maybe not) over 14% also mentioned the importance of creativity and soft skills and 7% mentioned that we need to be constantly re-learning and be flexible in our job choices. One quote by a respondent captures the spirit and importance of creativity skills and constant re-learning brilliantly:

> "*Focus less on pure academics, and more on creativity and presentation skills. The enormous likelihood is that however good you are at STEM subjects, there are likely to be people in the world who are infinitely better than you — this is to say nothing of the computers that will eventually take over all STEM related roles. Communication skills, creativity and the ability to adapt to change are hugely more valuable and a much better differentiator medium-term".*

Figure 42. Where Should Individuals Focus their Learning?



Source: Citi Research

Other studies have highlighted the importance of adapting our current skills for future employment. One such study is the work that has been done by the Institute for Future Work, which identified ten skills as being important and most relevant to the workforce of the future. These include:

- Sense-making - the ability to determine the deeper meaning of significance of what is being expressed,
- Social intelligence
- Novel and adapting thinking
- Cross-cultural competency
- Computational thinking
- New Media Literacy
- Transdisciplinarity - literacy in and the ability to understand concepts across multiple disciplines

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- Design mindset - ability to represent and develop tasks and work processes for desired outcomes
- Cognitive load management- ability to discriminate and filter information for importance
- Virtual collaboration – the ability to work productively, drive engagement, and demonstrate presence as a member of a virtual team

Geoff Colvin in his book '*Humans are Underrated: What High Achievers Know That Brilliant Machines Never Will'* states that our inbuilt propensity for social interaction, communication, and empathy is what makes people special — something that machines can never replace. According to the author, these are the qualities that women are exceptional at, putting them in the driving seat. In our Citi GPS report 'Women in the Economy', we highlighted the importance of women in the labour market, where even just a 50% reduction in the gender gap in the labour market can lead to a 5% increase in global GDP. With an even more important role to play in the digital economy, women can become an even greater asset in the labour market.

Predicting what future jobs and skills might be available or needed in the future is extremely difficult. O*NET uses the US Bureau of Labor Statistics data that analyses future employment for approximately 300 detailed industries and 800 occupations. The accuracy of projections of these individual occupations is subject to error because of the many unknown factors that may affect the US economy over the time period studied. Other jobs that the data highlight as 'bright outlook' jobs include traditional jobs such as baristas (268,000 job openings from 2012-2022), child care workers (570,000 job openings), and lawyers (197,000 job openings) which are all estimated to increase over the time period.

Innovations in technology are likely to continue to reduce the need for labour to do routine work and cognitive work in the near future; however this is not to say that labour markets would not absorb the impact, as technology has been making inroads into labour for a number of decades. The nature of work will likely change and the new jobs that will be created will require a different skill set to the ones that we currently have or are training for. We therefore need to be better prepared, and aim to achieve skills that will allow us to work with machines rather than compete against them. Government, lawyers and educational boards should be better prepared to handle such changes. What is clear is that the largest job openings are expected in the health sector, this is not surprising given that we are living longer-demographic change is occurring in advanced and some emerging countries, this is discussed in more detail in the next chapter.

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Demography vs Automation: Will We Run Out of Workers or Out of Jobs?

Highlights

- The working age population in industrial countries peaked in 2011 at 388 million and is expected to decline by 30 million by 2030. Growth in working age populations for industrial countries has slowed from 1% per year in 1970-90 to 0.4% per year in 1990-2010 and is expected to fall by 0.3% per year over the next 20 years. Growth in human capital may also slow.
- We calculate that the change in demographics could impact living standards by about -0.2% per year over the next 20 years, or the equivalent of 26 million workers.
- Incremental productivity gains through automation could plausibly offset the demographic developments in a number of countries. However automation could pose more risks to jobs than demographic changes.

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The long-running decline in fertility rates in industrial countries over the last few decades — the average number of children per woman has fallen from 2.8 in 1960 to 1.7 recently — is leading to some major demographic changes. According to UN data, the working age population (defined as the population ages15 to 64) in industrial countries peaked in 2011 at 388 million people and is expected to decline by roughly 30 million people by 2030. In Japan, the working-age population (WAP) already peaked in 1995 and in Germany in 1998 (even though most recently, high inward migration is leading to some growth in the working-age population); while in the US the peak is projected to occur in 2026.

Median population ages have been rising in most industrial countries

The recent decline in working-age populations and its projected continuation, stand in sharp contrast to previous decades. Between 1995 and 2011, the working-age population in industrial countries increased by roughly 50 million, after increasing by roughly 70 million between 1980 and 1995. Even though globally the working-age population is still growing (and indeed foreseen by the UN to continue to grow for the rest of this century), declining working-age populations are not exclusively an industrial country phenomenon: for instance, working-age populations in Eastern Europe peaked in 2008 and in China in 2014. In general, the peak in total populations is expected to follow the peak in working-age populations with some delay (e.g. for the industrial country age, the total population is expected to start falling in 2041). Meanwhile, as fertility rates have fallen and life expectancy risen, median population ages have been rising in most industrial countries, from 29.5 years in 1960 to 34.4 in 1990 in the industrial country average, reaching 41.0 years in 2014. By 2030, the median age will probably have gone up by another 3-4 years (Harper, 2014).[56]

[56] Harper, S., (2014), Economic and Social implications of Aging Societies, *Science*, Vol 346, Issue 6209.

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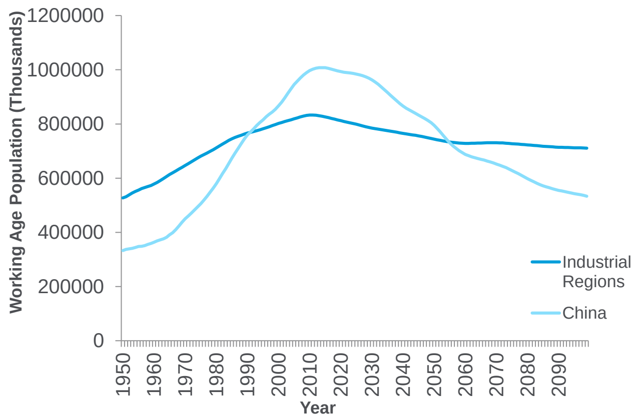
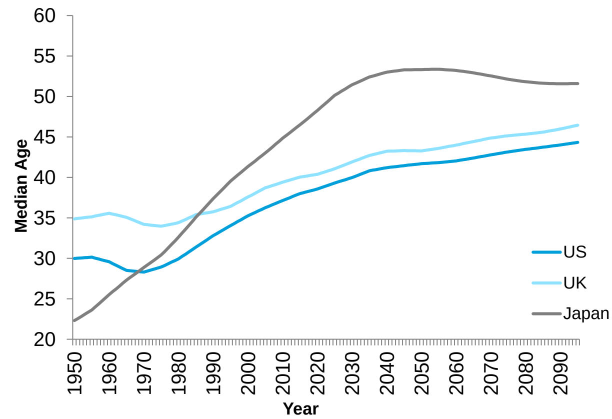
Figure 43. Peaking of Working Age Population in Industrial Regions and China



Source: UN Population Statistics, Citi Research

Figure 44. Median Age in US, UK, and Japan



Source: UN Population Statistics, Citi Research

The fall in working-age populations and the projected continued decline has been cited as a major drag on future growth — indeed, a slowdown in population growth was at the heart of the original 'secular stagnation' hypothesis of Alvin Hansen in the 1930s. The question is therefore whether, far from being a challenge that needs to be addressed by policy, technological change, including automation, could be the answer to the challenges that demographic developments pose.

Demographics and Economic Growth

Demographic changes can affect labour force, investments in capital and improvements in factors of production

Demographic developments can have a very significant effect on economic growth prospects. In a stylised way, economists think of potential growth as reflecting the contributions of growth in the size of the labour force, investments in capital and improvements in the efficiency of using the factors of production (labour and capital), including through technological innovation. Demographics can have an effect on all three.

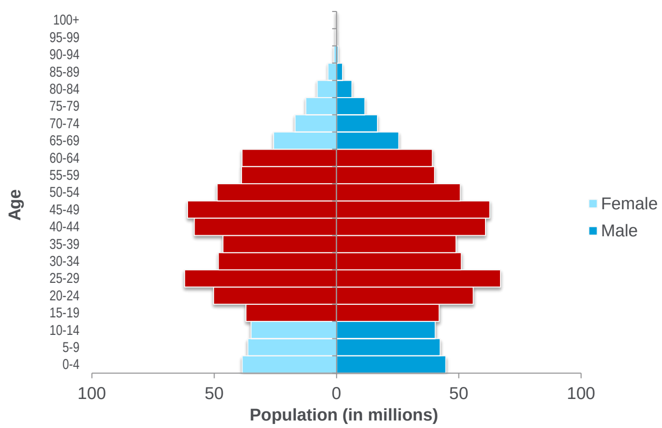
The labour supply effect alone could slow down growth by 0.5% per year in industrial countries

The most direct effect of demographics on growth may be through its effect on the labour supply. Growth in working-age populations for industrial countries has indeed slowed down substantially, from around 1% per year in 1970-90 to 0.4% per year in 1990-2010. Over the next 20 years, the UN predicts the average working-age population in the advanced economies to *fall* by 0.3% per year. In addition to the slowdown in the growth of the working-age population, the growth in 'human capital' may be slower than previously, as a lot of the low-hanging fruit as regards educational improvements may have been plucked: primary- and secondary-school attendance in industrial countries is nearly universal and improvements in tertiary education may not be equivalent to the overall improvements in educational coverage in previous decades. But abstracting from changes in educational quality, the labour-supply effect alone may imply that demographics would slow down average growth prospects in industrial countries in the order of around 0.5%pa over the next 20 years relative to the 1990-2010 period.[57]

[57] As noted above the difference in average growth of the WAP is around 0.7% per year. To arrive at the rough effect on growth, this difference needs to be multiplied by the share of labour in production, which we assume to be two thirds.

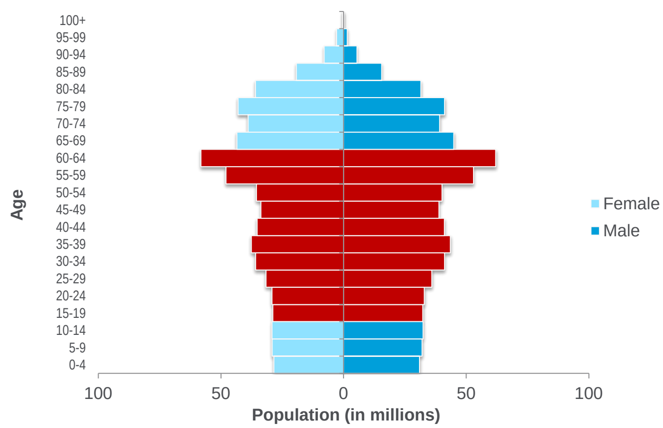
The effect of falling WAPs on GDP growth is not limited to its effect on the labour supply. There are good reasons to believe that slower population growth and older populations may weigh on investment and perhaps efficiency, too, even though in principle the effects could go either way. For investment, smaller populations (or at least slower population growth) may mean that existing capacities may suffice for longer and therefore lower investment needs. Or falling WAPs may push up wages and therefore increase the incentive to substitute capital for labour. Similarly, older populations may have bias political economy incentives against production and therefore hurt efficiency. Or a shortage of workers may stimulate labour-saving technology — after all, the drive to install robots in Japan has been linked to its poor demographic prospects.

Figure 45. China's Population Age Structure in 2015



Source: UN Population Statistics, Citi Research

Figure 46. China's Population Age Structure in 2050



Source: UN Population Statistics, Citi Research

Overall, slower population growth is, other things equal, likely to be associated with slower GDP growth. However, when it comes to standards of living, it is mostly GDP growth *per capita* rather than GDP growth that is of interest. But GDP growth per capita is also likely to be dampened by lower population growth. The reason is that, at least for some time, lower working-age population growth is likely to be associated with rising dependency ratios (the ratio of those of working-age population relative to those too young or too old to work). The average dependency ratio (specifically the number of people aged up to 15 and above 64 divided by the number of people aged 15-64) in industrial countries fell from 58 per 100 people in 1960 until it troughed in 2005 at 47.5. In 2014, it stood at 50.8 and continues to rise quickly. By 2030, the UN estimates the average dependency ratio to be 64, with the dependency ratio to be around or above 70 in Germany, Italy or Japan (the dependency ratio in the US and UK is forecast to be close to the industrial country average).

China's dependency ratio is set to increase from 36 in 2014 to 70 by 2050

In China, the rise in dependency ratios is also likely to be quite dramatic, in part due to its ill-fated one-child policy: China's working-age population is expected to decrease from 1 billion people in 2015 to 960 billion in 2030 and 800 billion people in 2050, whilst its population aged 65 and over is projected to increase by 240 million people by 2050 (Figure 45 and Figure 46). Its dependency ratio is set for a steep rise: from 36 in 2014 to 47 in 2030 and 70 by 2050.

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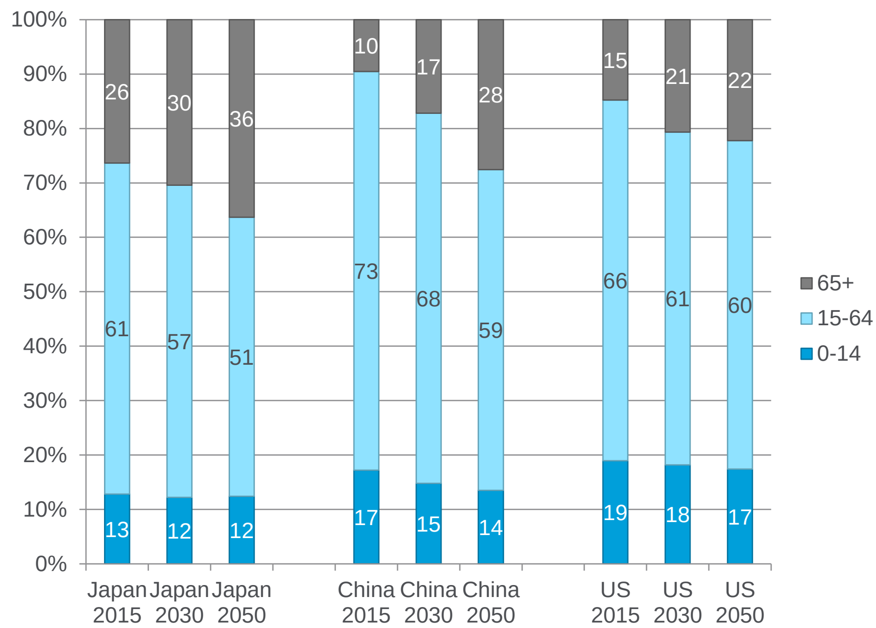
Figure 47. Comparison of Population by Age Group in Japan, China, and the US Under a Medium Fertility Scenario (%)



Source: UN population estimates, Citi Research

Another way to illustrate the rise in dependency ratios in various countries is to plot the change in the population shares of those below and above working-age, as in Figure 47. There we see in particular how the share of those above 65 years of age is set to rise strongly in China and Japan in coming decades (and somewhat less so in the US).[58] Therefore it is not a surprise that we many job openings in the health sector as described in the previous chapter.

To keep the WAP ratio constant at 2015 levels, 26 million additional workers would be needed

Similar to our basic calculations above, we can quantify the direct effect of changing demographics on the growth of GDP per capita: above we highlighted that the estimated slowdown in GDP growth due to slower growth in WAPs in the industrial country average would be around 0.5% per year. Meanwhile, the slowdown in population growth between say 1990-2010 and the next twenty years is estimated to be in the order of 0.3% per year. These basic calculations therefore suggest that the direct cost to living standards due to demographics may be around 0.2% per year. Another way to illustrate the demographic effects is that to keep the WAP ratio in industrial countries constant in 2035 at estimated 2015 levels, we would need 26 million additional workers.

[58] According to the Pew Research Center the principal driver of US population growth is likely to be immigration; the US is home to more immigrants than any country estimated at 42.8 million people in 2010. Source: Pew Research Center, 2014, Attitudes About Aging: A Global Perspective.

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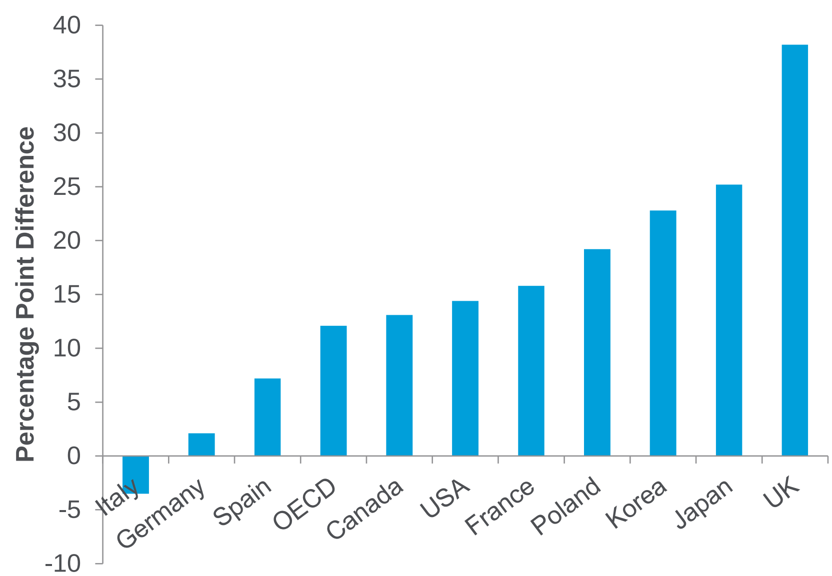
These are simplistic calculations, of course. Various indirect effects are likely to apply. We mention two: (1) congestion and depopulation effects and (2) political economy effects.

- **Congestion and depopulation.** Above we noted that GDP growth may be less relevant than GDP growth per capita. But economies or diseconomies of scale may apply. The former are particularly relevant when there are fixed costs of production or operation. For instance, a road or a school may be economic when there are sufficient users and prohibitively expensive when there are too few. Conversely, a congested road may increase travel times substantially. The net overall effects of these non-linearities for economic growth are difficult to sign, let alone quantify.

- **Political economy.** Political economy factors are highly likely to have a significant impact. As we noted above, median population ages are rising across the advanced economies (and many emerging markets). Meanwhile, turnout rates tend to be higher for older people. For instance, in the 2012 US election, the voter turnout rate for those 60 years and above was roughly 70%, compared to 40% for those between 18-29 years and around 55% for those 30-44.[59] Unless these patterns reverse dramatically, population aging is therefore likely to put more political power into the hands of the old.

Figure 48. Percentage Point Difference in Voting Rates Between Those 55+ Years Old and Those 16-35 Years Old



Source: OECD[60], Citi Research

What effects such shifts in the demographic balance of political power can have is difficult to predict, but the presumption should be that, given that a rising share of the electorate will be in retirement, these shifts may be growth-unfriendly, other things equal.

[59] Source: http://www.electproject.org/home/voter-turnout/demographics
[60] OECD, 2011, Society at a Glance.

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An increase in labour force participation, migration and increase in fertility rates could all be solutions for demographic challenges

However, there are likely to be some mitigants for the demographic effects on growth, including longer (and often healthier) working lives (and higher participation rates for the old), policies to boost fertility and increased scope for migration to advanced economies.

- **Labour force participation**. In the Eurozone, the labour force participation rate for those aged 65-69 rose from 7% in 2005 to 10% in 2015. In the UK, the increase was from 15% to 22%, while average participation rates for the old have also increased in Japan and the US. Policies to increase labour force participation rates are increasingly prominent, including to tighten benefit eligibility for the inactive (e.g. in the UK) and policies that would boost participation rates for women (e.g. in Japan).[61] However, on average older workers tend to work less hours and are somewhat less productive than the average workforce: one study suggests that the combination of the two implies that a worker above 65 will tend to add just below 80% of the productive potential of the average worker below 65.[62]

- **Migration.** Migration rates could potentially pick up, even though for now there seems little political appetite to allow large-scale migration (which, given that the demographic challenges affect a large number of advanced economies, would mainly have to be migration from EMs to advanced economies). The UN estimates that total migration to 'more developed regions', which include all of Europe, North America, Australia/New Zealand and Japan, is expected to amount to less than 12 million people over the 2010 period, or roughly 0.2% per year. The future projections imply a roughly stable flow of net immigrants (which is already incorporated into the projections for the total and working-age population cited above).

- **Fertility.** Some countries are also trying to boost fertility rates. For instance, China's recent decision to formally scrap its one-child policy should be seen in that context, even though it remains unclear how effective this move will be in raising birth rates and any effect on working-age populations will be many years in coming.

Despite these mitigants, the economic effects of demographic change could well be significant, even though these effects may also differ quite widely across countries. The economic effects of demographic change are not limited to those on growth only. For instance, demographic changes may have distributional effects, too. As noted above, a shortage of workers could lead to higher growth in average wages and rising labour shares and therefore potentially reverse some long-standing distributional trends in many advanced economies, including in income and wealth inequality — and those distributional effects may be more welcome than the dampening effect of falling WAPs on average growth rates. In addition, shrinking and aging populations would, other things equal, likely have significant implications for interest rates and inflation, too.

[61] Women in the Economy, Global Growth Generators, Citi GPS. https://www.citivelocity.com/citigps/ReportSeries.action?recordId=37&src=Home
[62] Barry Bluestone and Mark Melnick, 2010, After the Recovery: Help needed, The coming labour shortage and how people in encore careers can help solve it.

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Can Automation Offset Demographics?

A central thesis of our ongoing work on technological change and innovation has been that these changes are significant in both a micro and a macro sense. Pinning down the precise effects remains difficult, but the above rules of thumb at least give us a sense of how significant technological innovation needs to be to offset some of the economic effects of demographic change.

Embracing automation could also be solution to demographic change; a strategy that is being pursued in various countries

Above we derived simple estimates of the economic effect of demographic change on the workforce, which suggested that those effects could be in the order of 0.2% per year or 26 million additional workers over 20 years. Could innovation therefore offset the (macro) effects of demographic change? Indeed, embracing automation has been among the strategies being pursued by various countries, including China and Japan, to address demographic developments.

Automation could pose more risks than demographic changes

Even though forecasting the contribution of demographic change remains extremely uncertain, we suspect that the answer is therefore quite conceivably yes. For instance, a previous Citi GPS report highlighted that up to 47% of current US employment is at risk of being automated, a report by Deloitte and Frey and Osborne (2014) suggested 35% of UK jobs are similarly at risk and a Nomura and Oxford Martin School study put the share of Japan's workforce at risk at 49%.[63] Even though these shares are not to be interpreted as productivity gains, they suggest to us that the incremental productivity gains are potentially very significant and could plausibly offset the demographic developments. However when we compare the effect that automation could have on the labour force itself we could potentially see a different picture. For example Japan faces a large demographic challenge ahead with 8 million additional workers (12% of working age cohort in 2030) needed in 2030, if they are to maintain the same working age ratio as 2015. This is below the potential jobs that could be susceptible to automation (49%). So ultimately automation could pose more risks to jobs than demographic changes.

However, we caution against seeing the race between demography and automation as purely one-dimensional. Both developments are multi-faceted and the effects of each are unlikely to always be offsetting. For instance, above we noted that demographic change is likely to have a number of political economy consequences, including through the rising political power of the old. Those are unlikely to be significantly altered by automation (unless the robots rapidly acquire voting rights) and are likely to have significant economic, social and political consequences, even if they are hard to predict for now.

The effects of demography and innovation are unlikely to offset each other exactly at the individual or sectoral level

In general, the effects of demography and innovation are unlikely to offset each other exactly at the individual or sectoral level, even if they happened to do so in the aggregate. That is, those losing their job to a robot, will not necessarily land an equivalent job of someone who just retired. And those benefiting from technological innovations will not necessarily see their benefit withered away by increasing prices of other goods they demand. In general, the supply and demand effects of demographic change on the one hand and automation on the other may only in part overlap, if at all, for individuals and sectors.

At the policy level, that means that rather than offsetting the challenges from shrinking and aging populations, rapid technological change may offer another layer of growing challenges, potentially complicating the necessary policy response and possibly magnifying it.

[63] The Wall Street Journal, "Nearly half all jobs in Japan could be done by robots, AI: report", December 3rd 2015.

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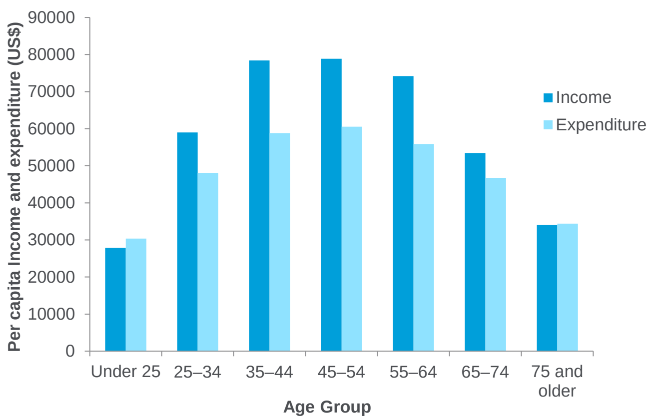
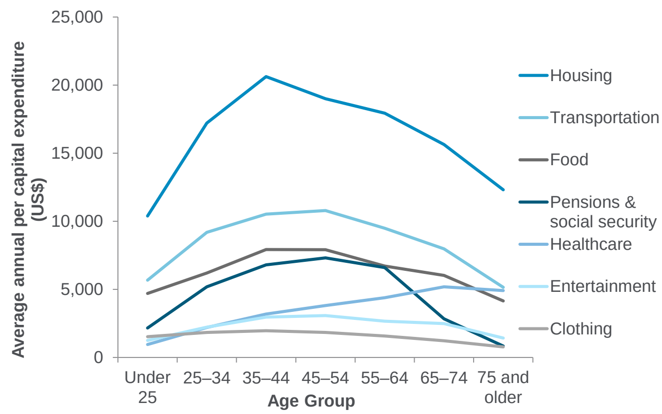
At the industry level, that means there will be opportunities as well as challenges, too. Demographic effects in each sector reflect the fact that spending levels change dramatically over the consumer's life cycle. Figure 50 below illustrates this point for seven sectors in the US. Each sector with the exception of healthcare exhibits an inverted-U shape; this shows how consumers increase spending through their mid-life years and reduce spending when they get older. The demand for health care is likely to rise substantially as populations age, and in particular countries, such as China, where healthcare remains underdeveloped. Meanwhile, it remains to be seen how well technologies can progress to satisfy the increased demand. On the other hand, transport services are among those that may be less in demand as populations age, while innovation in transport, including driverless cars, is likely to be rapid. In fact per capita spending in the US on transport declines by 48% going from the 45-54 to 75+ age group. In total it is estimated that cumulatively through 2030, the evolution of demographics in the US will subtract $360 billion from personal consumption expenditure to the current demography to growth.[64]

Figure 49. Average Annual Per Capita Income and Expenditure (US$ in 2013)



Source: BLS[65], Citi Research

Figure 50. Average Annual Per Capita Expenditure Based on Age Groupings and Sectors (US$ in 2013)



Source: BLS, Citi Research

In conclusion demographic change is likely to have a number of consequences to an economy. Automation could offset some of the macro effects of demographic change - however this will depend on a number of factors as described above. Automation is seen in a number of countries as a solution to demographic challenges in lieu of the fact that it could ultimately increase productivity- however we are currently facing a productivity paradox- this is described in more detail in the next chapter.

[64] [Perspectives: How Demography is Transforming Consumer Spending: Evidence from the United States]

[65] Bureau of Labor Statistics, Consumer Expenditures Vary by Age, December 2015

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Impact of Automation on Productivity: Are Traditional Measurement Tools Failing to Capture Productivity and GDP Improvements?

Highlights

- We face a productivity paradox - if technological progress and innovation are so rampant, why do we not see it in the productivity statistics? Across advanced economies, labour productivity growth has slowed from 4% in 1965-75, to about 2% from 1975-2005 and 1% from 2005-2014.
- Rather than a view that the 'low-hanging fruit' of innovation has been plucked we see limitations in the current measurement of productivity, a lag effect in measurement and a wider distribution of productivity across firms and workers
- In our client survey 81% responded that technological developments are inadequately reflected in productivity statistics and 95% expect automation and technology will drive some kind of an increase in productivity growth over time.

The New Productivity Paradox

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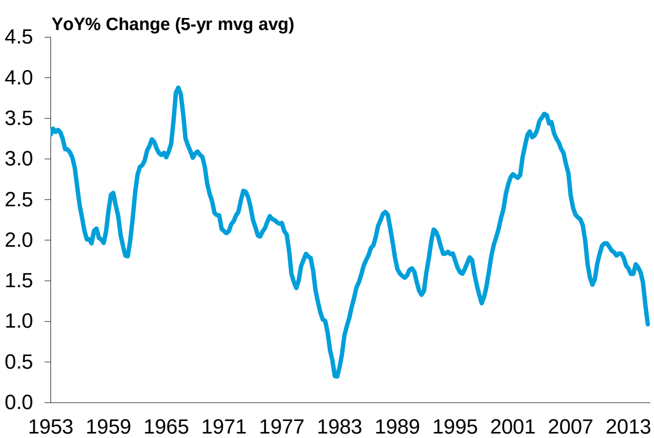
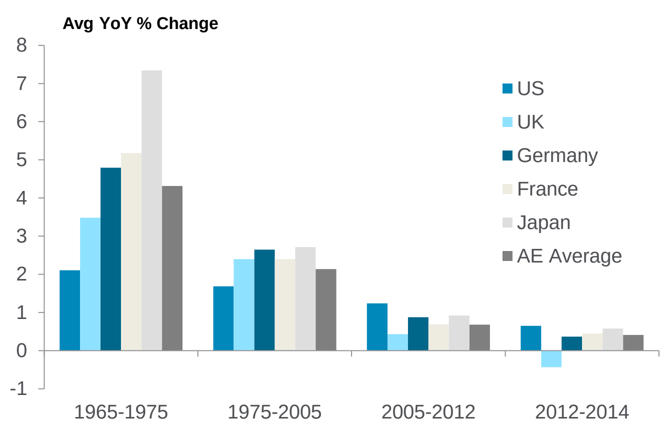
If technological progress and innovation are so rampant, should we not expect to see it in productivity statistics? Yet, across the advanced economies (and many EMs), measured productivity growth is low in historical comparison (see Figure 51). Across the advanced economies, labour productivity (LP) growth has on average slowed significantly, from around 4% in 1965-75 to roughly 2% from 1975-2005 and 1% from 2005-14, with no sign of a pickup in the most recent data (see Figure 52).[66]

Figure 51. US: Labour Productivity, 1953-2015



Note: Defined as real output per hour worked in the nonfarm business sector.
Source: BLS and Citi Research

Figure 52. AE: Avg Labour Productivity Growth, 1965-2014



Source: Conference Board and Citi Research. Note: LP is defined as real output per hour worked. The AE average series is GDP weighted including 35 AEs, where the weights are time varying depending on data availability.

66 These numbers refer to a GDP-weighted advanced economy index of LP growth rates, using Conference Board data. For the advanced economy-ex-US aggregate, the numbers are 5%, 2.5% and 1%, respectively.

One interpretation of the low growth in measured productivity is that it refutes the narrative that innovation is vibrant. Indeed, some have argued that the 'low-hanging fruit' of innovation have been picked, as the benefits of previous transformative innovations (such as electrification or indoor plumbing) have been exhausted and that recent innovations have been much less significant than innovations in the past.[67]

We offer three explanations for the low growth in measured productivity

In our view, three alternative explanations are more relevant. First, we point to several limitations in the measurement of productivity. Second, even though productivity may not be mis-measured in a strict sense, changes in the composition of production have taken place that imply a wider distribution of productivities across firms and workers. In addition, it is likely, in our view, that sometimes the drastic changes in technology we see today require significant adaptation and learning to develop their full productive potential and there is reason to believe that the progress in various technologies seen to date will spawn even more significant innovations in the future.[68]

Measurement Issues

The view that current national account statistics are increasingly inadequate for modern economies and are therefore in need of some overhaul is gaining currency and has e.g. in the case of the UK led to an official review to suggest improvements in the statistics.[69]

National accounts statistics are underestimating quality improvements in several areas

There is indeed evidence that current national account statistics probably understate quality improvements in a number of areas. Such understatements of quality improvement seem to be particularly evident for IT-related activity, such as the production of software (see Figure 53), where Copeland (2013) found that the US national account statistics probably understate the improvements in the quality of pre-packaged software by a factor of two.[70] Other areas where quality improvements are probably insufficiently reflected are healthcare, education, government services, R&D and transportation.[71] Note that for such mis-measurement to account for even part of the slowdown in measured productivity; its scope must have grown over time. However, in our view, there is good reason to believe so, as the share of the sectors most likely to be affected by such biases has grown over time.

[67] See e.g. Tyler Cowen (2011), "The Great Stagnation." Also, Robert Gordon (2014), "The Demise of U.S. Economic Growth: Restatement, Rebuttal, and Reflections," NBER Working Paper No. 19895.
[68] Our clients are also skeptical that a slowdown in innovation is to blame for the productivity slowdown in advanced economies, with a slowdown in investment and measurement problems the most widely cited factors.
[69] See https://www.gov.uk/government/publications/review-of-economic-statistics-call-for-evidence/press-notice-charles-bean-kicks-off-review-to-future-proof-uk-statistics
[70] See Copeland (2013), "Seasonality, Consumer Heterogeneity and Price Indices: The Case of Pre-Packaged Software", Journal of Productivity Analysis, February 2013. Quality improvements for non-prepackaged software (custom and own-account software) are likely to be even more understated, as the methodology used for those product types does not incorporate much scope to reflect improvements in quality.
[71] To potentially explain the slowdown in measured productivity, it is not sufficient that quality improvements may be understated, but rather they would need to be *increasingly* so. Even though an increase in the size of the bias for these products is often hard to establish, the growing size of the relevant sectors would suggest that a stable bias per sector indeed suggests an increasing overall bias in understating quality improvements.

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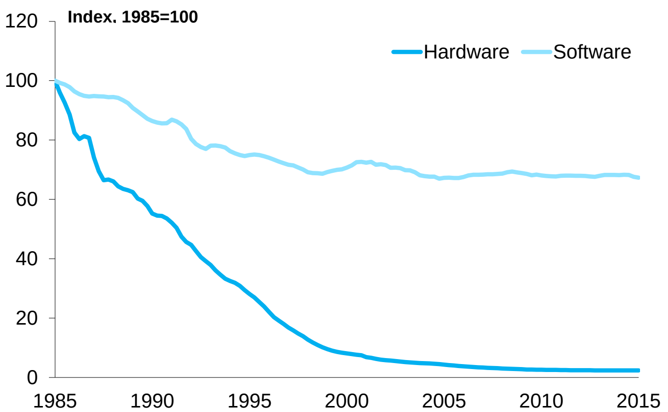
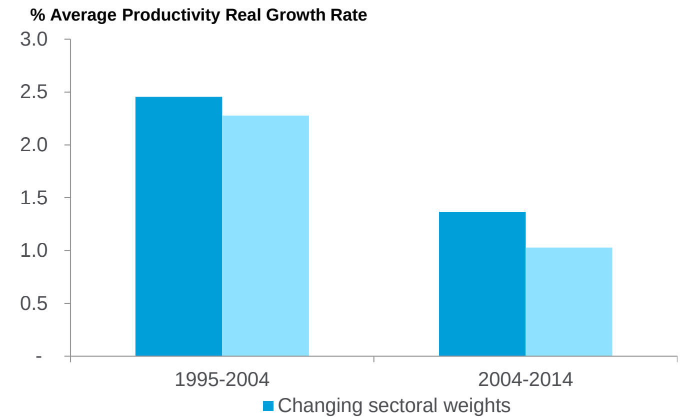
Figure 53. United States – IT Hardware vs. Software Chained Price Indexes (1985=100), 1985-2015



Note: Hardware refers to the 'computers and peripheral equipment' component of non-residential fixed investment.
Source: BEA and Citi Research

Figure 54. Graph with Productivity Growth Based on Old Weights



Note: The custom and own-account deflators are virtually identical, due to a similar way in which the indexes are calculated. The Copeland (2013) line adapts the pre-packaged software deflator by applying the bias found in Copeland (2013) from 1996 to 2013.

Source: BEA, Copeland (2013) and Citi Research

Some types of activity do not appear at all in national accounts statistics

The measurement of productivity may also suffer from the fact that some types of activity do not appear at all in national account statistics. These include many activities that are usually not explicitly remunerated (such as the unremunerated services usually provided in the home referred to as 'household production', such as child-rearing, cleaning, cooking, tending the garden, etc.), and activities that are not categorised as value-added in national account statistics (e.g. some types of investment in intangibles, such as in brands). Current surveys may miss some of the production that is now more fragmented and produced by individuals (e.g. as part of the 'app economy'), while other innovations that increase the ability to use existing capacity (such as ways to survey available capacities in real-time) are also often not included in GDP and productivity statistics. Improvements that save time but are not readily converted into monetary equivalents may also only be insufficiently reflected in national accounts.

However, it is worth noting that the fact that some of these activities are not reflected adequately in GDP and productivity statistics does not necessarily imply that productivity growth is currently understated relative to the past. GDP statistics have always omitted a significant share of economic activity – e.g. a BEA study noted in 2012 that accounting for non-market household production would have raised nominal GDP in the US by 26% in 2010. One significant source of omitted activity, household production, has probably fallen over time relative to the size of the formal economy (the BEA notes that average weekly hours spent by women on home production fell from 40 hours in 1965 to 26 hours in 2010). And the shift from household production to formal work probably biased down the measurement of productivity in the past.

81% of our clients believe that recent technological developments are not reflected in productivity statistics

In general, our clients seem to share the view that there are significant measurement difficulties- 81% think that recent technological developments are inadequately reflected in productivity statistics, and 36% think that this inadequacy is significant (see Figure 55 below).

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Figure 55. 81% of Respondents Do Not Believe that Recent Technological Developments are Adequately Reflected in Productivity Statistics

Source: Citi Research

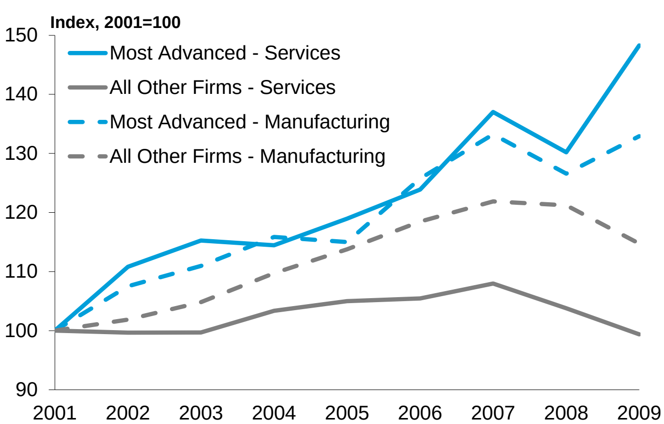
Growing Polarisation in Productivity

Rising polarisation can also be a factor

But in our view, true measurement errors are unlikely to account for all of the decline in measured productivity growth. In addition, compositional factors are likely to play a major role. One factor that may well be important is that there is some evidence that the dispersion of productivities across firms and workers has increased over time, a phenomenon we call 'rising polarisation' in productivity.

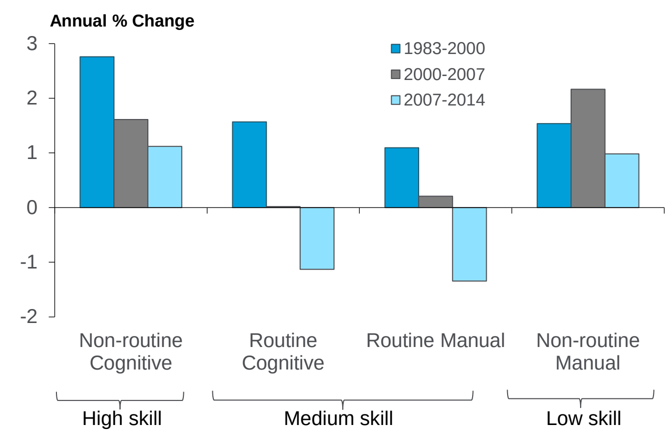
For instance, a recent OECD study showed that productivity growth of the globally leading firms did not slow in the 2000s (the data run from 2000-2009) and was still 3½% per year on average in the manufacturing sector. But productivity growth slowed for the 'laggard' firms to a mere 0.5% per year, and the discrepancy between productivity growth for the leading firms and the laggards has been growing. [72] The divergence between the productivity growth of leading firms and the remainder was even larger for firms in the service sector (Figure 56).

Figure 56. Global – Firm-Specific Labour Productivity (Index, 2001=100), 2001-2009



Note: 'Most advanced firms' corresponds to the average labour productivity of the 100 globally most productive firms. See Criscuolo and Gal (2015).
Source: OECD and Citi Research

Figure 57. United States – Employment Growth Reflecting Job Polarization (Annual % Change), 1983-2014



Note: Employment categories, using Household Survey data, are based off Valletta's (2015) calculations.
Source: BLS and Citi Research

[72] Andrews, D., Criscuolo, C., and Gal, P., (2015). "Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries", OECD.

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The dispersion of incomes across workers has also grown.[73] This may be because some workers lack the skills needed to be very productive, they may lack the funds to invest in the required training or indeed in job search for more suitable and higher-productivity jobs. For example, a paper by the New York Fed recently noted that the share of recent college graduates that have low quality (low-paid or part-time) jobs has risen over time. Compositional changes in the labour force (e.g. due to more migration, due to higher labour force participation in general or of women and older people) may also have contributed to lower measured productivity growth.

The nature of recent innovation may also have played a part, as various of our studies have argued, i.e. recent innovation may well have become more disruptive and recent technological developments are increasingly of a 'winner take all' nature.

This could be because recent innovations are less complementary (and more substitutive) to widely available skills than in the past and could therefore potentially replace and destroy a large(r) number of jobs. For instance, there is recent — and increasing — evidence of growing labour market polarisation. For example, the employment shares of both high- and low-skill workers have recently risen at the expense of the 'squeezed middle' in many advanced economies (see Figure 57).[74] Autor (2015) notes that in the US out of seven broad occupational categories ranked by pay (as a proxy for skill) employment shares of the higher-skilled/higher-pay occupations generally expanded between 1940 and 1980. Since 1980, however, the employment shares of low-pay and high-pay jobs have expanded, while the number of middle-pay jobs has fallen and a similar pattern holds across a range of other advanced economies, too.

The winner-take all nature of competition in some sectors is also likely to be relevant here. Furman and Orszag (2015) note that the share of firms earning very high returns in the US has risen over time (with the bulk of these firms residing in the technology or healthcare sectors).

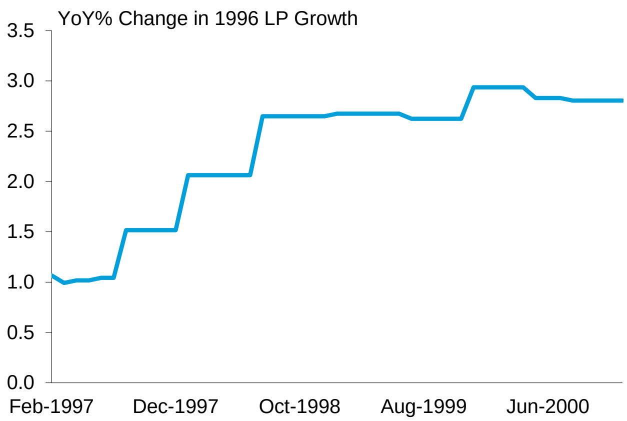
Some of These Shifts are Likely Temporary

The measurement of activity is likely to improve over time

It is possible, indeed plausible, that some of the developments we discuss will fade over time. The measurement of activity is likely to improve and to in part catch up with the changes in the economy. Recent years have already seen a number of changes in national account statistics, including widening the scope of intangible investment included in GDP statistics. In this context, it is worth noting that measures of GDP and productivity growth in the mid-1990s were revised up, sometimes substantially, as time went on. For instance, Figure 58 shows that LP growth for 1996 was revised up from roughly 1% originally to close to 3% eventually.[75]

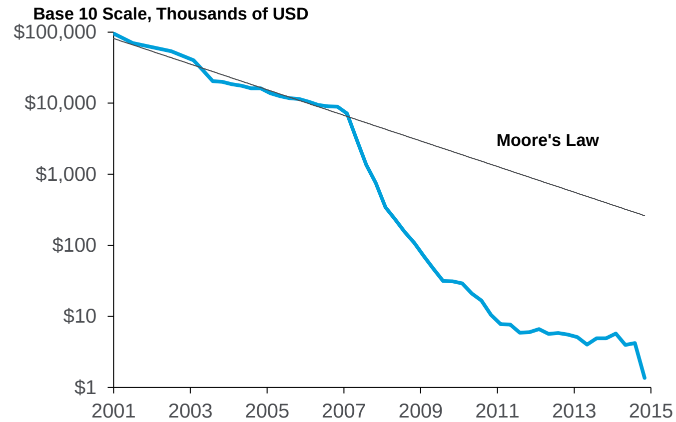
[73] Barth, E., Bryson, A., Davis, J.C., Freeman, R., (2014), It's Where You Work: Increase in earnings dispersion across establishments and individuals in the U.S., National Bureau of Economic Research, September 2014 and Song, J., Price, D.J., Guvenen, F., Bloom, N. (2015), Firming up Inequality.
[74] Valletta R. (2015), "Higher Education, Wages, and Polarization," FRBSF Economic Letter 2015-02.
[75] See Richard G. Anderson and Kevin L. Kliesen (2006), "The 1990s Acceleration in Labour Productivity: Causes and Measurement," Federal Reserve Bank of St. Louis *Review*, May/June 2006, pp. 181-202. A notable revision occurred in 1999, when software purchased by firms was reclassified as business fixed investment rather than as an intermediate expense. The 1999 revisions boosted real GDP growth from 1987-1998

Figure 58. United States – Estimated Labour Productivity Growth For 1996 (YY% Change), 1997-2000



Source: Anderson and Kliesen (2006) and Citi Research

Figure 59. Cost of Sequencing a Human-Sized Genome (Base 10 Scale, Thousands of USD), 2001-2015



Source: National Human Genome Research Institute and Citi Research

On a substantive level, it is possible that for some of the recent technological changes to translate into meaningful increases in actual productivity, changes to skills, processes and capital are required. This adaptation takes both time and resources. That is, it may not be that current productivity is just mis-measured, but that actual productivity is subdued as the economy reorganises and retools to take full advantage of the opportunities that new technology has created.

Indeed, the academic literature on general purpose technologies (GPTs) suggests the possibility of a temporary productivity slowdown, as the required adaptation takes place to use the new technology before productivity growth takes off.[76] For instance, Brynjolfsson and Hitt[77] highlight that in the 1990s it required complementary investments in organisational capital and new processes for IT-related innovations to deliver productivity gains, which eventually materialised, while Brynjolfsson and McAfee (2011) note that electrification took 30 years in the US to produce major productivity gains.[78]

It is plausible that productivity benefits of recent innovations are yet to be reaped

Systematic empirical evidence of such effects associated with GPTs is very limited, in part because there are so few observations of these big technological changes.[79] Nevertheless, we certainly regard it as plausible that we are in the adaptation stage for some of the more recent innovations and that the productivity benefits of some of the recent innovations are yet to be reaped. In addition, there are good reasons to believe that the interaction of progress in the various technologies that are currently enjoying major (often exponential) progress will lead to additional major

by an average of 0.4pp per year. The notable revisions prior to 1999 mainly reflect better measurement of source data, particularly in the durable goods manufacturing sector.

[76] See e.g. Eichengreen (2015), "Secular Stagnation: The Long View", NBER Working Paper 20836.

[77] Brynjolfsson, E., and Hitt, L., (2000), "Beyond Computation: Information Technology, Organizational Transformation and Business Performance", Journal of Economic Perspectives, Fall 2000.

[78] Brynjolfsson, E and A McAfee (2011), "Race against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy", Digital Frontier Press.

[79] See Ristuccia, Christiano and Solomos Solomu (2014), "General Purpose Technologies and Economic Growth: Electricity Diffusion in the Manufacturing Sector Before WWII," European Review of Economic History 18, pp. 227-247.

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innovations in the future.[80] A recent study by the Boston Consulting Group indeed forecasts that the economics for automation and robotics is nearing an inflection point, where the adoption rate of robotics and the resulting productivity gains, would pick up sharply – the study estimates that labour productivity per worker in the manufacturing sector could be boosted by 10-30% over the next ten years by improvements in automation alone.[81] Our clients are also somewhat optimistic about future productivity growth, with a whopping 95% expecting that automation and technology will drive an increase in productivity growth over time (see figure below).

Figure 60. 95% of Respondents Believe that Automation and Technology will Help Drive Productivity Growth

Source: Citi Research

Productivity ≠ Innovation or Living Standards

It is also worth keeping in mind that the translation of productivity into the issues we truly care about (such as changes in living standards or the capacity to supply, which, given demand, determines the path for inflation and interest rates) is far from perfect. In particular, GDP and productivity are based on spending, which implies that they are not automatically good reflections of consumer surplus (the value consumers' capture over and above what they pay for). The fact that GDP and productivity statistics are based on expenditure weights also implies that fast-improving sectors are likely to have increasingly smaller shares in consumption (unless the elasticity of demand in those sectors is very large).

The discrepancy between GDP statistics and living standards may well be increasing. This is because in the world that is populated increasingly by products with very low (sometimes zero) marginal cost, the consumer surplus is often very high relative to the price paid, and it is only the latter that is counted in GDP and productivity statistics.

Measured productivity may also not be the best guide

Similarly, when it comes to increases in potential activity, measured productivity may not be the best guide. For instance, the sharing economy (including Uber, Airbnb, etc.) increases effective supply without finding their way into measured productivity statistics.

[80] Pratt (2015), "Is a Cambrian Explosion Coming for Robotics?", Journal of Economic Perspectives, Summer 2015.
[81] See Boston Consulting Group, "The Robotics Revolution: The Next Great Leap In Manufacturing", 23 September 2015, https://www.bcgperspectives.com/content/articles/lean-manufacturing-innovation-robotics-revolution-next-great-leap-manufacturing/

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Impact of Automation on Inflation: What Does this Point Imply for Economic and Interest Rate Cycles?

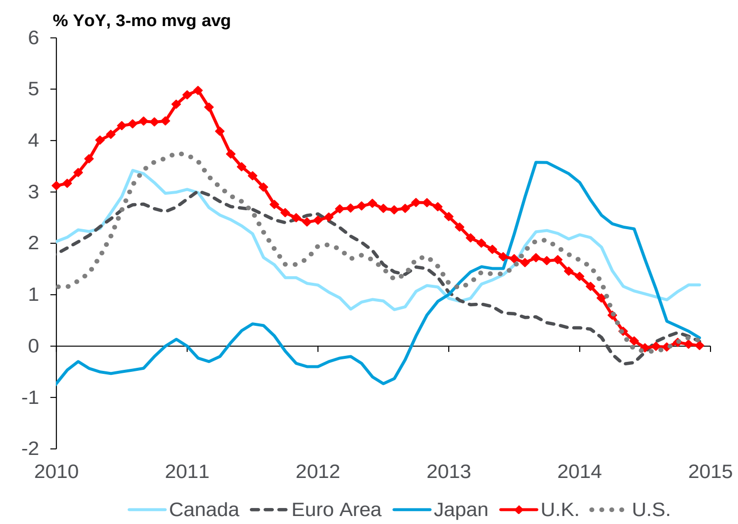
Highlights

- The rise in automation and technology is likely to reinforce the current low inflation environment, due to increased uncertainty and the narrow distribution of productivity gains. There is also good reason to suspect that current price deflators and measures of inflation are overstated.
- We may already be observing some of these effects given the Phillips curve has flattened. To close output gaps, demand stimulus will continue to be needed, with monetary policy remaining accommodative and more creative in most advanced economies.

Ebrahim Rahbari
Global Economics Team, Citi

In recent years low inflation – sometimes referred to as 'low-flation' – has been common across most advanced economies (see Figure 61). Anecdotally, the technological changes we describe seem to be pushing down prices in a growing number of industries – and even beyond the digital ones into those where innovations are inputs. The rapid advances in technology therefore raise the question of whether they may put even more downward pressure on prices and therefore either prolong this low-flation scenario or push inflation down even further.

Figure 61. Selected Countries, Headline Consumer Price Index Inflation



Source: National Statistics Offices and Citi Research

The major rise in automation will reinforce the low inflation environment at least in advanced economies

The implications of a relentless rise in automation on inflation and interest rates are likely to be complex. Ultimately we think that the major rise in automation will probably reinforce the low inflation environment that we have observed in at least the advanced economies in recent years and probably also low (nominal and real) interest rates, but whether it does so will depend both on the predictability of the 'Rise of the Robots' as well as the distribution of the gains in productivity. However, the reasoning does not quite follow the conventional logic that current productivity gains are per se disinflationary, but owe much to their unpredictability and the narrow distribution of productivity gains.

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Why High Productivity Growth Could Boost Rather Than Lower Inflationary Pressure

In modern economies, central banks tend to be tasked to keep inflation close to an explicitly or implicitly defined target. As Milton Friedman famously remarked, inflation tends to be a monetary phenomenon. In general (or under the assumption that monetary policy is *effective*), monetary policy can steer inflation towards its desired range by varying demand through adjusting the various instruments at its disposal. Our exposition of the impact of innovation on inflation here proceeds under the assumption that monetary policy is either ineffective or indeed simply assumed to be invariant for expositional purposes to trace out the effects of automation and other types of innovation in the absence of an effective monetary policy reaction.

In market economies, prices are the main tool to guide production decisions: prices are there to equilibrate supply and demand. If supply exceeds demand, prices should fall and if supply falls short of demand, prices should rise. To find out whether prices and inflation will rise or fall therefore depends on the effect of innovation on the balance of supply and demand (again, taking policy to be constant). The direct impact of the increase in productivity is an increase in potential supply. Other things equal, we would therefore expect inflation to fall, i.e. innovation would have a disinflationary impact.

But usually there is an indirect impact too: as Say's law indicates supply usually creates its own demand. So even abstracting from monetary policy, it is not automatically true that productivity increases will be disinflationary, and indeed they have not been so as a general rule.

But increases in productivity may well be expected to continue in the future. In that case, the future would be even better than the — already improved — situation today. Households anticipating such a bright future would in general then be inclined to try to take advantage of some of those future gains and smooth their consumption by increasing consumption already today – for instance by borrowing. Companies would be tempted to invest today in anticipation of high returns (and, again, potentially try to borrow to do so). The expectation of persistent productivity gains could therefore on balance raise demand today *even relative to the increase in supply*. In this scenario, where productivity increases are expected to continue in the future and their spoils are likely to be distributed fairly evenly across the population, both real interest rates and, other things equal, inflation would rise, and therefore imply that nominal interest rates would rise even more.

Such implications are not just theoretical, but can be observed fairly regularly (and at least locally) in the face of positive productivity shocks. For instance, major discoveries of natural resource deposits usually boost investment, consumption and the prices of nearly all products in its vicinity and sometimes for a country as a whole. The big boom in IT productivity in recent years in the Silicon Valley has also pushed prices of many other products (notably rents and house prices) up rather than down. Far from having a disinflationary impact, predictable and widely shared future productivity gains would therefore likely lead to higher inflation and higher real and nominal interest rates, not lower ones.

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The Predictability and Distribution of Productivity Gains Matters

The question of how productivity changes will impact inflation depends on whether demand will rise faster than supply

Ultimately, the question of how productivity changes will impact inflation and interest rates will hinge on whether demand will rise faster than supply. For innovation to be disinflationary, demand must rise less than supply. What could hold back demand? The main candidates are uncertainty or a very unequal distribution of the spoils of innovation. If the technological changes spur increases in uncertainty – uncertainty about the trajectory of innovation or more generally – desired saving rates may rise for everyone.

If the spoils of the innovations are highly concentrated, the saving rates of the techno-entrepreneurs may well fall and their demand rise. But meanwhile, the desired saving rates of those negatively affected or at least at risk of being negatively affected may well rise. If the number of people in the latter category is much larger than in the former category, the result could be an increase in the average desired saving rate in the economy – which would be disinflationary.

Innovation Will Likely Reinforce Low-flation

In our view, both conditions for demand to be held back are likely to be satisfied.

First, forecasting the future is always uncertain, but for now, the lively debate about whether innovation even today is fast or lacking suggests that current uncertainty about future progress and innovation is unusually large. This is not only the uncertainty about the path that the technologies will take, but also what impact they will have on economies and societies. The pervasive increase in uncertainty will most likely boost precautionary saving motives for many households that consider themselves at risk from some of these potential changes, while the fear of disruption may weigh on the desire of many firms to invest.

Absent an effective policy response, wealth inequality will increase and this will boost saving rates. Taken together technological advances will increase supply more than demand – this will reinforce the low-inflation outlook

Absent significant changes in policy, the gains from these innovations are also likely to be very highly concentrated. As noted above, there is already some evidence of a 'winner take all' nature of some recent innovations, with large between-firm differences in returns and income growth. There is, of course, also plenty of evidence by now that income and wealth inequalities have risen across most economies. It is therefore quite likely, in our view, that – absent an effective policy response – inequalities in wealth and income will widen further and that those increases in inequality in turn will boost average desired saving rates. Taken together, we therefore expect that even the prospect of persistent technological advances will probably boost supply today in the near future more than it will boost demand, which should reinforce the low-inflation outlook.

In addition, the starting points are likely to be off. As we noted above, there are good reasons to suspect that current economic statistics understate quality improvements in many products. This would imply that many current price deflators — and current measures of inflation — would be overstated, as these price indices are mostly calculated on a quality-adjusted or 'constant-quality' basis. If much of the bias of understanding quality improvements in the statistics originates in investment spending, the investment goods deflator is likely to be most biased upwards and to a lesser extent that would also apply to the overall GDP deflator or the personal consumption expenditure (PCE).

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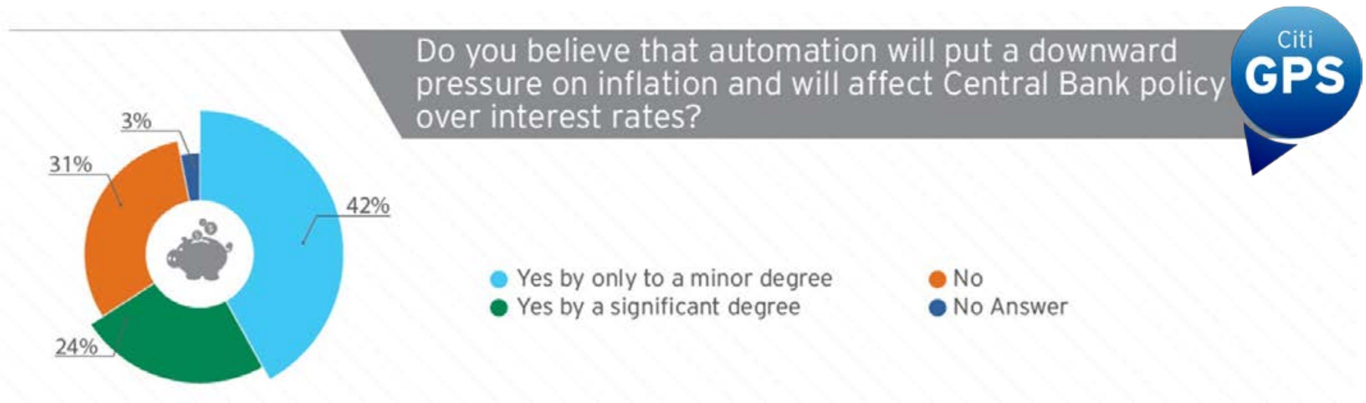
Interestingly, our clients seem to be split on the effects of automation and innovation on job prospects: 51% of respondents in our client survey expect that innovation will create fewer jobs than it destroys, while 48% think that jobs created will exceed those lost. On inflation, the verdict seems clearer, with 66% expecting disinflationary effects to some degree (see figure below).

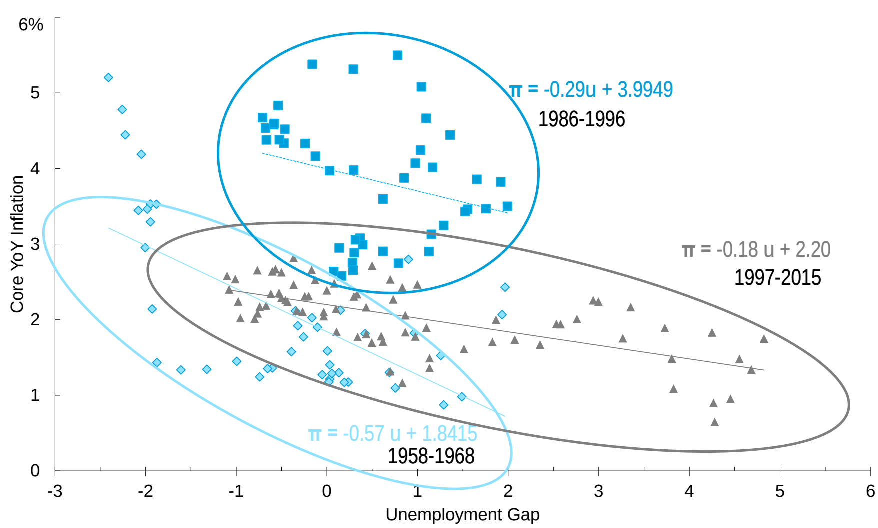
Figure 62. Over 60% of Respondents Believe that Automation will Put a Downward Pressure on Inflation



Source: Citi Research

An interesting question is whether we may already be observing some of these effects. After all, unemployment rates in a range of advanced economies, including Japan, the UK, and the US are relatively low by historical standards and yet inflation is even lower (relative to historical norms). Indeed, there is plenty of literature by now on the observation that so-called Phillips curves (the usually negative relationship between inflation rates and the amounts of slack in the economy) have flattened. Put differently, there are signs that lower measured slack in the economy now puts less upward pressure on inflation than it used to in the past.

Figure 63. United States – Core Inflation and the Unemployment Gap, 1958-2014



Note: The unemployment gap is the difference between unemployment and the estimated non-accelerating-inflation rate of unemployment (NAIRU).

Source: Citi Research

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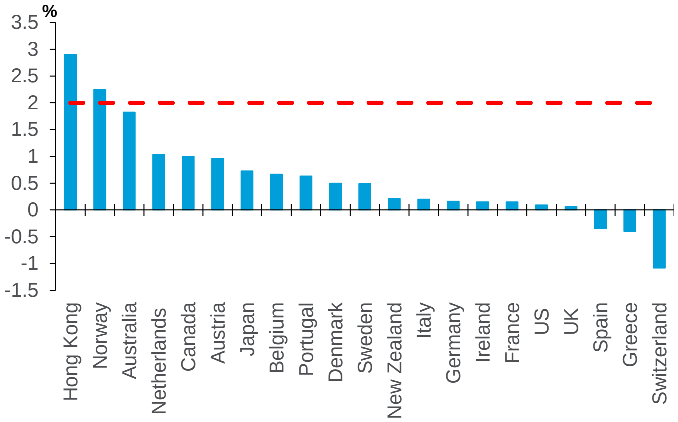
Monetary Policy Rates Will Likely Have to Remain Lower for Longer

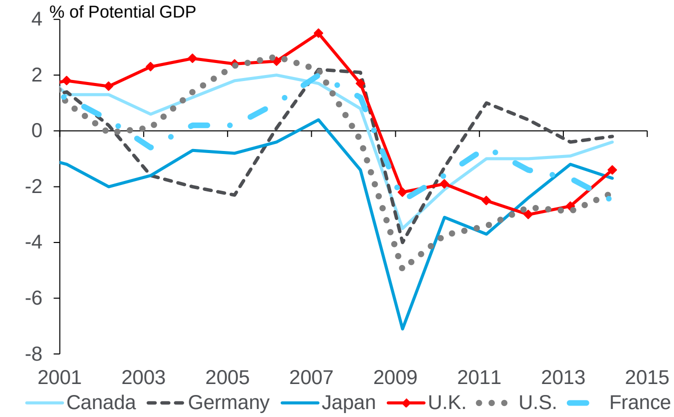
Inflation rates across the advanced economies are already far below central bank targets in most countries and not expected to reach them even over the next 1-2 years (see Figure 64). As noted above, there is some evidence that even these very low inflation rates are still overstated and we think that the rapid advances in technology will likely reinforce the current low-flation trend, due to the uncertainty associated with them and the narrow distribution of the productivity gains.

Figure 64. Selected Countries: 2015 CPI Inflation Forecast (%)



Source: Citi Research

Figure 65. Selected Countries: Output Gap 2001-15



Source: IMF and Citi Research

It is therefore likely that the current gaps between supply and demand – which according to most estimates are large – will remain ample or possibly even widen. To close the gap, some type of demand stimulus will therefore continue to be needed. Even though fiscal policy probably has a major – and growing – role to play, as we discuss below, the use of fiscal policy in most advanced economies will probably continue to face major challenges and constraints. It is therefore highly likely, in our view, that monetary policy will continue to be and have to be very accommodative in most advanced economies.

Policy interest rates are likely to remain low in advanced economies

In the first place, that implies that policy interest rates are likely to remain low across most advanced economies for a long time. This is not to say that we will never see rate hikes, but we suspect that rate increases will be few and far between, often short-lived and sometimes reversed. Indeed, we expect that the historical lows for policy interest rates will be tested in more and more countries and that negative policy interest rates will become increasingly common.

In addition, asset purchases — fast becoming the most conventional of the so-called 'unconventional' monetary policy tools will continue to be used widely. But since even the more conventional of the unconventional tools of monetary policy (both on the interest rate side and on the asset purchase side) are already fairly stretched it is likely that monetary policy will become even more creative over time, including through buying an even wider range of assets than to date, more negative policy rates or explicit targets for certain asset prices (including the exchange rate).[82]

[82] See High Time To Get Low: Getting Rid Of The Lower Bound On Nominal Interest Rates.

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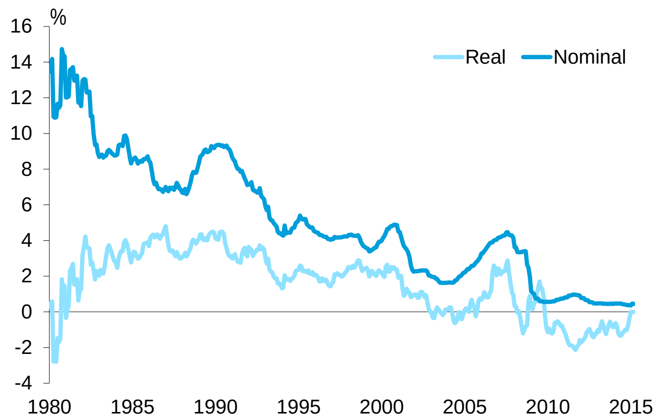
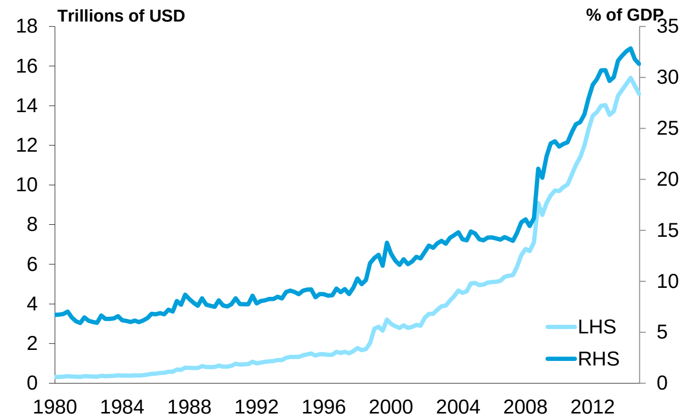
Figure 66. Advanced Economies: Average Real and Nominal Short-Term Interest Rates (%), 1980-2015



Note: Series are GDP-weighted averages of short-term interest rates (usually the central bank policy rate) for 37 advanced economies. Real series is deflated with local CPIs.
Source: National Sources and Citi Research

Figure 67. Advanced Economies: Average Central Bank Balance Sheet Size (USD and % of GDP), 1980-2014



Note: Series are GDP-weighted averages of central bank assets for 34 advanced economies
Source: National Sources and Citi Research

Sector Analysis: How is Automation Impacting Jobs in the Near Term?

Highlights

- Robots are extending their functions in manufacturing and are increasingly being used across supply chains, warehouses and transportation. 3D Printing could alter both manufacturing and supply chains.
- We find increasing examples that technology is increasingly impacting lower-end service jobs. Restaurant automation of both ordering and paying, via tablets in store or mobiles out of store, is starting to impact labour.
- Natural Language Processing could impact jobs in call centres and report writing, while automated decision support systems can impact tasks.
- Technological change is expected to further impact employment in the media and telecom sectors, while Cloud computing could have a significant impact on IT employment.

Robert Garlick
Global Equity Product Head, Citi

In the previous chapters we analysed the susceptibility of automation in countries and US cities and the effect on productivity and inflation. In this section our analysts report on the changes that they are already see happening in various different industries. Much of the work around the risks of jobs from automation looks at susceptibility over the next couple of decades. A natural follow on question has been- which areas look at higher risk in the near to medium term (3-5 years). Citi analysts highlighted a wide number of areas in the first Technology At Work GPS report and in this chapter we narrow in on several sectors including the food sector, journalism and business, call centres, factories and others impacted both by technological change and employing a large number of people.

Figure 68 shows the ten most endangered jobs in the US in 2015, as listed on a website called Career Cast who used data from the US Bureau of Labor Statistics to estimate the jobs that have a negative growth outlook from 2012 to 2022. For comparison we have added the results on automation probabilities from Frey and Osborne's Oxford Martin School study.

Technology and computerisation is directly affecting at least four of these jobs including mail carriers and meter reader jobs which are expected to lose around 28% and 19% respectively of their workforce by 2022, logging workers (-9%) and drill press operators (-6%). Most of these also have a high probability score of being automated. For example it was estimated that meter readers and mail carriers have a 0.85 and 0.66 probability of being automated (Figure 68). [83]

[83] Frey, C. B. and Osborne, M. A., (2013). The Future of Employment: How Susceptible are Jobs to Computerisation? Oxford Martin School Working Paper No. 7.

Figure 68. Ten of the Most Endangered Jobs in 2015 (the first four are directly affected by technology and computerisation)

Job description[84]	Projected growth outlook	Reason for decrease	Probability of being automated
Mail carrier	-28%	Impacted by technological changes in communication	0.68 for postal service carriers, 0.75 for mail superintendents, 0.79 for mail sorters
Meter Reader	-19%	Companies are able to track usage with automated meters	0.85
Logging worker	-9%	Technology has streamlined logging work to require a fewer hands and the usage of paper is decreasing	0.79
Drill Press Operator	-6%	Stagnant hiring in the manufacturing sector and streamline processes through technological advances	0.94 for drilling and boring machine tool setters
Reporters, correspondents, and broadcast news analysts	-13%	Declining advertising revenue in radio, newspapers, and television will negatively impact the employment growth for these occupations[85].	0.11 for reporters and correspondents, 0.067 for broadcast news analysts
Insurance Underwriter	-6%	Streamlined processes allow agents to take on work handled previously by underwriters	0.99
Seamstress/tailor	-4%	Consumers buying new clothes rather than hiring tailors to mend their own	0.84
Jewellers	-10%	Outsourcing of jewel manufacturing means fewer employment prospects	0.95
Flight attendant	-7%	Downsizing in the airline business and consolidation of staff	0.35
Farmer	-19%	The decline in farming is expected to continue in the years to come. Fewer farms are able to produce more food than ever before	0.0047 for farmers and ranchers, 0.97 for farm labour contractors

Source: Career Cluster, Frey and Osborne, Citi Research

Greg R Badishkanian
US Leisure, Restaurant & Healthy Lifestyle Analyst, Citi

Automation in the Restaurant Industry

The US Bureau of Labor Statistics (BLS) estimates that in 2012 4.4 million people were working in the US as food and beverage workers and over 2.3 million were employed as waiters/waitresses. We previously noted in our first Technology At Work report highlighted that 86.7% of US Accommodation and Food Services jobs could be susceptible to automation. In the restaurant sector, technology influences are being seen across three main areas: digital ordering, loyalty, and labour. While most operators play down the near-term opportunity for tech-related labour savings, rising minimum wages and growing competition for staff might force automation into focus sooner than initially expected.

While many restaurant chains have some sort of mobile or digital capability, quick service restaurants (QSRs) such as coffee shops and pizza parlours remain particularly well positioned to benefit from the increased adoption of technology, notably smartphones. Millennials are particularly prone to online ordering with 18% citing convenient ordering options as one of the top three reasons they order from their primary pizza location.

[84] http://www.careercast.com/jobs-rated/most-endangered-jobs-2015
[85] http://www.bls.gov/ooh/media-and-communication/reporters-correspondents-and-broadcast-news-analysts.htm

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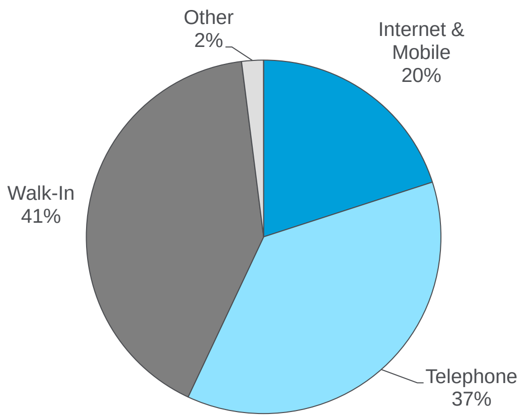
Figure 69. Digital Sales as Percent of QSR Pizza Sales



Source: NPD

Figure 70. Degree to Which Recruiting & Retaining Employees is a Challenge to Operators

	Significant Challenge	Moderate Challenge	Little or No Challenge
Family Dining	16%	31%	53%
Casual Dining	23%	36%	40%
Fine Dining	11%	40%	46%
Quick Service	21%	38%	40%
Fast Casual	22%	37%	39%

Source: National Restaurant Association

QSR coffee operators have also benefitted from the proliferation of smartphones and an uptick in mobile spending trends. In the fiscal third quarter of 2015 Starbucks reported that roughly one in five transactions at US company-owned stores took place using the mobile app, up from 8% in the same quarter of 2013. Starbucks 'Recall, Mobile Order & Pay' allows customers to choose a store from a map view, browse, select, and customise beverage and food items, view the estimated timeframe the order will be ready, and pre-pay for his or her order. By September 2015 the company had completed the national rollout across its more than 7,400 stores.

Tablets like Ziosk are increasingly being used in restaurants and have the potential to lead to labour savings

Casual dining operators have also increased automation efforts in recent years through the use of table-top tablet systems. Darden, Chili's and Buffalo Wild Wings have all implemented tablet-based solutions. These systems typically enable guests to see menu items, play games, view news, order food/beverages, and pay their bill at their table. One of the largest third-party restaurant tablet operators is Ziosk, which is currently installed at over 1,400 restaurants across the country (including Chili's and Olive Garden). Ziosk's tablets enable restaurants to increase table turns and grow the average check. Additionally, the technology drives higher guest frequency, improves guest satisfaction, and increases the amount of guest feedback a restaurant receives. While there is a potential opportunity to save on labour, most companies who have deployed Ziosk to-date are focused on driving increased traffic and table turns, though we believe the potential labour savings could be a larger benefit moving forward.

Industry commentators have frequently pointed towards increased labour competition as one of the most significant challenges facing today's restaurant operators. With numerous concepts expanding domestic unit counts, along with an overall improving employment picture in the US labour market, hiring and retaining workers has been a front-of-mind concern for operators for most of 2015. Restaurant wages have been steadily rising over the past several years and recent comments from Wendy's management suggest that the combination of rising minimum wages and increased competition is having a meaningful impact on operations. Given the changing environment the company could look to offset rising costs through self-service technologies.

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"We continue to see pressure on wages on two fronts, one is minimum wages at the state level continue to increase, and as there is a war on talent to make sure that we're competitive in certain markets. So we've made some adjustments to that starting wage in certain markets. The impact hasn't been material at the moment, but we continue to look at initiatives on how we do work to offset any impact to future wage inflation through technology initiatives, whether that's customer self-order kiosks, whether that's automating more in the back of the house in the restaurant, and you'll see a lot more coming on that front later this year from us."

Todd Penegor, Wendy's CFO (2Q EPS 8/5/15)

Recent comments from Domino's management have also noted labour savings as an increasing portion of overall orders come through digital channels, although meaningful savings took longer than initially anticipated:

"When we were first getting digital ordering going, I will tell you that we expected labour efficiency faster than we saw it. We didn't really start seeing a lot of labour efficiency in the stores until we got to kind of the 15% to 20% digital order range….And the reality is that you've got a fixed amount of labour in stores to cover shift, to cover the basic functions in the store. And when it was a relatively low level of digital orders, your ability to offset labour was pretty minimal. As it's gotten higher, we started to see more impact from that. And we're in the range now with digital sales around 50% that we clearly can see some savings in the store."

Patrick Doyle, Domino's CEO (3Q EPS 10/8/15)[86].

Natural Language Processing To Impact Call Centres

Ashwin Shirvaiker, CFA
US Computer Service & IT Consulting Analyst, Citi

Interest in Natural Language Processing (NLP) has grown by leaps and bounds over the past few years, thanks to IBM's Watson (on the Jeopardy! show in the US) and Apple's Siri. NLP is the ability of a computer program (machine) to understand and interpret human speech. Ideally, the human should not have to radically change the natural way they speak. While this sounds simple, it is mathematically intensive as it requires algorithms that perform word and sentence tokenisation, text classification and sentiment analysis, spelling correction, information extraction, parsing, meaning extraction, and question answering.

There are a number of examples of NLP usage in our everyday lives. Obviously Apple's Siri was mentioned above. Similarly, Google has an advanced NLP application that is used in searches. The Human-Machine Interface (HMI) of an advanced car can recognise and interpret over 5,000 words — this is often used in a car's entertainment system to change channels or to call a person from a list. But when one considers productivity enhancing corporate applications, the use of NLP in call centres likely tops the list. In fact, when you call a live call centre agent and hear "this conversation may be recorded for training purposes", it is most likely the NLP algorithms that are being trained!

IVR systems are widely used in call centres to direct flows and answer simple questions

Simple voice recognition techniques have been used in call centres for over a decade. We are all familiar with IVR (interactive voice response) systems, which employ a combination of voice recognition and DTMF (dual-tone multi-frequency) tones input via the phone pad. IVR systems help improve call centre efficiency and reduce costs. They are now widely used in call centres to direct the flow of calls and answer simple questions. However, they are fairly primitive deployments of voice

[86] https://blog.ap.org/announcements/automated-earnings-stories-multiply

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techniques that tend to use key words and scripts that prompt the caller with specific questions and options.

The leap forward is to understand context so that the machine-based speech interaction is as close to human interaction as possible. To be an effective service, NLP-based systems have to rely on open-ended questions — for example, "How may I help you?" — and understand not just the specific words a caller says, but also what that caller means.

There are a couple of different impacts from such technology advancements.

- **There is already a loss of billable hours** – this can either be outright job loss or fewer available hours for humans. This does not happen in every part of the call centre industry but has started to occur in both the telemarketing and the medical transcription areas of the broader call centre industry.
- **The "human" focus has shifted higher up in the stack of available jobs.** In other words, simpler "Level 1" and "Level 2" jobs — those that involve simple information gathering, basic product knowledge and form-based trouble-shooting — can be automated. This implies that the average call handling time goes up since the remaining work is necessarily more complex.

The US, Philippines and India are the three largest destinations for call centres

The three largest call centre destinations are the US, the Philippines and India. The US has over 2 million call centre jobs (this includes both in-house and outsourced jobs) while the Philippines is the largest outsourced call centre destination with over 1 million call centre jobs. While the above-mentioned impacts are difficult to quantify (especially the part where technology causes a job to change from full-time to part-time status), we believe that the trend will continue to be towards fewer but higher-value and higher-paid call centre jobs.

Natural Language Processing in Journalism & Business

Peter Chalif
Head of Structured Trading, Citi Municipal Securities

The production of language is notably easier than the complexities of interpreting language. The Associated Press (AP) is already producing thousands of financial stories through its joint venture with Automated Insights, a company that specialises in automated writing. They produce primarily fact reporting pieces currently. However, with the increase in computing capacity and machine expertise the complexity and number of fields automated writing can handle is increasing rapidly.

Automotive reporting could increase as algorithms improve over time

The AP has also started sports reporting where articles were either unwritten or written by employed people. Similarly, companies such as Arria offer combined automated data analysis and report writing. These products combine statistics and pattern recognition-based data analysis with natural language reporting. As computers increase in speed and algorithms improve the analysis, automated report writing will only improve.

Writers that focus on fact reporting are already under pressure of automation

The amount of written content produced daily is extraordinary, and the number of people involved in writing content is also high. In the United States in 2012, there were 129,100 writers and authors, 49,500 technical writers, 57,600 reporters and correspondents, and 63,600 interpreters and translators according to the BLS for a total of 299,800 jobs. These jobs cover most of the externally generated writing about companies, sports, local news, and other topics produced daily. Writers that focus on fact reporting are already under pressure in some areas, with others at risk through combining data analysis and automated report writing.

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Internal reports by banks and other corporations about their financial condition, risks, credit reporting, and other topics are numerous, often produced daily, weekly, monthly, and quarterly. Management, audit, regulators, and investors all require analysis and reporting. In 2012, according to the US BLS there were 61,700 budget analysts, 253,000 financial analysts, 29,200 financial examiners, and 1,275,400 accountants and auditors employed in the United States for a total of 1,620,000 jobs. While not all of these jobs are gathering data in Excel, doing analysis or review, and then writing about the results, many of them are.

Corporations are under extreme pressure to improve data collection and management due to regulatory requirements, management analytics, control processes, investor analytics, and the associated costs. While requirements for corporations to improve data collection and reporting could lead to increases in investment, the mechanical processing and reporting of information will likely experience greater disruption going forward.

Technology Is Impacting Media Employment

Jason B Bazinet
US Cable & Satellite Analyst, Citi

While technological change is everywhere, the pace of change seems particularly brisk within the media and telco sectors. Indeed, over the last decade, we've seen dramatic changes:

- In 2004, Blockbuster Entertainment employed 60,000 people across the globe. With the rise of Netflix, the firm filed for bankruptcy in 2013.

With the rise of the internet, employment in the publishing business has decreased

- In 2002, over 700,000 Americans worked in the newspaper, book and directory publishing business. With the rise of the Internet, employment in this sector of the economy dropped to just 450,000 by 2012. And, the US Labor Department expects further job losses. Physical publishing will employ just under 350,000 people by 2022.
- In 2002, over 840,000 Americans worked for the US Postal Service (USPS). With the rise of email and social media, USPS employment dropped to 610,000 in 2012. The US Labor Department expects employment at the USPS to drop to below 350,000 by 2022.

iTunes and other music related technology has changed the music industry over the years

- In 2000, US consumers purchased over 1 billion CDs. With the rise of iTunes, Spotify and Pandora, US consumers purchase fewer than 200 million albums today. And, with the collapse of the physical music market retailers like HMV, FYE, Sam Goody and Tower Records all but disappeared.
- With the rise of mobile phone services, US consumers are increasingly terminating their landline phone service. In 2002, nearly every US household had a landline connection. By 2015, only 50% of US households paid for a home phone. In tandem, employment in the telecommunications sector has fallen from 1.28 million in 2002 to just 860,000 in 2012. The US Labor Department expects telecommunications employment to keep falling reaching just 807,000 by 2022.

While you might think that the lost employment in areas like publishing, telecommunications and the US Postal Service would migrate to newer industries like web hosting or software publishing, job gains in these digital sectors are scant. In 2002, software publishing and web hosting services employed 680,000 people. By 2022, just over 810,000 people will work in these two sectors. Indeed, between 2002 and 2012, 33 legacy jobs were lost for every new digital job that was created.

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Figure 71. Employment in Media and Telecommunications Sector

	2002	2012	2022E
Telecommunications (legacy)	1,281	858	807
+ Postal Service (legacy)	842	611	442
+ Newspaper, book, and directory publishing (legacy)	711	452	347
+Hosting, data processing (digital)	428	424	453
+ Video and sound recording (legacy)	388	372	350
+ Broadcasting (legacy)	334	285	297
+ Software publishing (digital)	253	286	359
= Total information services employment ('000)	4,237	3,289	3,054
Hosting, data processing	428	424	453
+ Software publishing	253	286	359
= Total 'digital'	681	710	812
+ Total information services employment	4,237	3,289	3,054
= Share from digital	16%	22%	27%
memo: legacy job loss to digital job gain		33.4x	3.3x
Total information services employment ('000)	4,237	3,289	3,054
/ Total employment ('000)	142,295	145,356	160,984
= Share from information Services	2.98%	2.26%	1.90%

Source: Citi Research

Decision Support Systems in Medicine

Peter Chalif
Head of Structured Trading, Citi Municipal Securities

Decision support systems have a long history in computer science. Some of the attempts at modern artificial intelligence were simple rules engines, but the origins of Artificial Intelligence (AI) go back much further, perhaps as far back as Aristotle's syllogism. Some of the core mathematical concepts of AI were already in development by the time of Thomas Bayes (1702-1761) and Pierre-Simon Laplace (1749-1827). Bayesian methods are still one of the primary techniques for machine learning, and implementation of the probabilistic models they create are a fundamental technique of AI. Given a set of data, Bayesian methods calculate the conditional probability of an outcome.

Many fields require deductive reasoning, and one of the most common of those is medicine, and particularly diagnostic medicine, which gathers symptoms and test data to form an opinion on a particular case. Fifty years ago there were far fewer blood and tissue tests available, and the accuracy of those tests had a large error term. For example, the resolution of the X-ray wasn't very clear, and magnetic resonance imaging didn't exist. Doctors had severely limited amounts of information, and often no information until the condition became acute. Medicine, like many fields, has become a field of both hard data, i.e. number of white blood cells of different types in a patient's bloodstream, and soft data from the patient, i.e. "it hurts over here". Most patients aren't able to identify when their spleen hurts, so data from the patient might be understandably vague. With the refinement of biomarker tests, genetic testing, high-resolution X-rays, MRIs, PET scans, dual x-ray bone densitometers and countless other technologies, the practice of diagnostic medicine is changing. Diagnostic medicine is becoming a mechanical process of ordering tests, reviewing automatically generated results and drawing a data-driven conclusion. Testing laboratories typically provide acceptable ranges for results along with the result itself, making it even easier for doctors to focus on a subset of data most relevant to the case.

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Machines like IBM's Watson can perform diagnoses that exceed the performance of an experienced doctor

Proactive scanning for potential issues would allow significantly earlier diagnosis, and in some cases determines successful or unsuccessful outcomes. Increased automation can help reduce the cost of testing, and how much human time it would take to review all the data. Moving to a higher level, systems such as IBM's Watson for Medicine can be described as "cognitive diagnostic engines". By accessing patient data, prior diagnoses, journal articles, and using data and natural language processing to form patterns of diagnosis, a machine with a large amount of data and the right algorithms can perform diagnoses that approach or exceed the performance of an experienced doctor. Most medical diagnoses "fit" within a recognised pattern with constraints, exactly what machines do well. Unlike humans, machines will not make mistakes because it is tired or be blinded by false bias or pre-judge a situation. Cognitive diagnostic engines will also be assimilating new information, and can near instantly share that information across all machines like it.

A frequent complaint about decision support systems from human practitioners in medicine is that machine decisions are typically difficult to understand or in some cases interrogable. When implementing AI systems in finance we hear exactly the same complaint. One of the critical areas of development needed in these systems is to provide AI with a method to explain why it arrived at a particular conclusion. The natural language production methods described above are an important component of that. When decision support systems improve their ability to provide insight into their decision, greater acceptance is likely to come next.

The medical industry will shift towards more technology attracting more data scientists, engineers etc.

Functions employed in the medical industry will shift towards more technology and the industry will attract engineers, data scientists, and researchers. Non-specialised family physicians may find themselves marginalised by health centres staffed with a team of nurse practitioners armed with Watson Health and overseen by a single doctor. One example of commoditisation of medicine is evident with eye doctor offices in chain eyeglass stores. The impact on employment in medicine will likely be greater specialisation, more technical and engineering staff, and reduction in the number and compensation of mid-skilled participants

Impact of Cloud Computing on IT Employment

Walter H Pritchard, CFA
US Software Analyst, Citi

Steve Rogers
US Software Associate, Citi

Technology overall is about driving automation, human productivity, and process efficiency and thus for many years has been at odds with employment growth. Examples here are countless. The manual phone operator was replaced with automated switchboards and PBX systems. Forms processing (highly people intensive) has been replaced by an end-to-end digital process (IT-based), reducing employment in areas such as claims processing in insurance and new customer activation in telecommunications. Floor brokers in stock exchanges and clerks in clearinghouses have been replaced with computer systems that automatically match up and clear trades. The majority of these gains that have come from adoption of IT have been in non-IT areas. IT has used technology itself to drive increased automation, productivity, and efficiencies. Over time, the incremental demand for IT, driven by price elasticity, has usurped the efficiency gains IT has found in its own organisation. Over the last 12 years, IT headcount has grown by 4% (~6x overall employment growth) in the US with total employment of approximately 4 million people (3% of workforce).

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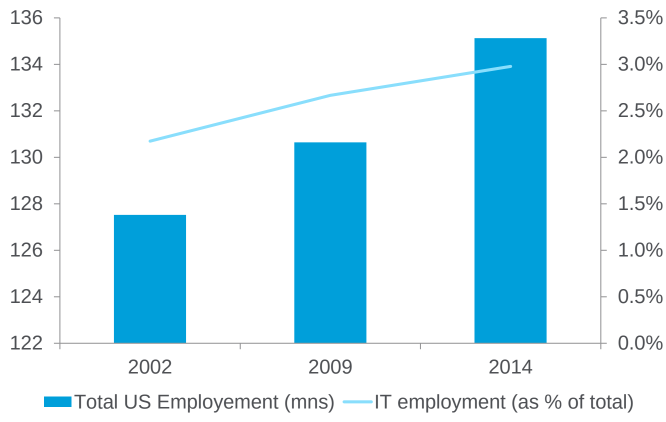
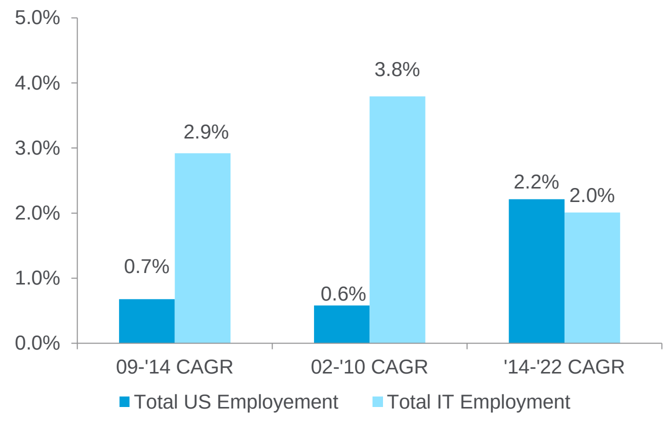
Figure 72. Total US Employment vs. IT Employment



Source: BLS, Citi Research

Figure 73. Growth in Total US Employment vs. IT Employment

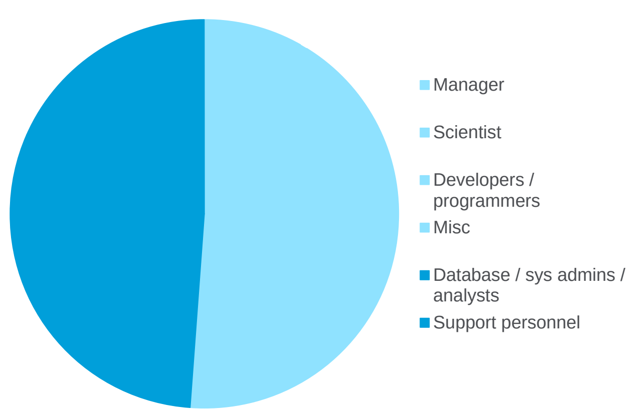


Source: BLS, Citi Research

Cloud computing could lead to further automation in several sectors

The mainstream adoption of cloud computing has the potential to change this dynamic. The disruptive trend here, in our view, is the advent of utility-like public cloud services from the likes of Amazon, Microsoft and Google. These providers have assembled IT capacity that is several orders of magnitude greater than what the largest corporate buyers of IT run in house (banks, telecoms, and government agencies), not to mention exponentially dwarfing the scale of the average IT shop. As customers adopt Amazon's AWS, they no longer need to manage their own servers and employ as many systems administrators to perform these duties. The public cloud players employ scale and automation that enables a very low ratio of headcount to IT capacity. For example, we believe a well-run enterprise IT organisation has "server to admin" ratio of 40:1. In the technology industry, where companies are running businesses primarily off their servers, we hear of ratios of ~150:1. We believe highly automated public cloud services are able to run 5,000+:1 ratios. Here, some quick math would suggest that 124 system administrators or support personnel could be eliminated for each 5,000 servers that move to the public cloud. Also, over time, as internal IT groups are pressured by the economics, they will be forced to run their operations more efficiently. This indirect pressure will likely lead to further automation and an increase in the server to admin ratio.

Figure 74. US IT Employment by Category



Source: BLS, Citi Research

Nearly 50% of the 4 million IT jobs could be at risk if IT operations move to the public cloud

Our analysis of US IT employment suggests that nearly 50% of the 4 million jobs (above coloured dark blue) could ultimately be at risk if IT operations move substantially to the public cloud. This would include job titles such as systems administrator, database administrators and IT support professional.

The potential counterpoint here is whether the general efficiencies of cloud computing drive enough elasticity of demand that there is an acceleration in job creation in areas such as software programmers and generally in the technology, telecom and Internet industries. These fields/industries employ 5-6% of the US population and will likely to continue to see secular growth despite potential pressures in other areas of IT.

The Increased Use of Robots in Warehouses

Arthur Lai
Asia Display & Touch Panel Analyst, Citi

Amazon continues to take share within retail and automate the processes within the 120 giant warehouses that it has worldwide. Since acquiring *Kiva Systems* (now *Amazon Robotics*) in 2012 for $775 million, Amazon employs about 30,000 Kiva robots in 13 fulfilment centres (as of Oct 2015), up from 1,400 at the end of 2013. In total it is estimated in 2015 that over 780,000 people in the US were employed in warehousing and storage centres.[87]

Figure 75. Number of Kiva Robots Employed

Time	Number of Kiva Robots	# of fulfilment centres that Kiva is in
Dec 2013	1,400	n/a
Dec 2014	15,000	10
Dec 2015	30,000	13

Source: Company reports, Citi Research

Amazon's workers used to roam around in the warehouses searching for the products needed to fulfil each order. Now, with the help from *Kiva robots,* the shelves themselves glide across the floor to the workers, who then pick and pack the goods. According to Amazon, Kiva robots have significantly reduced the order processing time from 1.5 hours to as fast as 13 minutes.

While the mobile shelves are faster and more efficient, having workers pick the items off the shelves by hand is still an expensive and tedious task. This inspired the *Amazon Picking Challenge* in 2015, to find ways to replace the human stock picker with robots. The winning team came from the Technical University of Berlin.

Figure 76. Before the Deployment of Kiva Robots

Source: Amazon, Citi Research

Figure 77. After the Deployment of Kiva Robots

Source: Amazon, Citi Research

Beyond robotic shelves, items in Amazon warehouses are also tracked from arrival to dispatch from a computer system. Upon arrival, items are recognised by a sophisticated computer vision system after they are unpacked. At the packing side, computers allocate the right box for each order with its knowledge of the dimensions of each product. The computer even allocates the right amount of packing tape.

[87] BLS, http://data.bls.gov/timeseries/CES4349300001?data_tool=XGtable

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Moreover, before boxes are sent to trucks for dispatching, they are weighed to make sure no mistakes have been made in packing.

Other companies like Alibaba are also keen to develop robotic logistic systems

While Amazon may be at the forefront of bringing the savings and scalability of robots into warehouses, logistics and distribution, we believe Alibaba and other e-commerce makers in China are also keen to develop their own robot logistic systems.

Alex Chang
China Industrials & Infrastructure Analyst, Citi

In China, the warehouse gross floor area (GFA) per capita is only 1/10 that of US. Given strong ecommerce momentum, at a CAGR of 21% in 2014-17E, demand for warehouses should be strong, especially for modern warehouses equipped with automated storage and retrieval systems (ASRS). In 2012, there were ~1,200 warehouses with ASRS in China and ~130 units were under construction. CLTA forecasts that the market size of ASRS could deliver a CAGR of 17% in 2011-15E, to Rmb32 billion ($4.9 billion).

Surging land prices are driving the application of ASRS in China

The adoption of ASRS should significantly reduce labour for transporting items into and out of inventory, allowing more accurate tracking of inventory and reducing inventory levels. However, it is the surging land price that is driving the application of ASRS in China, allowing for more storage space due to high-density storage with narrower aisles. On the same piece of land, warehouse with ASRS could be built as high as ~50 metres, to house more than 10 times the volume of a traditional warehouse.

ASRS also ushers in Just-In-Time production, which requires sub-pallet level availability of production inputs. ASRS is a much faster way of organising the storage of smaller items next to production lines. This enables a seamless link to order processing and logistics management in order to pick, pack, and ship product out of the facility. By tracking and analysing the data of raw materials through finished goods, companies can control inventory levels, maximise the use of warehouse space, and are more prepared for the demands and supplies of the market, especially during special circumstances such as a peak season. Accordingly, the advanced production mode would require various hardware and software suppliers to complete the production process, creating jobs in smart equipment manufacturing, system design & integration, installation & maintenance, as well as customised transportation & delivery.

Visual & Environment Processing and Cargo Transportation

Peter Chalif
Head of Structured Trading, Citi Municipal Services

Many different fields use visual processing, where the extraordinary rise in the quality of optical sensors, significant reduction in their cost, and exponential increase in computing and algorithm capability is driving rapid improvements and expanded capability. Visual processing is typically used to map an environment and recognise objects. Other technologies such as LIDAR perform related tasks, also mapping the physical environment. One of the highest profile examples of visual and environment processing is in autonomous vehicles. Unlike humans, machines don't get tired, get distracted, have road rage, drink or text and drive, and they can monitor 360 degrees of visual field continuously rather than the typical human limit of about 200 degrees, not to mention the optical nerve's blind spot. While components might fail, sensors and machines are often developed to alert for a failure condition, and can be made redundant. On October 9th, 2015, the California Department of Motor Vehicles released its conclusions on the nine accidents to date involving self-driving cars in that State. All were determined to be human error.[88]

[88] https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/autonomousveh_ol316

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The adoption rate of autonomous vehicles will accelerate over the next decade due to the impact on human safety and also financial impacts through insurance industry changes.

Multiple articles have described the potential economic impact of autonomous vehicles. "A World Without Work" by Derek Thompson[89] cites driving as the single most common occupation for American men. Away from the more obvious jobs, taxi driving and trucking, there are other potential economic impacts as well. Computer vision and the development of autonomous vehicles could lead to fully autonomous transportation of goods from factory to end consumer, and disruption of the trucking, shipping, retail, and insurance industries.

With the increase of machines used for loading, transporting etc. there could be a near zero or zero human work needed in these areas

There are about 20,000 general cargo ships and 5,000 container ships operational at any given time in the world. Machines guided by humans already do most of the loading, transporting, unloading, and delivery of standardised units of trade due to the size and weight of the objects involved. With autonomous trucking, robotic warehouses, and self-driving delivery on the horizon there might be near zero or zero human work needed from the point of factory straight through to consumer delivery. The technology for all these functions already exists and the components are either partially or fully deployed or being tested. Daimler-Benz is testing autonomous trucks in its Future Truck 2025 program. Amazon repeatedly shows its brilliance and flexibility in logistics, and Bombardier's automated people movers (Bombardier.com) are one of the leaders in automated trains with over 40 years of operation. With machine vision and environmental processing as critical components the transport and shipping industries may change radically and employ far fewer people in the years ahead.

Automation in Supply Chains

Kate McShane, CFA
US Apparel & Footwear and Retail/ Hardline Analyst, Citi

With raw material prices stable or on the decline, labour inflation continues to be the biggest challenge to apparel & footwear manufacturers' input costs (~15% growth year-on-year), and the industry is not seeing any meaningful offset from recent currency devaluation/a stronger US dollar. Nevertheless, the industry has been effectively mitigating higher wage costs with increased supply chain efficiencies, notably lean manufacturing, automation, and improved technology. New technologies include: (1) the use of 3D printing for creating rapid prototypes, drastically reducing production cycle times; and (2) systems integrating real-time POS data to inform the production process and thus reduce inventory risk.

While currently only utilised by a small percentage of the industry, over time automation should enable vendors to bring manufacturing to local markets, thus drastically reducing shipping times (for example from 4+ weeks from Asia to days). Automation will also benefit the consumer by enabling new opportunities for customer personalisation/customisation. However, the majority of the industry is still several years away from investing in the systems, staff training, and adjusting their organisational structure in order to leverage these newer advances, with an estimated 85% of retail companies still operating as they did 15 years ago on manual spreadsheets and lack of real time data.

Nike is at the forefront of supply chain innovation using platforms like Flyknit

Nike remains at the forefront of supply chain innovation in the industry with early automation used in its Flyknit platform. Management highlighted opportunities to eventually lower overhead and increase quality in more than 50% of Nike's current production through automation. The company recently completed pilot testing on

[89] Thompson, D., (2015) "A World Without Work" by Derek Thompson,The Atlantic, July/August 2015.

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automated stitching, reducing production on a typical size run of its iconic Air Force 1 shoe from over 500 components across multiple factories to just a single machine and operator (savings of $0.18 per pair of shoes). The company is also in the early stages of a new partnership with Grabit to automate material adhesion, logistics, and distribution process.

The Increased Use of Robots in Factories

Martin Wilkie
Head of European Capital Goods Research, Citi

Henry Ford II (president of Ford): Walter, how are you going to get those robots to pay your union dues?

Walter Reuther (leader of the automobile workers union): Henry, how are you going to get them to buy your cars?[90]

The above conversation allegedly took place in the early 1950s, yet seventy years later assembly line workers still exist, especially in small parts assembly where humans have tended to trump robots on flexibility, adaptability, and the ability to visually identify and select small components hidden amongst an assortment of other parts.

Lights-out factories already exist with Fanuc already having factories that run without human intervention

Is that about to change? Earlier this year, numerous press reports picked up on the rise of robots to replace production assembly workers in China. Guangdong Everwin Precision Technology commented that *"by using 60 industrial robots, an assembly line that would have needed about 600 workers in the past now needs just 100."* The investment was seemingly made to counter labour shortages in the region, but still evoked fears in the popular press that robots could finally replace labour on the assembly line. The rise of co-bots — collaborative robots that can work alongside human labour on a factory floor (rather than in a segregated area for safety reasons, as is common on an auto assembly line) — has stoked this argument further. Lights-out factories (factories that require no human presence onsite) already exist — Fanuc, a robot manufacturer, famously already has factories that can run without human intervention.

Small parts assembly has (so far) been relatively more immune to robotics than in the auto industry. Human hands are more adaptable (so can switch tasks) than most robots, and small parts assembly is different to the predictive and repetitive process of welding or painting in an auto plant. Features like dexterous grippers, sensitive force control feedback, and visual identification software are changing this. This year's Hannover Messe in Germany saw the commercial launch of ABB's Yumi co-bot — as well as several from other manufacturers — with small parts assembly a key target market.

Graeme McDonald
Japanese Machinery & Shipbuilding Analyst, Citi

A couple of recent visits to factories in southern Japan highlighted not just the scale of automation at some plants but, more importantly, the scope for more work to be automated. In northern Kyushu we visited a Unipres facility which mainly supplies pressed parts to Nissan. This plant employs 365 full-time employees but has more than 500 Fanuc robots. These robots are picking up random parts from bins delivered to their cells (taking advantage of Fanuc's 3D vision systems) and then literally handing them over to the next robot which sets them in place to be welded (again by robots), before being assembled by more robots. Some processes like loading sheet metal into the magazine of a press are still labour intensive but it seems likely that this kind of job could be easily automated. This plant does have one co-bot supplied by Yaskawa, and its name is Kathleen.

[90] It is not known whether this conversation actually took place with Henry Ford II or a manger representative of Ford.

Kantunori (a name given to a co-bot) is at least 30% more efficient than his human counterpart

At THK's main linear guide assembly plant in Yamaguchi prefecture there are nearly 700 full-time employees. As the products being assembled are smaller, with more customisation, the level of automation was much less. We counted less than 30 small-sized, compact robots including a number of Fanuc's parallel-link robots, Fanuc's arm sized LR mate robots and Nachi's M-207 high speed assembly robot. However, what literally stood out were the five Nextage humanoid robots supplied by Kawada. With bi-lateral vision, these robots are employed at two places assembling linear guides, working outside of a cage with no safety curtain. These robots have name tags and we were impressed to hear that one robot called "Katunori" is at least 30% more efficient than his human counterparts. THK said that this plant has been visited by three large Japanese auto OEMs recently who all want to see these guys at work. THK plans to increase the number of robot workers but recognises the need to balance the concerns of full-time employers in a rural area with limited alternative job opportunities.

In Aichi Prefecture, we also recently toured OSG's largest cutting tool plant, which employs 450 people. With an average lot size of only 130 pieces (and monthly capacity of 1.5 million pieces) the manufacturing process is largely already automated but most of the inspection is still done visually. This is slowly changing as advancements in high-spec vision inspection systems means that this process can now also be automated with workers moved over to packaging and loading. However, with companies like Daifuku now collaborating with robot supplier Yaskawa to automate these very unique steps in the value chain, we wonder if this is the next process to be automated.

Automation 2016: 3D Printing

Ken Wong, CFA
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Additive manufacturing, also known to many as 3D printing, has the long term potential to revolutionise the manufacturing landscape. The technology combined with innovations in computer design software (CAD) will digitise production and enable deeper levels of automation across the manufacturing workflow. We believe the digital factory floor has the potential to expand the limits of product design, form, and function. More importantly, at-scale additive manufacturing could drive manufacturing to new levels of efficiency by automating the human elements of production (both design and operations).

Today's 3D printers have yet to achieve the speed, capacity, and most importantly the price to rival traditional manufacturing processes such as injection moulding and milling. However our visits to 3D printing service bureaus revealed that a factory floor with north of a hundred machines could be operated by shifts of no more than a dozen workers. While some engineers were on site to monitor and manage the builds, a majority of the staff were simply emptying build boxes and replenishing print materials.

Dentists are increasingly using 3D printing for medical implants and dental moulds, cutting out the service centres completely in the process

There are several markets where 3D printing has or will make an immediate impact. We believe the medical implants market will be one of the first to convert to a fully digital manufacturing process. In one sub segment of this, the manual process of creating dental moulds and implants has begun shifting to 3D labs. With small commercial machines falling below the $10,000 price range we have even seen a shift towards dentists bringing those capabilities in-house and cutting out the service centre completely. Special effects departments have also shifted a lot of prop making capabilities to 3D printing. The props are more realistic and cheaper to make with 3D printing.

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Lastly we have seen the slow demise of the traditional model makers and job shops. This is a very broad category, but many larger manufacturers employ regional workshops to create one off jigs, fixtures, prototypes, and other products. We believe this lesser known craftsman has seen the most immediate impact from 3D printing and has made some headlines with unions in Detroit calling out that 3D printing has driven down the value of these jobs. Some job shops have adapted by rebuilding their businesses by incorporating the 3D technology.

The next big step of the 3D printing revolution will require CAD software vendors like Autodesk, PTC and Dassault to get more involved in additive manufacturing. By more tightly integrating the hardware with software, the digital production workflow process from design to production would be completely automated. Given 3D printing allows for complete freedom of design, it could enable the creation of structures previously unbuildable, including moving components within parts. The ability to print moving parts within a single build could potentially eliminate the need for factory workers to assemble the finished product.

At this time, 3D printing is not completely absent human involvement; technicians are still needed to periodically monitor the fabrication process, empty build boxes, replenish consumables, and perform some post processing (remove excess build material and in some instances polish items). However, even these basic manual processes are likely to be eliminated as printer original equipment manufacturers (OEMs) are already trying to incorporate monitoring and continuous printing capabilities into systems.

In conclusion we see a number of industries that are already computerising and automating a number of their tasks. The technology is improving at a fast pace, as shown in our discussion on natural language processing and decision support systems. Costs of automation are also expected to decrease over time as highlighted in the next chapter, removing the economic barriers over time and therefore encouraging new industries which have traditionally kept away from automation to introduce such systems.

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What are the Barriers to Automation?

Highlights

- As technology improves, one of the biggest barriers to adoption should be the economic cost of investment. However payback periods for robots are falling fast: 1.7 years for the most popular auto robot used in China; less than half a year in metal manufacturing in Germany; less than 2 years for hospital co-bots; or 195 days for Universal Robot's co-bot. This is positive for companies and consumers, but not for workers.
- However there remain some barriers especially in SME's which pride themselves on their fixed to variable ratio, and have additional burdens such as high installation costs for bespoke systems.
- Other barriers besides costs remain such as finding the right skills for the jobs available and systems lock in with proprietary systems, even though robots using open platforms are increasing.

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As robots become faster and cheaper they will revolutionise the manufacturing and service industry. The International Federation of Robotics (IFR) have estimated that global sales of industrial robots are expected to grow 15% year on year with the number of units expected to double to around 400,000 units in 2018.[91] Service robots are also expected to increase to around 35 million units with a sales value upwards of $12 billion from 2015 to 2018.

Despite strong potential growth, there nevertheless still exist barriers to the widespread adoption of automation and robotics in various sectors. These include the initial capital investment required, a shortage of skills and expertise, and a lack of understanding of how companies, especially small and medium firms can produce an attractive return on their investment.[92] As we will see from this chapter the costs of industrial robots are decreasing, therefore reducing the economic barriers to their adoption. Collaboration robots are also becoming an affordable solution for SMEs that address both the costs and flexibility needs of these companies.

Industrial Robots: Manufacturing

Industrial robots are not new and have been in operation since the 1960's. They are primarily used in just four industrial sectors: (1) the auto industry, (2) computers and electronics, (3) electrical equipment and appliances; and (4) machinery. Robots are used for a number of different applications including spot and arc welding in the auto and metal manufacturing industry, material handling, palletising and various operations for metal machining and plastic moulding, assembly, and pick and place, product inspection; all accomplished with high endurance, speed, and precision. Historically they have been quite expensive to own and operate and therefore are mainly found in large factories owned by large corporations with large budgets.[93]

[91] World Robotics Survey, Industrial Robots are Conquering the World.
[92] PWC, 2014, The New Hire: How a New Generation of Robots is Transforming Manufacturing.
[93] The Boston Consulting Group, 2015, The Robotics Revolution, The Next Great Leap in manufacturing.

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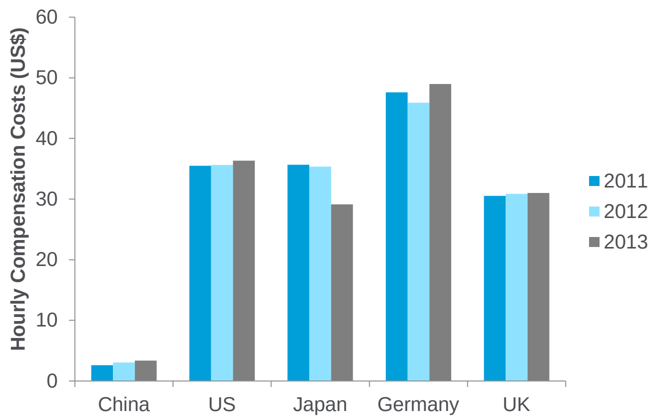
The price of a spot welding robot is expected to decrease by $30,000 over the next 20 years

But robots are getting cheaper and the economic and technical barriers to their adoption are beginning to fall. In fact the Boston Consulting Group has estimated that the cost of a typical spot welding robot used in the U.S automotive industry will decrease from $133,000 in 2014 to $103,000 in 2035.

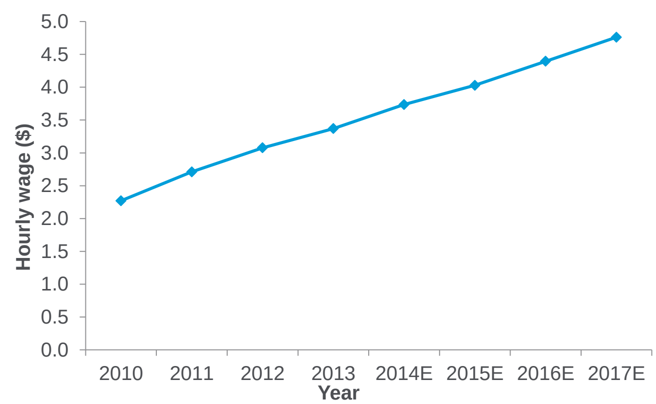
Even though the cost of robots is an important factor in a company's decision to automate, issues such as the cost of labour, labour shortages, productivity gains and quality improvements are also important. Figure 78 below shows the average manufacturing wages in the US, UK, Japan and China. Despite China currently having among the lowest manufacturing wages, it is currently ramping up automation and is becoming the largest and fastest growing robotics market in the world. This push towards automation is in response to the rising labour wages which have risen by over 40% between 2010 and 2013 and are predicted to continue to increase over time (Figure 79).

Figure 78. Average Manufacturing Wages in Different Countries



Source: The Conference Board[94], Citi Research

Figure 79. Wages in China are Expected to Increase over Time



Source: Citi Research

Payback period of a spot welding robot in China is expected to reach 1.3 years in 2017

Due to the decreasing costs of robots and increasing labour wages over time, the payback period of a typical 165kg spot welding articulated robot used in the auto industry is expected to decrease in China from 2.5 years in 2013 to 1.3 years in 2017 (see table below). The costs of the automation could decrease even further if components are built in China itself, rather than imported.

Figure 80. Payback Period of a 165kg Spot Welding Robot in China Used in the Auto Industry

	2010	2011	2012	2013	2014E	2015E	2016E	2017E
Robot ASP(Rmb K)	463	441	420	400	376	353	332	312
Annual Maintenance	46	44	42	40	38	35	33	31
No. of workers replaced	3	3	3	3	3	3	3	3
Workers annual wages (Rmb K)	31	37	42	46	51	55	60	65
Total labour cost saved per year, including social welfare (Rmb K)	134	158	180	201	221	238	258	279
Payback period (years)	5.3	3.9	3.0	2.5	2.1	1.7	1.5	1.3

Source: Citi Research[95]

[94] The Conference Board, International Comparison of Hourly Compensation costs in manufacturing, update to 2013.
[95] Alex Chang, Eric Lau, Paul Gong, Graeme McDonald, China Automation in a Global Context, 21 May, 2015, Citi Research.

Similar results are seen for a typical arc welder robot system which is traditionally used in the metal industry. Based on an ABB ARC flex 250R robot system and using current wages in the metal manufacturing industry, current payback periods in the US, UK, Germany, and Japan for this particular system are estimated at less than half a year and over 2 and 5 years in China and Thailand respectively (refer to Figure 81). The cost of the robot system is estimated at $80,000 and operational costs for the system are calculated at one person per robot as stated by ABB on their website. The ARC welder robot system replaces 3 people per shift as it is assumed to work continuously for 2 shifts replacing 6 people in total. If we assume a 6% decrease in the cost of the robot arm every year, and an increase in China's and Thailand's labour wages (based on wage increases in the previous years) then the payback period for this particular system would reduce to 1.2 and 2.6 years respectively in 2017.

Figure 81. Current Payback Periods for a Typical Arc Welder

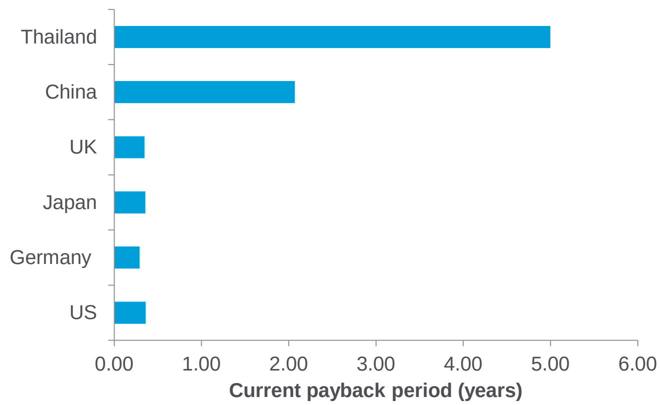
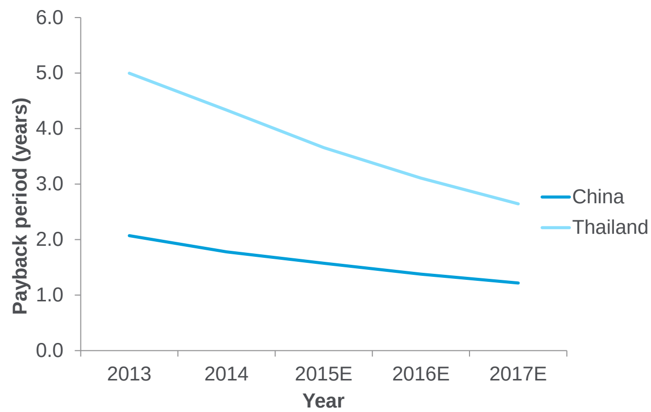


Figure 82. Payback Period Decreases Over Time



Source: Citi Research

The payback period is based on the cost of the robot system, average wages for metal manufacturing (for China and Thailand average manufacturing wages were used) and replacement labour based on 2 shifts. The costs also take into account a 5% additional potential savings through reduced staff welfare costs, optimised energy consumption, increased throughput and reduced wages.

Even though costs of robots are decreasing, barriers for SME's still exist

Manufacturers, especially SMEs, pride themselves on their fixed to variable cost ratio. But even though the payback time of a robot is falling, the robot is still a fixed cost. During a recession period, factories will typically reduce shifts by laying off some workers to reduce expenses. If instead of workers, they borrowed money to buy a robot they, would still be paying interest on the loan even though the robot would temporarily be left idle. The good news is that there is a second hand robot market, so companies can claw back some of their investment if they determine that it is not feasible to keep the robotic system in place.

Installation costs are an additional barrier-estimated at 35-45% of the total cost

There is also however an additional cost burden — that of installation costs, especially for bespoke systems. The costs in our payback analysis only include robot systems (including tooling) and operational costs but do not include any installation and/or programming costs. These costs could be quite high, and are estimated at approximately 35-45% of the total costs of the automation.[96] In the case of large firms, these costs can be avoided if the firm has adequate skills on site and therefore has the capacity to install these systems themselves. For others this would mean hiring a number of engineers to undertake such a task or paying

[96] The Boston Consulting Group, 2015, The Robotics Revolution, The Next Great Leap in Manufacturing.

programming fees. But the installation for certain robot systems are becoming a lot easier. This is where collaboration robots come in to play — they are cheaper, less complex, and work directly with humans; however they are considered to be slower when compared to traditional industrial robots.

Collaboration robots (Co-Bots)

What makes collaboration robots different from regular industrial robots is that they work next to a person and there is no need for safety cages or other equipment or guards normally used with industrial robots. They also don't need to be programmed to do one specific task and can easily be taught to do new tasks for different applications. This is especially helpful for SMEs as one of their concerns is that their orders change from time to time requiring changes to be made to their manufacturing process. A quote from Chip Gear the president of Technology House who has a 72-employee manufacturing firm which produces medical devices and currently automates parts of this manufacturing process, highlights such issues: "Robots can work 24 hours a day. You set up the raw material and take off a finished part…But what scares a lot of smaller manufacturers like us is that you have repetitive work and when orders change or the parts mix changes it requires reprogramming or even a new robot."[97]

The costs of co-bots range from $29,000 to $60,000 and so are rather affordable compared to industrial robots

Collaboration robots are affordable and are not overly complex to set up; therefore there is no need for specialist knowledge to operate them. Examples of co-bots include Baxter and Sawyer made by Rethink Robotics and UR5 and UR10 made by Universal Robots. Sawyer is currently marketed at a base price of $29,000 and can be used for kitting, packaging, loading and unloading, machine tending, material handling, and electrochemical machining (ECM) automation. The price includes a one year warranty and a one-year subscription to software capability and additional tools and subscription packages are available. The UR5 robot is used for applications such as pick and place, injection moulding, packaging and palletising, and quality testing, it is currently marketed at a base price $34,000. Universal Robots claims that the average payback period for their UR-robot is 195 days.[98]

Figure 83. Collaborative Robots Working Closely with Humans

Source: Image taken from http://www.sme.org/MEMagazine/Article.aspx?id=73500

[97]http://www.cleveland.com/business/index.ssf/2014/10/robot_usage_in_manufacturers_c.html
[98] http://www.automateshow.com/exhibitor-details.cfm?id=96

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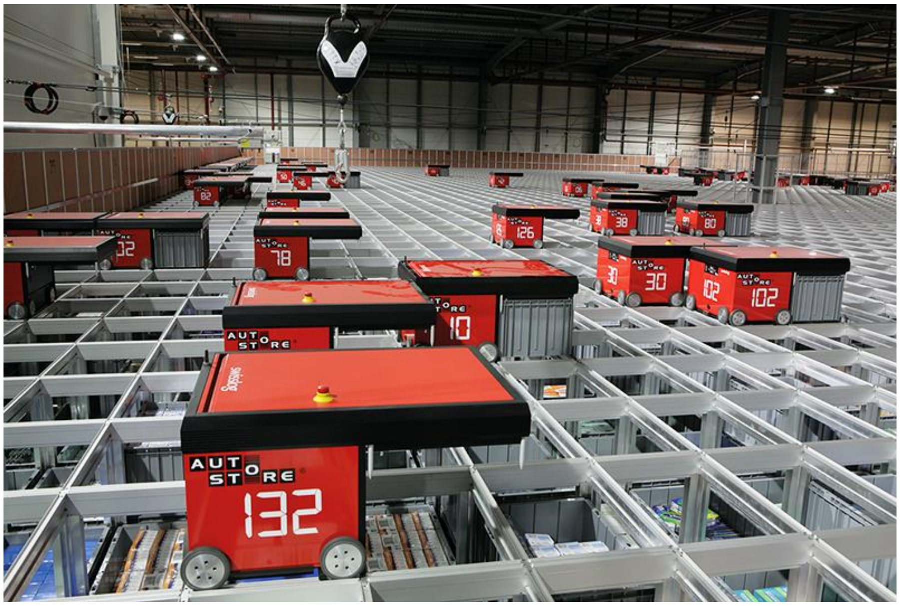
The relatively cheap cost of collaboration robots could ultimately change the manufacturing platform of SMEs. One of the barriers to the wide-adoption of co-bots is convincing clients of the benefits of collaborative solutions. The technology is also expected to improve over the coming years, so SMEs and other companies are worried about getting locked into a particular system when the technology is still at an early stage. They are however priced at less than an average person's salary in developed countries which means that the return on investment would be relatively quick, and they allow more flexible manufacturing practices when compared to the traditional industrial robots — something that SMEs typically require. To date, the sale of co-bots are only a small proportion of the total industrial robots sold per year with Universal Robots selling about 3,500 units of its co-bots since 2008 and only a few hundred Baxter's have been sold since its launch in 2012.[99] We do not believe these figures illustrate the future potential of the co-bot market.

Competing Robotic Warehouse Systems: The Increase in E-Commerce and Automation

Warehouse robots such as Swisslog's Carrypick system could have a payback period of 2.4 years

Packing and palletising industrial robots have been used for many years to prepare products for their end-use. Now large warehouse systems are installing robots/automated systems to also fetch and pack. These automated warehouse workers, the most well-known of which are Amazon's Kiva robots, typically use barcodes and other identifiers to find products stored in a warehouse and move them to a shipping queue. Other robots that are being used in this sector include the Carrypick system by Swisslog, GreyOrange and Fetch Robotics. Swisslog states that that their click and pick system which includes conveyer and lifting technology, warehouse management software, and preconfigured systems such as carry pick has a payback period of 2.4 years. This assumes a labour cost of $20/hour, average inventory value of $1,000,000 and building costs estimated at $11/square foot/month. The payback period increases to 3.6 years with labour costs estimated at $10/hour and inventory value at $500,000. Therefore low wage countries would see payback periods for warehouse automation to be much longer.

Figure 84. Carry and Pick Systems Used in Asda



Source: Image taken from http://www.swisslog.com/en/Success-Stories/WDS/References/ASDA

[99] Robots rub shoulders with human buddies, The Financial Times, March 19th, 2005.

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Health Care Robots

The health care sector has been using robotics and technology for many years, most notably the Da Vinci system a $1.5 million robot that assists in surgery. It was given approval by the FDA in 2000 and since then the system has performed minimally invasive surgery on more than 2.5 million patients worldwide.[100] It has also paved the way for new robotic advancements in health care including telemedicine which improves efficiency, and other important robots that are used for collecting, preparing and sorting medications, collecting and analysing laboratory samples, and caring, supporting and helping elderly and disabled people. Given estimates of a health care worker shortage in the robots/automation will likely play a very important role in making the health care sector more efficient and effective.

TUG robots are only available to large hospitals as their costs are prohibitive for smaller hospitals and medical centres

An example of a robot that can help improve efficiency in hospitals is the TUG robots developed by Pittsburgh-based Aethon. These robots move around the halls delivering medical supplies, blood, meals and more, and use lasers to avoid obstacles and humans, wirelessly open doors, and call for elevators. The University of California, San Francisco Medical Center purchased 25 of the TUG robots for $3.5 million and spent another $2.5 million retrofitting the robots and the hospital. Brian Herriot, Director of Operations Planning at the Medical Center stated that based on current employee pay and benefits he estimates the hospital will break even within two years.[101] It is difficult to say whether TUG robots will replace any workers as they are meant to allow staff to spend time on issues such as direct contact with patients, and are expected to improve the efficiency in hospitals. Because of their high price, however, they are currently only an option for larger hospital systems as they are too expensive for small hospitals and medical centres.

Figure 85. TUG Systems Used in Hospitals

Source: *Image taken by http://www.aethon.com/*

Other Barriers

Finding skilled people to repair and maintain robots could be a barrier to automation

Toyota has stated that it is finding it hard to employ advanced manufacturing technicians. One of the reasons Toyota is able to manufacture autos so quickly is that robots do a lot of the work, but like all machines they break down, and advanced manufacturing technicians are needed to fix and maintain the robots that help build cars. This is not only a Toyota problem, in fact according to Deloitte (2012) there were a total of 600,000 skilled manufacturing jobs which went unfilled. Governments and companies are launching campaigns and investing in new

[100] www.davincisurgery.com

[101] Pricy Robots 'Tug' hospital supplies, Althea Chang, CNBC, 30th April 2015

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education programmes to encourage more students to take science, technology, engineering and maths subjects. A lack of skills in these areas could provide an additional barrier to the robotics industry and the expansion of automation in different industries.

The shift from proprietary systems to open source platforms could lead to increased competition and lower costs for consumers

Whether robots should operate on proprietary systems or open platforms such as Robot Operating System (ROS) developed by Willow Garage is also up for debate. Proprietary robot systems have traditionally been the norm in robotics. These systems lock in customers to a particular robot, brand etc., and ultimately limit competitors entering the market due to the heavy investment and learning curve that is required to break-in. For example when a factory adds a robot to its operations, it is typically set up with proprietary software that comes with the robot hardware. Some such software offers modules that let robots adapt to dynamic environments such as changeable motions to manipulate objects but adaptive functionality is often limited. Some argue that proprietary systems ultimately raise the price for goods and services. Open platforms such as ROS offer more flexibility for customers and was created to help developers build robot systems at a faster rate, by allowing them to spend time on new applications and better functions rather than on getting robots to move between A and B, something which the industry has already addressed. Rethink and Universal Robotics both use ROS for software development but not for their control systems, whilst industrial robot manufacturers such as ABB Robotics are beginning to provide ROS-like capabilities in the form of updated software and simulation suites.[102] Open source robotics systems encourage innovation to happen at a faster rate and provide the opportunity for multiple companies to operate in the same space, increasing competition and therefore reducing the costs for consumers.

In conclusion, as robots become faster, smarter, cheaper, and develop advanced capabilities, industrial manufacturers across different industries will be looking to advanced robotics to gain a competitive advantage. We can already see that payback periods are decreasing over time and robots will become more affordable in countries like China and Thailand where labour wages are expected to increase.

However, there are still a number of barriers for small and medium manufacturers, including not only cost but the adaptation of robots to different tasks as their operations change from one order to the next. Collaboration robots offer a solution for SMEs as they are cheaper, flexible, and less complex than other industrial robots. Price is one consideration that SMEs look at, however they also take into consideration their complex manufacturing needs and requirements. Steve Somes, President of Force Robots in Cleveland has stated that ‘The challenge facing robot companies is that today’s manufacturers run lean, have stringent quality standards, and have complex needs. If your system is rugged and cannot perform the needed work reliably, it does not matter how inexpensive it is…Of the new robots available now, not all of them will succeed.”[103]

What is definitely clear is that industrial robots, service robots, and other automation processes such as 3D printing will change the manufacturing and working platforms in many industries. Barriers still exist for small SMEs but we believe these will reduce over time.

[102] http://robohub.org/frank-tobe-on-is-open-source-a-good-business-model-for-robotics-2/

[103] http://www.cleveland.com/business/index.ssf/2014/10/robot_usage_in_manufacturers_c.html

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Response: Policy and Job Risk from Automation

Highlights

- Active labour market policies (ALMPs) are a broad term to cover policies that either reduce the cost of labour, or that help people find jobs. We suspect the extent of public spending on ALMPs will need to rise substantially as the effects of automation and advanced technological change become increasingly clear.
- Some argue a basic income or benefit (healthcare, housing, pensions, etc.) should be provided to offset job loss.
- Changes in taxation are a material risk for investors, but likely also impede an effective policy response to challenges from technological change.

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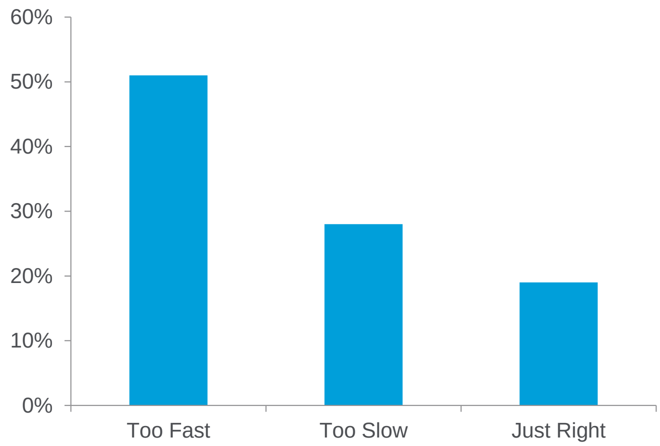
It should stand to reason that a world in which innovation is fast and abundant should be preferred to a world in which innovation is lacking. But this report and our original report on the potentially disruptive nature of automation and other potentially transformative technological developments show that, if unmanaged or poorly managed, these changes have the potential to create significant disruption, so much so that their overall impact may not even be benign.

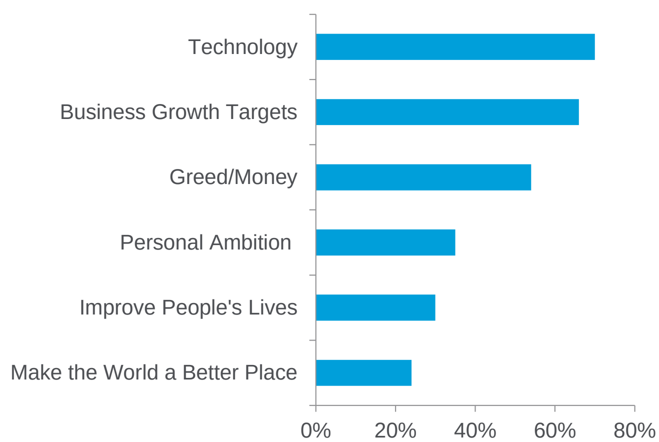
In our recent Citi GPS report called 'Global Political Risk' we highlighted that more than half of the global 'informed public'[104] believed that the pace of development and change in business today was too fast (Figure 86), and over 70% believed that technology was the largest driver of change in business (Figure 87). They also stated that there is not enough government regulation in a number of industries.

Figure 86. The Pace of Change is…



Source: Citi Research, The 2015 Edelman Trust Barometer

Figure 87. Technology is Seen as the Biggest Driver of Change in Business



Source: Citi Research, The 2015 Edelman Trust Barometer

[104] 'Informed public' meet the following: (1) criterial college-educated;(2) household income in the top quartile for their age in their country; (3) read or watch business/news at least several times a week; (4) follow public policy issues in the news at least several times a week.

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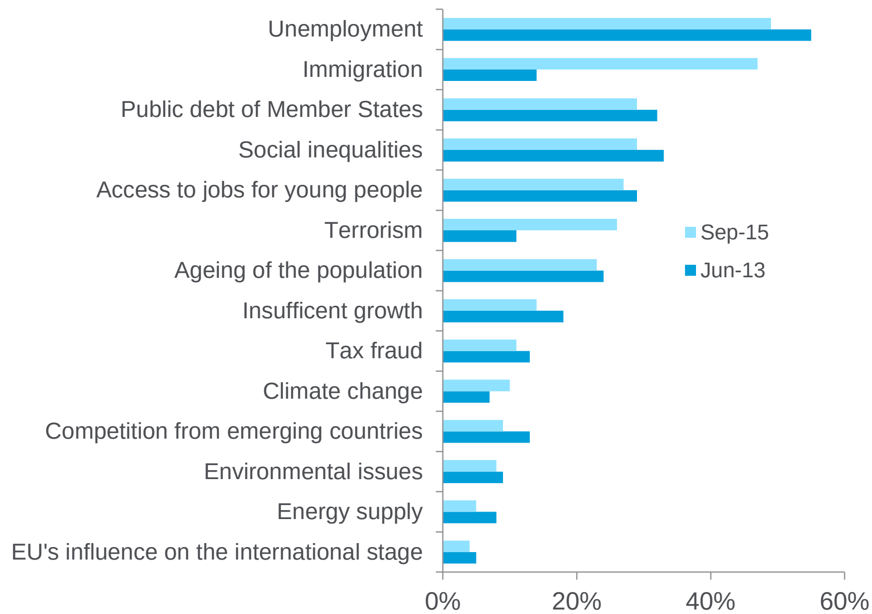
The issues from disruptive technological changes include potential loss of jobs, inadequacy of skills and winner-take-all approach

The first step to identifying what an adequate policy response to automation should be is to define the problem. In the case of the disruptive technological changes, the issues we are likely to encounter include the potential loss of jobs in many industries, the inadequacy of skills of some of the workforce to find equally good jobs, and the winner-take-all nature of much competition. Some of these issues may manifest themselves in high unemployment and are likely to be associated with even greater inequality of income and wealth than we see today. According to a survey undertaken by the European Parliament Eurobarometer, concerns about unemployment, social inequalities, and access to jobs for young people are considered some of the main challenges facing the EU and its Member States (see Figure 88). Unemployment is seen as being more of a challenge when compared to other pressing EU issues such as immigration and public debt.

Figure 88. Unemployment is Seen as the Largest Major Challenge in the EU



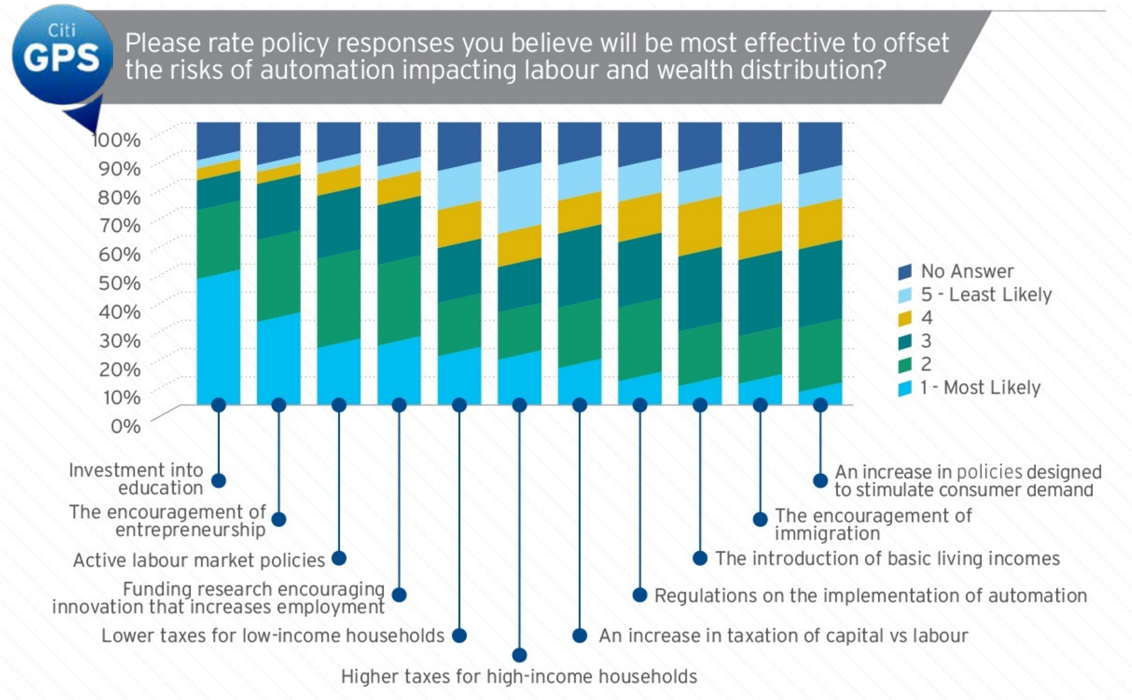
Source: Citi Research, European Parliament Eurobarometer (EB/EP 84.1): The main challenges for the EU, migration, and the economic and social situation, published 14 October 2015

Note: Question asked: In your opinion, what are the main challenges facing the EU and its Member States in order to face the future? Firstly? And secondly? And thirdly? Max 3 answers

Revamping education could be a solution

Part of the solution will clearly lie in revamping education, which Dr. Craig Holmes discusses in a later chapter in this publication. This is also the number one suggestion to address the challenges from innovation on the distribution of income, according to our client survey. But even successfully managing to change our educational system is unlikely to be sufficient to tame the destructive elements of major technological change. For one thing, there is increasing evidence that competition in the digital economy is increasingly 'winner takes all'. For instance, Furman and Orszag (2015) highlight that a substantial amount of the increase in income inequality in the US derives from income inequality between firms and therefore is presumably not dependent only on the skill and productivity of the individual. Policy responses will therefore need to be crafted to address negative consequences ex-post in addition to any effort to provide the workforce with the necessary skills and capabilities. Figure 89 below shows how our clients have responded with regards to important policies that will be most effective to offset the risk of automation impacting labour and wealth distribution.

Figure 89. Citi's Survey Results on Policy Responses

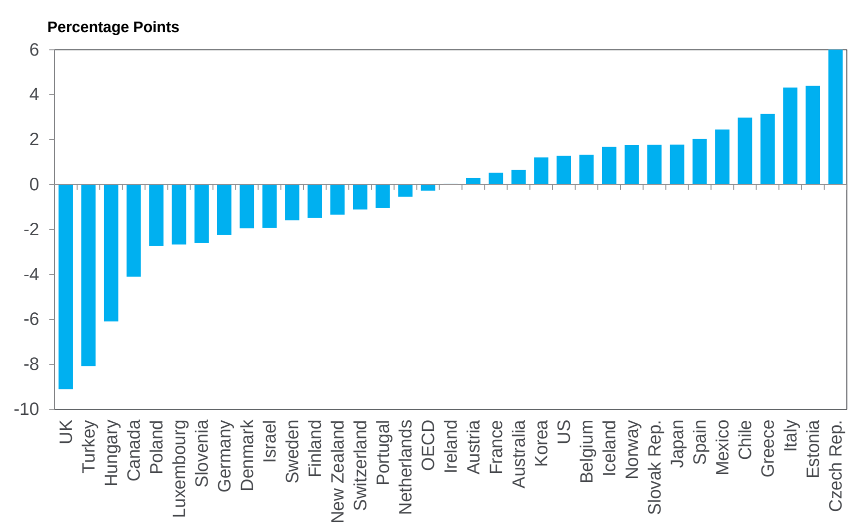


Source: Citi Research

Active Labour Market Policies

'Active labour market policies' (ALMPs) are a broad term to cover policies that should help people find jobs. Training and re-training can be thought of as types of ALMPs. Beyond those, ALMPs can be divided into policies that either reduce the cost of labour (or, increase labour income relative to the wage paid) or policies that make it easier to find jobs.

Figure 90. Change in Tax Wedge Between 2007 and 2012



Note: Data is for a single person at 67% of average earnings, with 2 children)
Source: OECD and Citi Research

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EITC could provide valuable income support for low-wage workers

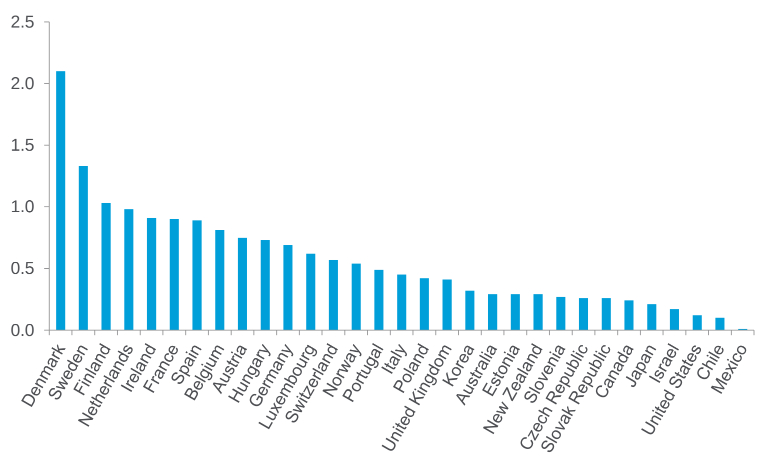
A crucial — and increasingly prominent — element of effective ALMPs is likely to be the widespread use of schemes that are similar to the Earned Income Tax Credit (EITC) in the US. Under such a scheme, workers receive a tax credit or refund at low levels of income. In the US, the credit is for up to around $6,000 for families with three or more children. The EITC therefore provide valuable income support for low-wage workers, while maintaining the incentive to find paid work.

There is plenty of room for EITCs, in our view. So-called tax wedges — the difference between gross labour costs and 'take-home pay' — are often very large, particularly in a number of European countries. The tax wedge is composed of employers' and employees' social security contributions and personal income taxes. In Belgium, France or Hungary it amounts to a staggering 50% of total labour costs for low-wage earners (i.e. those earning 67% of the average wage) according to OECD data. That is, a worker receives only about half of what the employer pays in total labour costs. Automation and some of the other ongoing technological changes imply that it is possible that the labour costs employers will be ready to pay may continue to stagnate or even fall. If that is the case, 50% of those labour costs is unlikely to amount to a 'living wage.'

Lowering tax wedges can be effective way to boost take-home pay or raise employment

Significantly lowering tax wedges can be an effective way to boost take-home pay (for unchanged gross labour costs) or raise employment (if gross labour costs fall) and likely a combination of the two. This is consistent with evidence in the UK, where the tax wedge was lowered substantially in the post-crisis period and the decline in the tax wedge along with a number or other measures (such as tightening benefit eligibility) likely contributed to rapid job growth in recent years. By contrast, in roughly half the OECD countries, the tax wedge *rose* in 2007-13, including in some of the fiscally challenged countries such as Spain, Greece, and Italy, but also in Japan and the US, which probably hindered job growth in those countries.

Figure 91. Expenditure on Active Labour Market Policies (% of GDP)



Source: OECD and Citi Research

In our view, it is likely that schemes such as the EITC will need to be extended significantly, including by raising the level of the subsidy and by changing its structure (e.g. currently the EITC in the US is only considered/paid once a year at the time of tax filing/refunds).[105]

[105] See also West (2015), "What happens if robots take the jobs? The impact of emerging technologies on employment and public policy", Brookings Center for Technology Innovation.

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Job placement services and special market programmes could also form part of the solution

In addition to EITC and other fiscal incentives for employment, active labour market policies also include job placement services and special labour market programmes that are aimed at helping the unemployed to find gainful employment. Such policies are particularly prominent in the Scandinavian countries, where these are sometimes credited as part of the reason why those countries can maintain generous social benefits with low unemployment rates.[106] A particular role among ALMPs is likely to be incentives and support for self-employment and entrepreneurship. ALMPs and support for entrepreneurship are among the policy responses most favoured in our client survey.

We suspect that the extent of public spending on ALMPs (which currently varies quite widely across countries) will need to rise substantially, as the effects of automation and other technological changes on the labour market become increasingly clear.

Boosting Volunteerism

Taking the idea of the EITC to an extreme, in some cases governments could decide to essentially sponsor volunteer work, i.e. reward workers that are not otherwise remunerated at all. Such work may be more or less coordinated by the state, which could draw up eligibility criteria. Since such work does not generate any direct income for the volunteer, the state would either directly (by paying stipends to volunteers) or indirectly (by subsidising those that fund the volunteers, including by giving them tax credits) need to bear the burden of the cost of the increased level of volunteering.

Minimum Wage

Minimum wages are sometimes considered as alternatives to EITCs and several countries have recently either increased the minimum wage (such as the UK or the US) or introduced a binding minimum wage for the first time (Germany). Supporters of a minimum wage stress that it does not create a direct fiscal cost and that, unlike EITCs, it does not let companies 'get away' with paying low wages.

We see EITCs as more appropriate versus minimum wages to deal with consequences of technological change

However, in our view, EITCs are more appropriate to deal with the likely consequences of technological change on the labour market than minimum wages: the rationale for minimum wages mainly derives from employers having too much bargaining power. But even though the innovations we describe imply that employers' bargaining power increases, we see the problem more that the marginal product of labour will be relatively low, which would require a lower wage for employers to create jobs. Put differently: in the world we describe, minimum wages would probably lead to higher unemployment rather than higher demand.

Basic Income and Benefits

In a world where full-time employment may be less common and more uncertain, the case to provide a minimum standard of living for those outside of full-time employment becomes stronger.

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http://www.brookings.edu/~/media/research/files/papers/2015/10/26-robots-emerging-technologies-public-policy-west/robotwork.pdf

[106] See e.g. European Commission (2006), "Employment in Europe" and Boone, J. and J.C. van Ours, "Effective Active Labour Market Policies".

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In some countries, e.g. the US, many benefits (including healthcare benefits and housing benefits) are linked to minimum requirements for paid work and contributions. Pension benefits are similarly dependent on consistent full-time work, with additional penalties for extended periods without full-time employment. Meanwhile, the self-employed are often exempted (and often excluded) from such arrangements for benefits and are expected to rely on their own provisions.

The idea of a basic income could also be sufficient to guarantee a minimum standard of living

One answer could be the idea of a 'basic income' that is sufficient to guarantee a minimum standard of living. Indeed, such a basic income has been advocated by a growing number of observers, including a number of prominent 'technologists.'[107] It has also been the subject of a popular referendum in Switzerland (where it was rejected).

The two main downsides of a basic income are (1) that it may blunt incentives to contribute productively to society and (2) that it may be an inadequate substitute for gainful employment even for the recipient. Proposed solutions to these two issues include lowering the gap between the basic income and/or introducing a scheme of extensive active labour market policies, supplemented by programs for volunteer work, similar to the Works Progress Administration in the US in the 1930s.

How to Pay for It

Most of the policy responses to the effects of technological innovations on the labour market that we can think of involve greater public spending, including greater public spending on education and training, on benefits (including earned income tax credits) and on helping the unemployed find jobs. The need for public spending may be even larger because such spending may need to be higher on a structural basis, rather than only during downturns.

How will we pay for such incentives given that the public coffers are stretched? Could an increase in income tax and wealth taxes be a solution?

The problem is how to pay for this, particular at a time when public purses feel rather stretched.

In principle, this problem may seem easy to solve. After all, if productivity growth is likely to be high, as our assessment suggests, *someone* should be benefiting from these developments. One possibility would therefore be to tax those who are better-off. This could be through an increase in top marginal income tax rates, increasing capital income tax rates, raising corporate income taxes, some form of wealth taxes or taxing goods or services more heavily that are consumed primarily by the wealthy.[108]

Such changes in taxation would seem sensible to us, but they would also be a reversal of the trends of the last few decades. The OECD notes that top statutory personal income tax rates have fallen significantly in each of the three decades between 1980 and 2010.[109] In 2010, the OECD average top statutory personal income tax rate was 41.7%. In 1981, it was 65.7%. Corporate income taxes have also fallen in recent decades, from 49% in 1981 to 32.5% in 2013.

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[107] See Brynjolfsson et al (2015), "Open Letter on the Digital Economy", http://www.technologyreview.com/view/538091/open-letter-on-the-digital-economy/
[108] Another direction would be to reduce other government expenditures. Given historically high ratios of government expenditure to GDP in many countries, this route strikes us as eminently sensible, but is outside the scope of this section. Governments should also in principle be able to take advantage of some of the improvements in technology to make government spending more efficient.
[109] See OECD (2011), "Taxing Wages".

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However, some of these trends may already be reversing. A number of countries have already increased their top personal income tax rates in recent years but there is no sign of headline corporate income tax rates rising systematically across countries. Significant efforts are under way to close loopholes in the current fiscal arrangements for corporates, to make life harder for tax havens and to tackle tax evasion and avoidance more effectively.

Could wealth taxes be the solution? Thomas Piketty, whose book 'Capital in the 21st Century' made headlines in 2014, has famously called for global wealth taxes as one of the main policy responses to rising (income and wealth) inequality (Piketty called for a tax of 1% on wealth of between €1m and €5m, 2% on wealth of greater than €5m and a much higher tax on fortunes significantly higher than €5m) and even the IMF has noted that a wealth tax may be appropriate in some circumstances. Yet outside of extreme circumstances there have been few (and usually only timid) attempts to increase the taxation of financial or real property in recent years (and they are quite rare in history). Similarly, the taxation of capital income has become increasingly prominent in policy discussions and speeches, notably the special treatment offered to particular types of capital income (such as for 'carried interest' of private equity owners). In his recent State of the Union address, US President Obama once more called for increases in capital income taxes and for abolishing some of these privileges. Yet we have seen very little in the way of an effective increase in the taxation of capital income anywhere.

One of the reasons why wealth taxes have not been raised more widely is that they are difficult to design, costly to administer, and often relatively easy to avoid. For ad-hoc wealth taxes, the risk is that households would fear that such taxes could be imposed again in the future. For financial assets, a major risk is that the capital will simply find a home elsewhere — a growing issue in a world of global financial mobility and still-increasing financial interdependence. Wealth taxes would therefore be much more likely to be effective if they were imposed globally (as Piketty argues). The same applies for corporate income and capital income taxation, but we see little scope for such an initiative in a world where global leadership is rare in any area, especially against what would likely be fierce lobbying.

The feasibility and effectiveness of even well-designed plans to raise taxes to address distributional implications of innovation are a key challenge. It is likely to be *harder* for governments to tax households and in particular businesses when the digital economy becomes an increasingly large part of the overall economy, as the digital economy has proven quite adept at escaping effective taxation.

Nevertheless, in light of the social, political and economic challenges that job polarisation creates, unexpected – and sometimes abrupt – changes in taxation are therefore a material risk for investors in the future. But equally worrying, the lack of an effective fiscal response implies that the strain on public finances will probably impede an effective policy response to those challenges. There is also another issue — whether governments are willing or able to make reforms and make difficult decisions. In democracies, countries with majority governments are able to push through reforms more easily than divided and multiparty governments. Other factors in determining reform capacity include high approval ratings, as Figure 92 highlights. How few elected leaders have approval ratings of over 65%, and how the majority languish in the bottom two segments, illustrate how limited the prospects for reform in the current political environment may be. For companies and investors, weak and divided governments can be a source of erratic policy-making and a more uncertain operating environment. Cohesive governments with sufficient political capital and legislative energy can be a source of policies that can drive growth, particularly through reforms.

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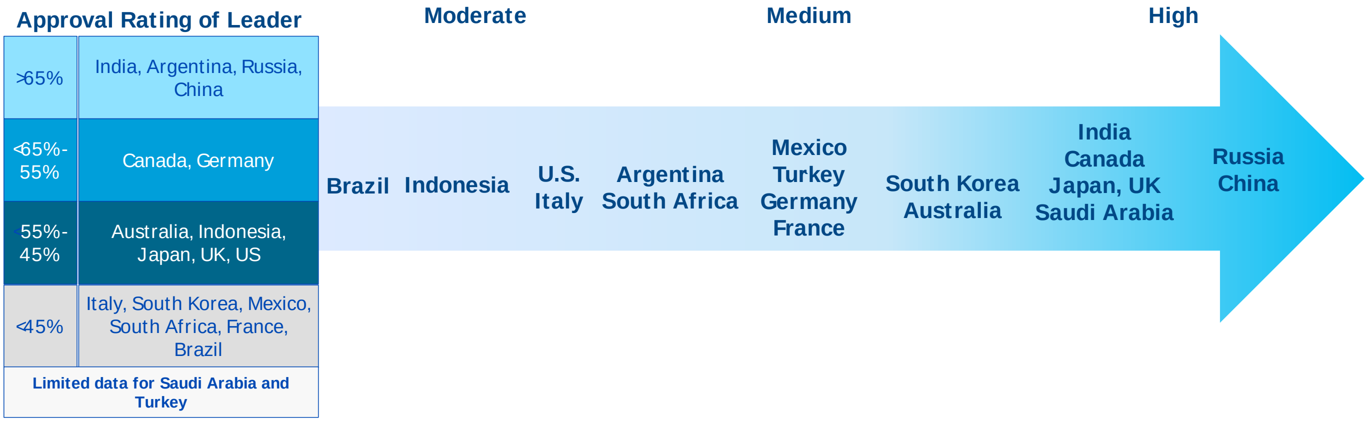
Figure 92. Reform Capacity of G20 Countries



Source: Citi Research, World Bank: World Bank Government indicators, IFES election Guide, various polls and government websites

Notes: We use four criteria to assess the reform capacity of G20 countries: (1) the approval rating of the country's leader, (2) the World Bank Government Effectiveness score;[110] (3) whether the government is (a) multi-party/divided, (b) "cohesive" (there is a majority), or (c) hybrid/communist/monarchy; and (4) whether there is an upcoming election/or has been a recent election

[110] World Bank. The Worldwide Governance Indicators (WGI) project. See: http://info.worldbank.org/governance/wgi/index.aspx#home

What Are the Challenges for State and Local Governments from Technological Change?

Highlights

- Local, regional and state governments face challenges in maintaining tax revenues from income disparities and from the difficulties in effectively taxing the digital economy.
- While the inflation and interest rate outlook should remain benign and technological change should help bend the healthcare cost curve down, several municipal costs face an upward bias, such as pensions and infrastructure.
- Technological change is likely to make economic growth increasingly uneven. To counter this there is a growing focus by some state and local governments on advanced industries.
- While we are confident a growing number of leaders are cognizant of the growing challenges of technological change, we are far less confident that leaders are willing to make this complex set of issues part of their political agendas.

What We Have Discussed So Far

George Friedlander
Municipal Strategy & Policy Analyst, Citi

We have been tracking the issues generated by accelerating technological change (ATC) for state and local governments and the municipal bond market for roughly 2 ½ years now. Our first goal at this point is to incorporate here the patterns we had identified, as a jumping off point for additional policy discussions below.

- **The inflation and interest rate outlook should remain benign.** These factors are covered in much greater detail elsewhere in this report. Suffice it to say that, for the purposes of this section, we expect inflation to stay extremely low and long-term interest rates to remain near current levels for an extended period of time. There is clearly a "good news" component in this for state and local governments, in the sense that their borrowing costs should remain low, and that the cost of capital facilities, in particular, should grow at a slowing rate in particular as energy costs remain low by recent historical standards (infrastructure building tends to be very energy-intensive). In addition, long, persistent benign periods for inflation will likely lead to longer, less volatile economic cycles, as central banks face reduced need to "take away the cookie jar" by raising short-term policy rates.

- **Another potential positive for costs is likely to occur in the health care sector.** Health benefits from technological change are likely to be dramatic, and methods for the delivery of health care will change dramatically. This is a highly complex and challenging topic in and of itself. Suffice it to say for now that many individuals in the health sector have noted a strong belief that over the intermediate term, technological change will help bend the health care cost curve downward, by making delivery of healthcare cheaper and easier to access, and by giving consumers much stronger access to choices. Given the large role of state and local governments in health care delivery and in paying employees for health care benefits, any downward bend in the cost curve should help ameliorate pressure on their budgets.

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- **Need for widespread additional policy responses.** Nevertheless, we believe that there is a growing body of evidence that policy responses at the Federal, state and local level beyond just accommodative monetary policy will be needed to respond to the changes and challenges currently under way. These changes include: (1) downward pressures on compensation for labour, and (2) potentially weakening demand — in the face of impressive output growth.

- **A key role for state and local governments as changes emerge and accelerate.** In our view, state and local governments will have to play a key role in identifying and implementing policy responses as the global and US economies adjust to a set of daunting new challenges. Particular challenges for state and local governments are likely to include:

Challenges for State and Local Governments

Local, regional, and state economic growth will become uneven

- **There is a high likelihood that local, regional, and state economic growth will become increasingly uneven** as some communities benefit from access to high-quality jobs, while others come under increasing pressure from competition from automated solutions. The implications of these patterns were discussed earlier in the section 'Cities at Risk'. Of course, in the United States specifically, the distinctions between governments and credits will occur at a much wider variety of levels than just cities — states, counties, special districts, and revenue-supported projects will also be exposed to increasing credit quality differentiation as some Standard Metropolitan Statistical Areas (SMSA) benefit from high availability of advanced industry jobs, while others do not.

  Bloomberg's "State Innovation Index" helps rank the 50 US states based on six factors: R&D intensity; productivity; high-tech density; STEM concentrations; science and engineering degree concentrations; and patent activity. Massachusetts, California and Washington were clustered at the top, with 17 states in a second tier.[111] Clearly in many states there will tend to be vast differences in the level of innovation. For example New York State ranks 17th, near the lower end of the second tier, but the New York City SMSA would likely rank highly if measured independently. On the other extreme the State of Arkansas ranks 47th in the survey, even as the city of Little Rock is working aggressively to grow its technology park, in a plan approved by the Little Rock Tech Park Authority in 2014. Be that as it may, we believe that this type of ranking may be useful for states, in the sense that it establishes targets and methodologies for lower-ranking states to incorporate into long-term plans.

It will be extremely difficult for state and local governments to respond to the declining cost structure in the consumer market

- **The challenge is keeping state and local costs from growing at historical rates,** even as overall private sector cost growth in the US economy is dampened by a growing output gap and downward pressures on the price of labour. In our view, one of the greatest challenges for state and local governments is that it will be extremely difficult for these governments to respond to the likely declining cost structure in the consumer market, and challenges on taxation in an increasingly digitised economy because many of their costs are contractually fixed or have a structural upward bias, such as pension funding. The result, we expect, will be an increase in "real" costs as inflation remains extremely low. Undoubtedly, these cost pressures will run full square into the need to respond to the growing and massive void in major maintenance and replacement of existing infrastructure, and legal limits on cost efficiencies in the construction and maintenance of such facilities.

[111] "Here are the Most Innovative States in America" from Benchmark, Bloomberg Business Week, January 7, 2016.

- **Challenges are likely to emerge in maintaining tax revenues** as aspects of the economy soften, and as income disparities widen over time in response to technological change, as the digital economy becomes more difficult to tax effectively. There will assuredly be pressures on the income tax revenue side as more types of jobs come under pressure from automated solutions, while many costs tend to be fixed or have an upward bias, particularly for pensions, employee compensation and infrastructure. And, at the same time, tax avoidance in sales tax-based revenue streams is likely to become a growing concern. And finally, as noted many aspects of the digital economy are exceedingly difficult to tax. (See "The Challenges in Taxing the Digital Economy," below.)

- **Undoubtedly, there will be a variety of challenges for state and local pension funds**, including in particular: (1) continuing low returns on the fixed income component of pension investments, and (2) growing post-retirement life-expectancies. The news isn't all negative, of course: to the extent that pension funds function as "owners" through the stock market and private equity, they will benefit from the increasing share of national income that is accruing to owners rather than labour. On the other hand, it remains an open question as to the extent to which the owner-side benefits will show up in portfolios consisting of publicly traded securities. A number of observers have suggested that large increases in the value of ownership shares may be: (1) limited to a relative handful of companies; and (2) particularly conducive to a venture capital-type model that does not fully accrue to the benefit of publicly traded companies such as those heavily owned by pension funds.

- **Infrastructure funding needs will compete with pensions and OPEB over time.** It is also important to note that a significant subset of the muni market is beginning to view the growing infrastructure shortfall as yet another unfunded "liability" along with pensions and unfunded healthcare benefits (OPEB). The logic is that over time, if a given state or local government does not begin to budget for and fund infrastructure needs, four patterns will occur that, in effect, compete with unfunded pension liabilities as a dollar amount due. First, quality of life, capacity to support economic activity, and attractiveness as a magnet for new economic activity, will begin to erode reducing the economic value of the state or local government as a creator of economic activity. Second, some types of infrastructure will simply give out, requiring nearly immediate funding out of budgets or through newly borrowed funds. Structural deficiencies of highways, roads, bridges and tunnels are likely to accelerate as more and more facilities remain in use well past their expected life cycle.

  Third, certain types of infrastructure spending will simply be needed to meet environmental laws such as the Clean Air and Clean Water Acts. And fourth, governments in certain areas of the country are likely to become increasingly exposed to the effects of climate change, including increased flooding and storm damage, and increased exposure to droughts that tax water supply capacity. All of this becomes particularly important in the context of the need to attract advanced industries as state and local governments compete with each other for this type of economic activity—the impact of falling behind in the race to provide governmental services at a satisfactory level and reasonable cost is likely to be to fall behind in the race to become a centre for advanced industrial activity. .

- **Pressure on the cost side as more workers who come under these additional pressures require governmental assistance** (refer to the section below called "Growing Recognition of The Need for Policy Responses").

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Preparing for Policy Responses

The challenge will be to bridge the gap between the availability of low-cost supply and a demand side

Identification of economic threats over the near to intermediate term (and beyond) that will require a policy response at the state and local level. There appears to be growing recognition of the potential threats to labour/economic strength, in the form of reduced demand for labour as described herein, growing pressure on middle-class jobs, and growing income/wealth disparities from the trends generated by ATC. In an "Open Letter on the Digital Economy" [112] to the public, a large number of renowned technologists led by an MIT team pointed to the economic and policy challenges that will be generated by ATC. The policy component of the letter was limited, but we believe that the goal was to initiate a dialogue, not reach detailed conclusions. A vast amount of additional work will be needed in this area. Futurists and technologists talk excitedly about growing "abundance," as the marginal cost of producing a wide range of goods and services collapses under momentum from these automated solutions. The challenge, as we discuss below, will be to bridge the gap between the availability of low-cost supply — "abundance" — and a demand side — consumers — that will come under increasing pressure from limits on wages and employability, long before the benefits of growing abundance kick in.

Policy and political battles will be dramatic and important

Futurists are optimists about the implications of declining marginal costs for living standards—but how do we get there as more and more types of jobs come under pressure and income/wealth disparities continue to grow? These issues, we suspect, will play out in vastly different ways from one local government to the next, and one state to the next, based upon a variety of factors, including relative economic strength to be sure, but also based heavily upon willingness to fund responses through taxation and through income supports as needed.

A growing focus by some state and local governments on 'advanced industries'

In addition to the discussion on cities above, we note that Brookings Institute, in particular, has done considerable work on the extent to which the economic outlook for geographic entities will differ, based upon the extent to which they are successful in attracting "advanced industries." In a report in February, 2015, Brookings asserted: - "the special importance to America's future of what the paper calls America's "advanced industries" sector. Characterised by its deep involvement with technology research and development (R&D) and STEM (science, technology, engineering, and math) workers, the sector encompasses 50 industries ranging from manufacturing industries such as automaking and aerospace to energy industries such as oil and gas extraction to high-tech services such as computer software and computer system design, including for health applications. These industries encompass the nation's "tech" sector at its broadest and most consequential. Their dynamism is going to be a central component of any future revitalised U.S. economy."

Some state and local government officials are beginning to align with public policy experts in an attempt to respond to these changes by identifying and attracting industry sectors with potential for continued strong growth. Brookings continues to expand its work on Advanced Industries, most recently entering into an agreement with the state of Rhode Island to help identify ways to bring such industries to the state to an increasing degree. Brookings has already worked with local governments in Buffalo, New York City, and Chicago on similar projects.

[112] Open Letter on the Digital Economy, MIT, June 4, 2015.

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Innovation districts could be an important way for cities to generate advanced industry jobs

In addition, Brookings has been doing substantial work on a related topic: “Innovation Districts.” As they have noted in a series of articles, innovation districts can be an important way for cities to generate a critical mass of advanced industry jobs that are likely to maintain their value as an economic anchor for an extended period of time. In a recent article[113] they noted two different models for innovation districts: Cambridge Mass., and Chattanooga, Tenn. In the former case, Cambridge is simply able to leverage the benefits of being close-on to high-tech universities, including, of course, MIT and a large additional network of universities and colleges that attract the tech sector. The latter case of Chattanooga is more challenging, and perhaps more impressive, in a sense, generated in large part by an initiative initiated by the Electric Power Board of Chattanooga (“EPB”), the city’s public utility. The Board employed $228 million in local revenue bonds and $111.6 million in funding from the Department of Energy’s Smart Grid Investment, to build one of the world’s most extensive municipal and cheapest high-speed internet networks, helping attract tech entrepreneurs and generate work on “smart grids” that attract partners on climate change and extreme weather analysis.

As Brookings notes, “Chattanooga’s innovation district is the product of genuine, enthusiastic collaboration—not often seen in bigger cities—between public, private, and civic institutions and leaders.” We note both the Cambridge and Chattanooga models for a simple reason: in our view, as technological change progresses, capacity to respond by maintaining a large proportion of advanced industry jobs is going to become a significant credit factor.

Lack of a Federal agenda

One of the greatest concerns from ATC for state and local governments, in our view, is the fact that Federal level notice of these concerns, let alone agendas to generate responses, has been virtually non-existent. Clearly, there has been considerable recognition and discussion of the facts that: the US economy is growing slowly; wages aren’t growing as expected at this phase of an economic rebound; middle class income and especially after-tax disposable income has been under pressure; and income and wealth disparities for the top rung versus everyone else continue to increase.

Lacking from discussion are concerns that technological change exists, that it will likely get worse over time and that traditional responses don’t take in the unique nature of the problem

What has been utterly lacking in the discussion so far are the clear concerns that: (1) a significant and growing component of these patterns relate to technological change; (2) consequently, they are likely to get worse over time, not better; and (3) traditional responses that do not take into account the unique nature of the current environment and its roots in technology are doomed to fail.

This is, clearly, a pattern that is going to have to change. Without a policy initiative at the Federal level, state and local responses are almost certain to be erratic, uneven, limited, and in many cases, set to fail. We will only begin to deal with governmental policy responses herein. We note, however a brief excerpt from an Op-Ed in The London Times on Friday, 16 October, 2015:

> *“In manufacturing, experts believe the proportion of tasks carried out by robots could quintuple by 2025. The benefits to economies that embrace them fastest will include higher wages in the skilled jobs that remain the preserve of humans — such as the 50 engineering posts that Amazon will create to maintain its new robots — and medium-term productivity gains of up to 30 percent.*

[113] http://www.brookings.edu/blogs/the-avenue/posts/2015/09/29-innovation-district-chattanooga-katz

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> *"Britain should be one of these economies. Our flexible labour market allows quicker adoption of new technologies than in much of Europe. Our universities are already producing the computer scientists who will program the next generation of robots. But for the whole workforce to thrive, computer science must be as deeply embedded in our curriculum as reading. The time is rapidly approaching when the choice for blue and white collar workers alike is to know how to manipulate technology, or be manipulated by it."*

In terms of policy responses, it would be extremely easy to replace "Britain," in the previous statement and substitute with "The United States." This will of course only become possible once our leaders: (a) admit there is a challenge from ATC; (b) begin to craft responses that apply across the entire nation; and (c) become willing to spend as needed on adaptations, including education, R&D, retraining, etc.

The discussion on ATC needs to become part of a political process

In other words, this discussion needs to become a part of the **political** process, so that our leaders can then begin to craft **policy** responses. At this point, we are not even having a dialogue. And, of course, if there aren't any Federal policy responses, state and local governments will often be unable to man the breech.

Another Issue Where the Need for a US Federal Response Is Becoming Imminent: Taxation

Interestingly, there is another segment of the economy where the need for a governmental response is becoming evident, and where Europe generally is pushing ahead much more rapidly than the US has done. That is in the area of responding the rapidly changing tax structures which will become essential in a highly digitised global society. There is, in Europe specifically, a growing recognition of the fact that value and income generation is simply different in a digitised society. On 16 September 2014, the OECD released a report on Action 1 of the OECD/G20 Base Erosion and Profit Shifting Project (also known as the "BEPS" project) titled "Addressing the Tax Challenges of the Digital Economy." These challenges are manifold, and will inevitably lead to very similar challenges in the US to those that are being identified in Europe.

For example, an enterprise may generate significant value by gathering data in a jurisdiction, even though the factors for allocating taxable income — i.e., functions, assets, and risks — are located outside of that jurisdiction. If so, it becomes easier to transfer income to tax havens well removed from the source of economic activity. In addition, in the "modern" tech-related corporation, capital generation often happens in ways that create no taxable income — i.e., are reinvested back into the firm, and create value in the form of capital gains that are not taxed unless a change in ownership takes place. As has been noted recently in the press, many new tech companies with high theoretical value are avoiding the sale of shares to the market for specifically this reason.[114] In addition, functions and operations may have less physical permanence that become easy to identify, and thus to tax in the country of origin.

[114] http://www.afr.com/technology/technology-firms-turn-off-public-share-sales-20160103-glyd32

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The Digital Economy Report also identifies several segments of the digital economy that raise issues as to the appropriate characterisation of income. For example the report notes that the character of payments for cloud computing is not addressed in the existing commentary to the OECD Model Tax Convention, and that it is unclear whether such payments should be treated as royalties, fees for technical services, service fees, rent, or business profits. In addition, the Digital Economy Report notes that 3D printing may raise character questions in the case of design licenses for remote printing by a purchaser.

Identifying and ring-fencing economic activity that can be taxed is a challenge. The US seems to be behind the curve which risks erosion of tax revenues

Our key points in the above are threefold. First, that identifying and ring-fencing economic activity that can be taxed is a growing challenge as larger portions of economic activity take place in digital forms that are not easily differentiated, priced and localized — and in a growing number of cases, provide revenues to the owner indirectly (think YouTube, for example). Second, that the US appears to be well behind the curve in identifying and responding to these challenges. And third, that to the extent we do not respond effectively, tax revenues will erode, just at the time when economic pressures — and needed policy responses —- generated by the Digital Economy are accelerating.

The next factor, of course relates to the potential impact on state and local governments. We return to the tax issues briefly at the end of the next section.

State and Local Governments at Risk of Falling Behind the Curve

There will be, we expect, considerable — and complex — implications for state and local creditworthiness.

Back on the plus side, there are likely to be significant positives for the cost of higher education, as more students begin to take advantage of online educational opportunities. Thus far, online delivery systems such as “MOOCs” (Massively Open Online Courses) have not been particularly successful, but we believe that their potential and use will grow over time. At the same time, the role of the Digital Economy in helping provide more effective K-12 education is likely to expand as well. Nevertheless, for a variety of reasons that we only begin to discuss below, the pressures on state and local governments will be substantial, we expect.

- The likelihood of increasing income/wealth disparities, and downward pressure on aggregate demand, if additional fiscal policies are not identified and implemented as well.
- The need for policymakers to respond to these challenging new patterns.
- Complex challenges in maintaining tax levels as more of the economy becomes digital as noted above.
- Potential spillovers to credit ratings/borrowing costs.

Rating concerns

A dialogue related to the potential implications for creditworthiness needs to be part of the response

This, of course, is an essential issue that we can only note briefly here, in the sense that there is as yet no evidence that rating agencies are beginning to react to the rapidly changing environment within which municipal issuers function through concrete changes in rating standards. . This is unsurprising, in the sense that there is as yet little to no tangible evidence that technological change is affecting state or local issuers in terms of employment patterns, taxation cost growth vs. revenue growth, income disparities, benefits and risks from advanced industry migration, etc.

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One of our goals here is to suggest that a dialogue related to potential implications for creditworthiness needs to be part of the response to these rapidly changing patterns. That dialogue would begin to identify potential new risks, but could also act as an impetus for additional responses from state and local governments, and help provide the "red flag" at the Federal level that something new here is going on that will require a combined Federal/state/local response as changes emerge.

In our view, the limited number of policy responses noted here in the fields of education, business planning and related activities is no more than the beginning of the need for a much more broad-based policy discussion. And, indeed, we believe that state and local governments will have to be at the forefront of any such discussions, given the likelihood of increasing income/wealth disparities, differing outcomes from one geographic sector to the next, and the relatively limited potential for education in a vacuum to solve the challenges generated by these changes.

Indeed, in an environment of potential disinflation, high and growing fixed costs from pensions and the like, high unmet infrastructure needs, and built-in upward pressure on total governmental compensation, state and local governments will be hard pressed to keep up with these rapidly changing patterns. On the other hand, there will certainly be some good news in the form of growing "abundance" over the long run. The test will be for state and local officials to plan how to get past the challenges in order to take advantage of the longer run benefits. This will be no easy task given: the ongoing underinvestment in infrastructure; the likely lack of support from the Federal level; and compensation and benefit pressures that will not easily give way, relative to the disinflation we expect to see occurring elsewhere in the US economy.

State and local tax/revenue issues

As we discuss above, concerns regarding taxation of the digital economy are already being examined as a threat to the revenue side of Federal governments, with the OECD leading the way in providing analysis of the impending changes. With respect to state and local governments in the US, we note several issues.

- **First,** the impact of changes related to taxation of the digital economy will not be uniform, by any means. Corporate income taxes would appear to be under the greatest potential pressure. Transitions of corporate income from one Federal jurisdiction to another will put pressure on states (and a handful of cities) that have historically relied on corporate taxes as a significant portion of their aggregate budget.

- **Second**, one of the key concerns in the OECD analysis relates to capture of consumption taxes—in this country, state and local sales taxes. The growing proportion of retail activity that is done on-line and/or offshore will tend to reduce the sales tax base, and make collection of sales taxes more difficult.

- **Third**, potential changes in corporate structures in an increasingly digitised economy are likely to lead to more income/wealth among the highest earners coming in the form of unrealised capital gains and/or reinvestment back into owned companies, rather than as taxable ordinary income.

- **Finally**, to the extent that these issues create downward pressure on Federal revenues, they will, of course, also continue the downtrend in Federal support for state and local activities. These transitions will not happen overnight, but they are likely to occur, and we expect that not all states and cities will be well prepared for these transitions as they arise.

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Pressures for Policy Responses Will Likely Have to Move Upward from the State and Local Level towards the Federal Level, Rather than the Reverse

We are confident that a growing number of Federal leaders are cognizant of the challenges for all levels of government that are likely to be created by accelerating technological change. However, we are far from confident that many of these leaders will be willing to make this complex set of issues part of their political agenda for some time to come. The sheer complexity of the issues, the challenges they create, and the magnitude for ongoing potential bad news coming out of the labour side of the equation are simply not the types of issues that make for attractive sound bites in a Federal political campaign. Consequently, we anticipate that a large proportion of the leadership in responding to these issues is likely to have come from governors and mayors.

As noted above, a number of states and cities have already begun to work to identify sources of advanced industry jobs, and to plan to attract such jobs, working in part with organisations such as the Brookings Institute. Indeed, the co-chair of one of Brookings' conferences on advanced industries was Governor McAuliffe of Virginia, and we are aware that a number of other state officials have begun to undertake initiatives in these areas. We are also aware of planning in a wider number of cities to create an environment conducive to advanced industries. For example, numerous large and small cities are beginning to plan or populate advanced industrial parks in order to attract the types of businesses likely to thrive in this new environment. Among their other tasks, however, will be the need to pressure Federal lawmakers and policy officials to (1) recognise the magnitude of the challenges, and (2) begin to develop agendas. In other words, they will need to insist that the Federal government play a visible leadership role in responding to the changes and challenges that will inevitably be wrought by technological acceleration and digitisation. As noted above, the current presidential campaign remains devoid of even the slightest discussion of the role these changes are playing in generating economic pressures. Given the void, it is the states, large cities and public interest group organisations that will have to take the lead.

Another Key Area for Adaptation: Outsourcing/PPPs

In January 2016, Governor Andrew Cuomo and the New York State Metropolitan Transportation Authority introduced plans to greatly accelerate the completion of massive technology improvements on the New York City Subways and other parts of the MTA system. Enhancements are projected to include WiFi on all stations in 2016, followed by cell phone service the following year, MetroCards will mostly be replaced by digital payments by 2017, followed by USB charging stations in 600 subway cars and 1,500 buses by 2018. According to published reports, "The MTA's board of directors said last year that replacing the MetroCard would take at least five years. Under the governor's accelerated time schedule, installing a new payment system will happen by the end of 2018 — and even sooner for the region's two commuter rail systems, the Long Island Rail Road and Metro North, which will get mobile payments in just six months."[115]

According to the Governor, the MTA is saving time and money by completely outsourcing a large proportion of the work to private sources .In our view, this, rather than just the nature of the upgrades, will become a key source of potential enhancements for state and local governments. A key set of challenges is going to

[115] http://www.theverge.com/2016/1/8/10737408/nyc-mta-subway-wifi-mobile-payment-cuomo

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be for state and local governments to take advantage of massive technology improvements that affect capital and operating costs, while dealing with potential resistance from public sector employees and unions and other sources of entrenched behaviours. A portion of this transition is likely to come in the form of public/private partnerships ("PPPs"), which historically have only had a modest aggregate effect on governments. As technological enhancements affect costs in the private sector for all of the reasons described herein, they will inevitably begin to have similar effects on activities that compete directly with public sector employees. We do not suggest that transitions in the public sector are likely to be as smooth or as rapid as on the private side, but as state and local governments come under additional pressures for all of the reasons described above, we believe that there will be increased pressures to effectuate cost saving in the public sector as well, by:

- reducing the use of human labour that is repetitive and cost-ineffective relative to automated solutions (just as in the private sector); and

- Accelerating modernisation of public sector infrastructure utilizing PPPs in combination with technological changes that reduce marginal costs. That, we note, is exactly what is being planned in New York State for the MTA. Other such transitions are likely to follow in fairly short order.

Indeed, just as in the case of innovation cities and high-tech states described above, we anticipate that state and local governments that are able to make these transitions effectively will achieve a number of competitive advantages that will impact quality of life, cost structures, and — in relatively short order — rating trends.

Policies for New Job Creation in Cities

Carl Benedikt Frey
Co-Director for the Oxford Martin Programme on Technology and Employment and Oxford Martin Citi Fellow

While new technologies have arrived everywhere, cities and regions have fared very differently over recent decades. As highlighted in the "How Does Susceptibility Vary Within Countries? - Cities at Risk" chapter, the expanding scope of automation is likely to exacerbate income disparities between US cities over the forthcoming decades, as new jobs have recently emerged in different locations from the ones where old ones are likely to disappear. As a result, workers will need to relocate from contracting cities to expanding ones. Supporting such relocation is particularly important since the arrival of new technology jobs creates additional demand for local services: estimates by Moretti (2010) shows that one additional job in the technology sector generates about 4.9 additional jobs due to increased demand for local services. Thus, because new technology jobs overwhelmingly cluster in cities that are already dense in skilled workers, demand for local services is relatively high in skilled cities, meaning that low-skilled workers in service occupations will have to follow.

However, as more workers are seeking to move to skilled cities, house prices have surged as a result. This has implications for unemployed and low-income workers, who often do not have the financial means to relocate to places where new jobs are available. The relatively low mobility of such workers, which has been extensively documented in various studies, also has implications for economic growth. According to estimates by Hsieh and Moretti (2015), for example, growing wage inequality across cities has reduced aggregate GDP in the United States by some 13.5% between 1964 and 2009. This, in turn, is largely a result of housing constraints in cities specialized in skilled activities, such as professional services and technology industries, including New York, San Francisco, and San Jose.

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The research by Hsieh and Moretti (2015) has clear implications for policy: lowering regulatory constraints on housing in skilled cities (to the median level) would not only expand their labour force, but also increase GDP in the United States by around 9.5 percent. To facilitate job creation and growth, policy-makers should thus focus on reducing regulatory constraints to support the construction of cheaper housing. In addition, they should support workers seeking to relocate to cities where new jobs emerge. For example, Moretti (2013) has persuasively argued that relocation vouchers would incentivise workers to move to expanding cities, increasing the mobility of particularly low-income workers. For example, if a worker moves from Fresno (with an unemployment rate of 9.9 percent, and 53.8 percent of their workforce susceptible to automation) to get a job in Boston (with an unemployment rate of 4.1 percent, and 38.4 percent of their workforce susceptible to automation), then that worker will need fewer transfer payments and pay more taxes. Because such relocation generates positive externalities, there is a compelling case for the introduction of relocation vouchers.

Nevertheless, while relocation vouchers would help workers move from declining cities to expanding ones, there is a risk that the most capable unemployed will be the most likely to leave, leading to a brain drain of lagging cities. The introduction of relocation vouchers would thus need to be accompanied by investments to boost the competitiveness of declining cities and regions. Although studies show that new jobs have clustered in skilled cities since the advent of the computer, these jobs tend to migrate as they gradually become old jobs. Following this observation, Duranton and Puga (2001) introduced the concept of nursery cities, suggesting that entrepreneurs and innovators that experiment with new technologies benefit from knowledge spillovers facilitated by the density of cities during the early stages of business formation. In other words, skilled places constitute “nursery cities” for new job creation. Only after production processes have become more standardized do they tend to diffuse to less skilled places, leading to convergence across locations unless skilled cities produce new jobs at a faster pace than old ones diffuse. Facilitating the diffusion of work, however, does require increased investment in transport connectivity between cities.

In addition, because knowledge spillovers exist, improving education in lagging regions should increase social welfare, while making the local labour force more resilient to technological change. The importance of human capital for industrial renewal is highlighted by the case of Boston (the city that is least exposed to future automation) which has reinvented itself from being a seaport, to a factory town, to becoming a centre for information technology. This transition required the formation of new types of knowledge and skills throughout the process. In a similar manner, today’s lagging manufacturing cities, such as Buffalo, Cleveland and Detroit, will need to adapt their skills. To do so successfully, investments in local schools and universities will be essential, as well as increasing the supply of technical and entrepreneurial skills.

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How Should Education Adapt In the Race Between Education and Technology?

Highlights

- Technological change is a key driver for the demand of both the level and the type of skills needed ahead. Careers are likely to be more disrupted than at any other point in the past, so people should anticipate the need to retrain in the future. Greater co-ordination will be needed between the educational, training and employment sectors.
- A talent mismatch exists in many countries and many well educated workers have found employment in lower-skilled employment.
- ICT skills will be needed, but significant differences currently exist in IT skills between countries, with USA and UK lagging other countries on some measures. While many argue STEM skills are needed, intermediate level skills in STEM seem to be a less safe educational investment. Non-cognitive skills can be increasingly important, but malleability of these skills should not be assumed.
- Education has typically been a low productivity growth sector as the teaching methods are typically labour intensive, but technology could drive down costs and raise productivity.

Skill Demand and the Education System: The Context

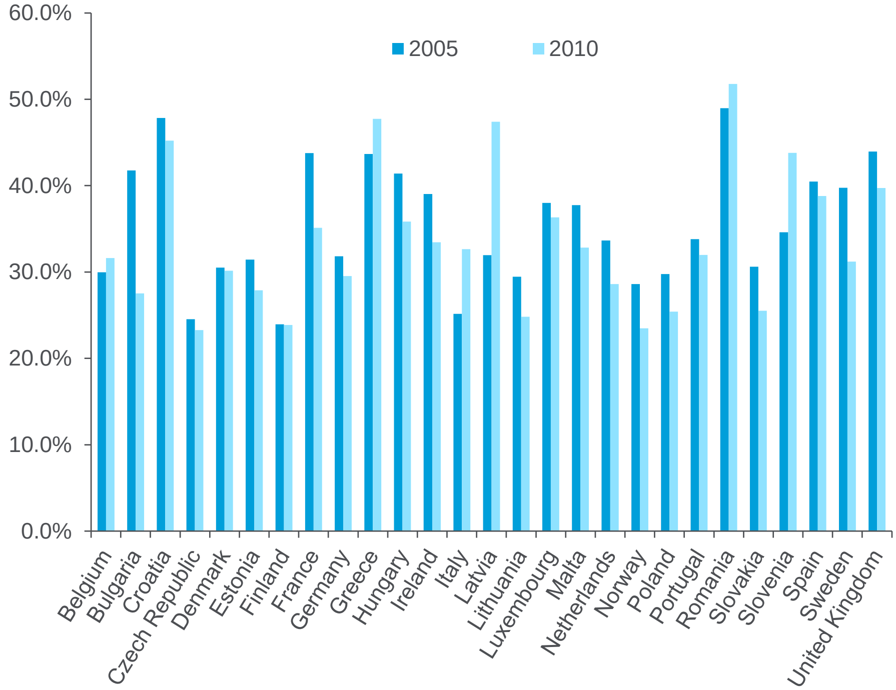
Dr. Craig Holmes
Senior Research Fellow at the Institute for New Economic Thinking at the Oxford Martin School and Teaching Fellow in Economics, Pembroke College, University of Oxford

Technological change is a key driver of the demand for skills, both in terms of level and type. In the developed world in the 20th century, innovations in both products and processes raised, on average, the skill requirements of the workforce. It also lead to a different mix of skills being required as technology drives down the need for labour engaged in certain tasks and their associated occupations: process operatives in manufacturing or clerical administration, for example. On the other hand, as well as there being an increase in demand for high skill non-routine tasks such as creativity or problem-solving, we have also observed increased importance of various lower skill service occupations like in retail or care sectors.

There is a need for the education sector to produce skills in relevant areas

Investment into education has been highlighted by a survey of Citi's clients as being one of the most effective policies to offset the risk of automation impacting labour and wealth distribution. The challenge for the education and training sector has been producing skills at the right level and in the relevant areas for the needs of the labour market and the economy more broadly. Many countries have long-standing problems along both dimensions.

Figure 93. Rates of Graduate Skill Underutilisation 2005 and 2010



Source: European Working Conditions Survey 2005 and 2010. Notes: Graduates only (ISCED 5-6). Underutilised defined as those who report they have skills to cope with more demanding duties.Citi Research

To illustrate, Figure 93 shows the extent of tertiary education graduate over-education across Europe using data from the European Working Conditions Survey (2005; 2010).[116] These data show that across Europe a significant proportion of highly educated workers feel they could take on a more demanding role relative to their current employment.

[116] Overeducation here is captured by self-reported skill utilisation levels. This is only one way in which overeducation can be measured, all of which face various problems (see Holmes and Mayhew, 2015). For example, more objective measures i.e. ones that do not rely on self-reports, typically make strong assumptions about the required level of education in a job over time that, absent of detail job and task evaluations, may bias findings in either direction.

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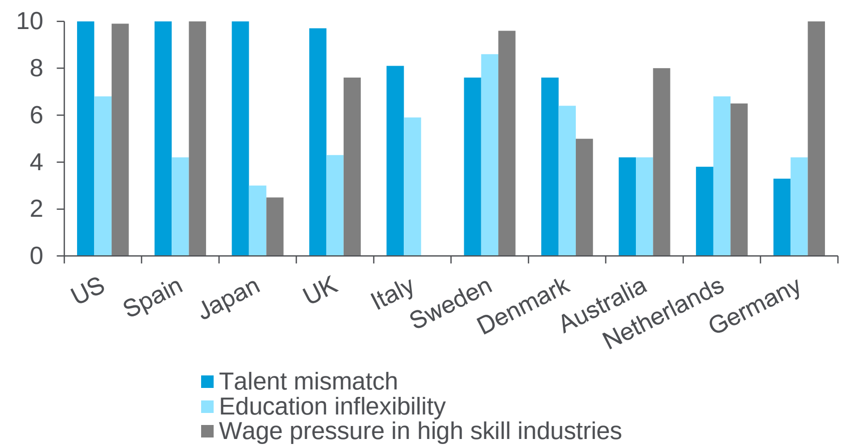
Figure 94. Skill Shortages and Mismatch



Source: Hays Global Talent Index (2015). Notes: Each element of the index scored out of 10. 'Talent Mismatch' measures the gap between the skills that businesses are looking for and the skills available in the labour market. A higher score indicates that businesses are facing a serious problem in matching available candidates with unfilled jobs. For 'Education inflexibility', lower scores indicate there is a better chance that the education system is flexible enough to meet labour market needs. 'Wage pressure in a high skill industry' measures the rate at which wages in high-skill industries are growing relative to those in low-skill industries relative to the past – a high score is indicative of the emergence of sector-specific skills shortages in areas like engineering or technology.

Skills shortages are observed in a number of different countries

At the same time, many employers feel that they face difficulties recruiting people with the right types of skills. Figure 94 draws on data from the Hays Global Skill Index (2015): here, the most relevant measure is the indicator on talent mismatch, which is complemented by the indices for educational inflexibility and wage pressures in high-skill industries.[117] In these data, skills shortages are observed in the UK, the US, Scandinavian countries and across Southern Europe, and are rather less notable in Northern European countries like the Netherlands and Germany, and in Australia.

The overall combination suggests that in many countries there is not currently sufficient demand for the higher skills that are available, leading to many well educated workers finding employment in lower-skilled employment, while at the same time the sectors or occupations which do have high skill requirements are unable to find the correct types of skills. What is not clear is how much the former could be dealt with by improvements made to the latter.

Predicting the Future Demand for Skills

Good predictions about the future demand for skills are needed

Ensuring the education system of a given country produces both the necessary level and mix of skills will continue to be a major challenge in the coming decades. A necessary requirement to address this challenge is to make the best possible predictions about the future demand for skills.

[117] Wage pressures in high skill industries is meant to indicate where relative demand for high skills (compared to low skills) is increasing faster than its supply, suggesting skills mismatch. In reality, such a measure is affected by other factors outside of relative skill demand. For example, the coverage and degree of centralisation in collective bargaining arrangements will have an impact, as in the case of Denmark, as will labour market reforms that reduce protection for lower skilled workers, as might arguably be the case in Germany.

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At present, however, predictions about the future of the occupational structure vary. Governmental estimates typically suggest a continuation of the above trends which is not unexpected given that the forecast models use past data to help predict the future. On the other hand, studies which suggest that recent technological advances represent a structural break in the relationship between technology and labour demand are, at times, at odds with such forecasts. Figure 95 shows a comparison between the expected changes in employment of occupational groups in the UK between 2012 and 2022 defined at the SOC2010 sub-major group level (UKCES, 2014)[118] and the probabilities of computerisation for these groups estimated by Frey and Osborne (2013).[119] The second column gives the net change in demand for workers in different occupations, so does not include replacement demand from workers leaving the labour market.

Figure 95. Comparison of UK Skills Forecasts and Estimated Probabilities of Automation

SOC group (2 digit)	Probability of Computerisation	UK projected increase, 2012-2022 (000s)
Corporate managers and directors	15.8%	493
Other managers and proprietors	18.4%	93
Science, research, engineering and technology professionals	11.3%	354
Health professionals	2.1%	332
Teaching and educational professionals	4.3%	152
Business, media and public service professionals	21.3%	337
Science, engineering and technology associate professionals	52.5%	47
Health and social care associate professionals	17.9%	102
Protective service occupations	25.9%	-39
Culture, media and sports occupations	21.8%	88
Business and public service associate professionals	44.4%	384
Administrative occupations	80.4%	-159
Secretarial and related occupations	78.4%	-327
Skilled agricultural and related trades	70.8%	-41
Skilled metal, electrical and electronic trades	48.1%	-103
Skilled construction and building trades	52.7%	73
Textiles, printing and other skilled trades	57.5%	-236
Caring personal service occupations	44.4%	594
Leisure, travel and related personal service occupations	49.7%	55
Sales occupations	85.5%	-202
Customer service occupations	66.9%	138
Process, plant and machine operatives	84.4%	-211
Transport and mobile machine drivers and operatives	52.7%	-3
Elementary trades and related occupations	69.5%	-23
Elementary administration and service occupations	71.8%	-44

Source: UKCES (2014), Frey and Osborne (2013). Notes: 'Probability of Computerisation' is an employment weighted average of estimated probabilities at the SOC 4 digit level. The table is divided into SOC2010 major groups 1-3 and 4-9.

The main areas of disagreement come in the lower parts of the occupational structure: in particular, several customer and personal service occupations are forecast to continue to grow despite being at a high risk of automation by Frey and Osborne's measure. Moreover, while some occupations are forecast to experience a decline in the total number of workers employed, these drops appear to be quite small compared to the estimated risk of computerisation. For example, if Frey and Osborne's estimates are correct, then the three occupational groups at the greatest risk of automation – administrative occupations, sales occupations and process

[118] UKCES, (2014), Working Futures 2012-2022, Evidence Report no 83.
[119] Frey, C. B. and Osborne, M. A. (2013). The Future of Employment: How Susceptible are Jobs to Computerisation? Oxford Martin School Working Paper No. 7.

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operatives — are predicted to experience a decline of, respectively, 5.7%, 10.0% and 26.1% of existing employment, which is far less disruptive than those high automation probabilities would suggest.

However, there are some examples further up the occupational hierarchy. The most striking example is for business and public service professionals, which includes associated professionals in law, finance, sales and a variety of public services, where computerisation risk is relatively high yet official forecasts predict the need for an additional 400,000 workers to fill newly created jobs in additional to the replacement demand. Therefore, in the higher skilled occupations, there are still some issues about the skill mix. Technician or intermediate level skills in STEM would certainly seem to be a less safe educational investment.

Beyond Occupational Forecasts

Attempts to increase the use of skills in certain occupations to improve individual outcomes have been unsuccessful

If the existing forecasts are wrong and the type of technological progress we will experience in the coming years leads to greater job losses in lower skilled occupation, then this would not be immediately unwelcome from a policymaker's perspective: a challenge in recent years has been the persistence of low-skilled jobs and the inability to fully shift towards the high-skill economy championed by many policymakers. Attempts to increase the use of skill in such occupations in order to improve both the individual outcomes of those who find work in such jobs and macroeconomic outcomes such as productivity have been largely unsuccessful. The computerisation of such jobs could therefore finally push an economy toward the high-skill vision, on the assumption that sufficient high-skill jobs became available at the same time.

One challenge for the education and training system is therefore to anticipate where technological innovations may lead to job creation. Figure 95 illustrates the probability of jobs being replaced by computerised machinery, but it is not necessarily true that we would expect to see huge growth in job opportunities for jobs with a low risk of computerisation if these occupations are no more complemented by technology than they can be substituted by it. For example, while Frey and Osborne predict little risk of automation for health and educational professionals, these have typically been thought of as sectors of the economy with low productivity growth and limited complementarity with new technology (Baumol, 2012).[120] Instead, demographics are more relevant predictors for the demand for skills required in these sectors, particularly with respect to an ageing population.

On the other hand, technological progress should lead to job creation in some areas. In part, this will affect occupations already being recorded, where improvements in technology raise the productivity of such jobs and encourage more of them to be created. Other jobs may be entirely new and only exist due to recent innovations. Looking at the creation of new industrial categories gives some insights into where new demand is already beginning to emerge, such as in Internet publishing, broadcasting and search, electronic shopping and auctions, and data processing and hosting (Berger and Frey, forthcoming)[121]. However, this growth has been relatively limited compared to the magnitude of the threat to employment in other sectors and occupations.

[120] Baumol, W, (2012), *Cost Disease: Why Computers Get Cheaper and Health Care Doesn't*, Yale University Press.
[121] Berger, T. and Fry, C.B., (2015), "Industrial Renewal in the 21st Century: Evidence from U.S. Cities", Regional Studies , forthcoming.

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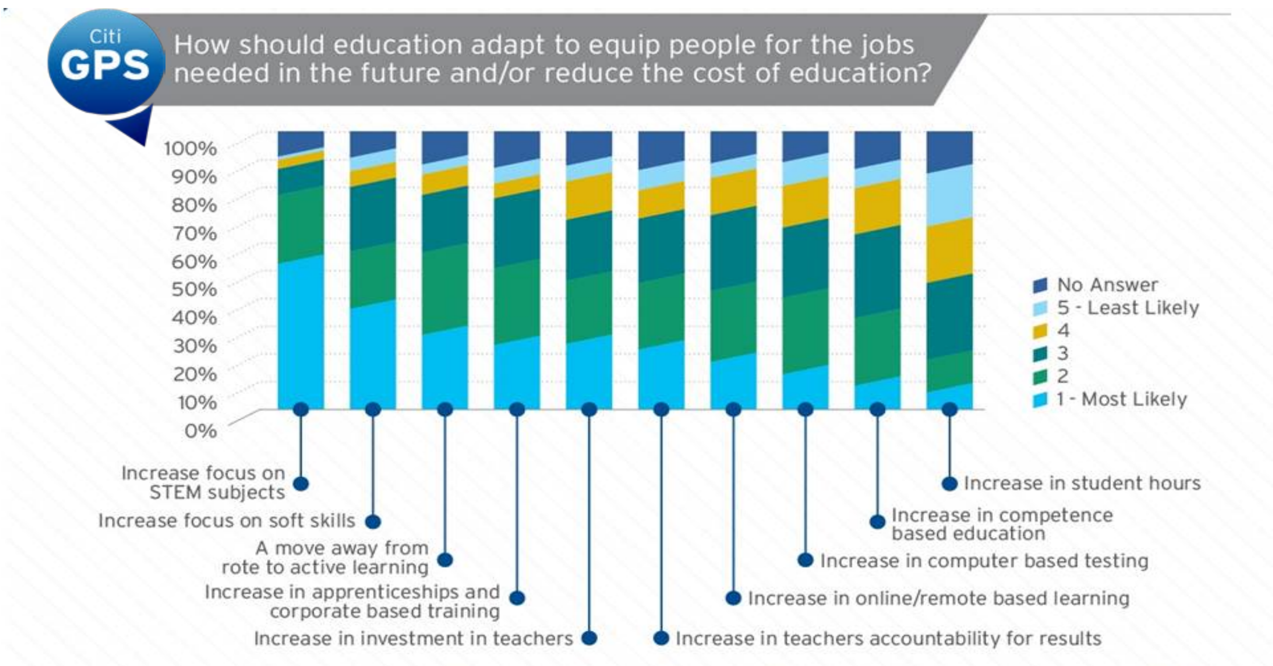
Moreover, it is important to recognise that technological progress does not just affect the occupational structure in terms of numbers of different types of jobs, but can also change the nature of work within those occupations. In the past decade, there is evidence that some occupations have already experienced what Brown *et al* (2011)[122] label 'Digital Taylorism', where knowledge work of many occupations is codified and routinised such that their respective labour-input has been deskilled — although typically performed by increasingly well-educated employees — while the high value part of these services is performed by computer algorithms. Examples in their research included bank managers and paralegals: in terms of a headcount, we would not conclude the demand for such occupations has reduced, but we certainly would when the nature of the work is examined. This may be increasingly relevant if technology begins to make it possible to automate more and more high-skilled tasks: the number of surgeons or engineers might not drop, but the value of their skills could be marginalised if their work begins to resemble more machine operative than highly skilled professionals.[123][124]

Education in an Age of Digitisation

How should the education and training system respond to some of these potential transformations?

Figure 96. The Majority of Respondents Highlighted an Increase Focus in STEM Subjects



Source: Citi Research

[122] Brown, P., Lauder, H., and Ashton, D, (2011), *The Global Auction*, New York: Oxford University Press.

[123] Susskind and Susskind (2015) provide support to the view that the nature of highly skilled work in the professions – lawyers, doctors, accountants, consultants, and so on – faces fundamental challenges from new technologies.

[124] Susskind, R., and Susskind, D,. (2015), *The Future of the Professions: How Technology Will Transform the Work of Human Experts*, Oxford: Oxford University Press.

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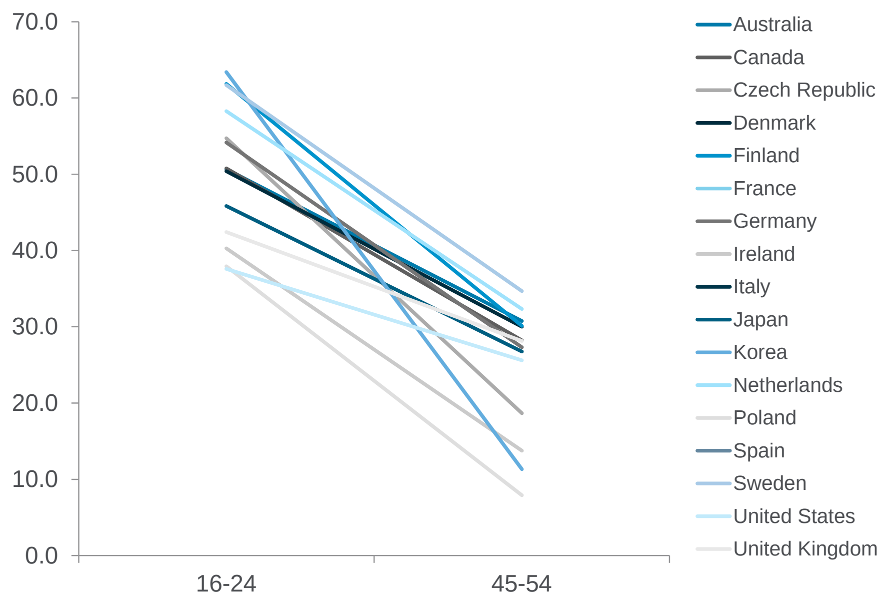
One issue is how young people will need to prepare for entry into this labour market. Careers are likely to be more disrupted than at any other point in the past, with the possibility that any occupationally-specific skill could lose a great deal of value if the occupation in question becomes automated. People should anticipate the need to retrain in the future, which places a greater emphasis on general skills such as literacy and numeracy. Moreover, it seems likely that there will be a need for particular ICT skills. For example, if jobs are going to be replaced by rapid computerisation and if new jobs are to emerge, there needs to be sufficient individuals able to create and programme these new technologies. This is indeed the general perception of Citi clients, suggesting that more focus on STEM skills is needed, followed by an increase in soft skills and a move away from rote to active learning (Figure 96).

Using data from the OECD's Programme for International Assessment of Adult Competences (PIAAC) suggests that significant differences currently exist between countries in terms of IT relevant skills. Figure 97 compares for a subsample of the countries assessed the percentage of adults achieving the top two highest levels in tests of problem solving in technology rich environments. For the most recent cohort (aged 16-24 at the time of the survey in 2012), the outcome ranges from below 45% for the US, UK, Ireland, and Poland to over 60% for Sweden, Finland, and Korea. Moreover, while all countries have better performing young people than older workers as might be expected, there is significant variation in how rapidly these skills are growing between cohorts — for example, based on its older workers (aged 45-55) Korea is ranked almost lowest out of all the OECD countries. Similar rapid increases are observed in the Czech Republic, while at the other end of the scale, the UK, US, and Japan have largely plateaued.

Figure 97. ICT Skills by Age-Group Across the OECD



Source: OECD, Citi Research

What explains this divergence requires further investigation, however, simple cross-country comparisons suggest that it is not easily explained by resources or teaching proficiency. Figure 98 shows there is a positive correlation between computers per student and the PIAAC score: - that is, a negative correlation between resources and performance. Of course, such a relationship could be endogenous – perhaps some countries, finding that their students to have poor ICT skills, have invested

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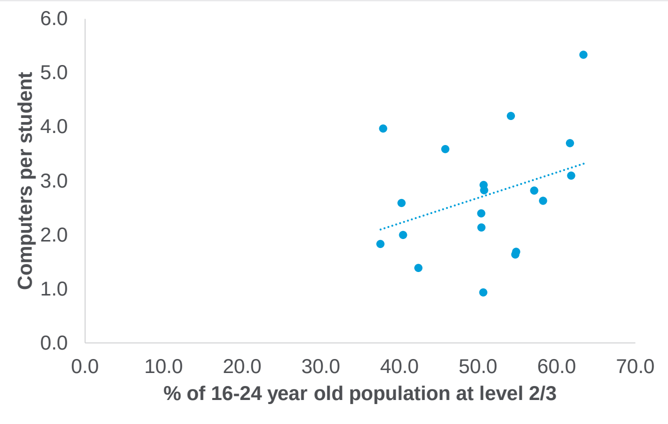
heavily in ICT resources. That said, countries like the UK and the US are reaching a point of having one computer per student and yet still fall behind, so even if resources do have a positive effect, clearly something else is needed.

Similarly, the countries scoring highest for ICT skills on PIACC are also those where secondary school teachers tend to report they have a need for professional development in IT (Figure 99). This could point towards differences in curriculum: - low performing countries for ICT skills might have teachers who believe they have sufficient ICT skills because what they are being asked to teach is at a basic level.

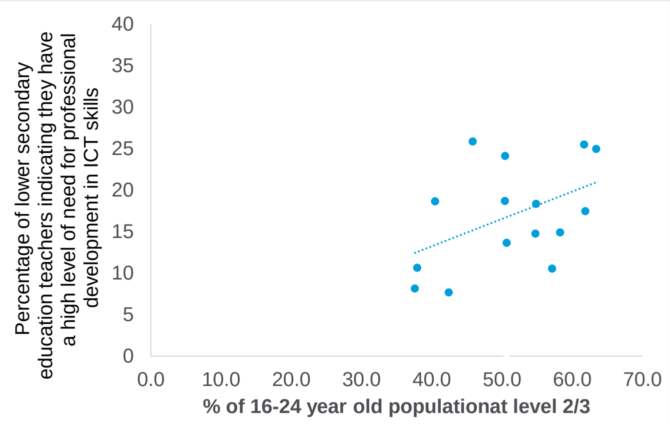
Just as important are non-cognitive skills — that is, the behavioural traits and characteristics that young people possess, such as motivation, perseverance and self-control (see Gutman and Schoon, 2013[125], for an in-depth survey of these skills and evidence on the success of interventions). To take one specific example, coping — that is, an individual's purposeful response to stress — is a valuable skill to possess in a labour market with high probabilities of automation.

Figure 98. ICT Skills and IT Resources



Source: PIACC (2012), OECD (2012)

Figure 99. ICT Skills and Teacher Self-Assessment of IT Capabilities



Source: TALIS (2013), PIACC (2012)

Remedial investment in non-cognitive skills in young adults seems to be more effective than cognitive skills

In terms of the implications for the education system, early childhood interventions to raise non-cognitive skills appear to lead to higher returns from educational investments made later on (Heckman, 2007),[126] although remedial investment in non-cognitive skills in young adults does seem to be more effective than remedial investment in cognitive skills like numeracy. However, malleability of non-cognitive skills is a key issue and it should not be assumed that education can significantly and causally improve all personality traits. For example, while there is evidence that something like coping or the ability to socially interact can be taught, there is rather less evidence at present for such a conclusion when it comes to a trait like creativity or leadership skills.

As well as more general skills and competences, there will still be a need for job-specific vocational skills, from high skilled professions down to lower-skill service sector occupations: - however, such investments will necessarily become riskier given the potential for unforeseeable automation of many labour processes. Moving this risk away from individuals towards employers and the state would be more efficient, but there are two potential problems.

[125] Gutman, L., and Schoon, I., (2013), The Impact of Non-Cognitive Skills on Outcomes for Young People, Education Endowment Fund.
[126] Heckman, J., (2007), Beyond Pre-K: rethinking the conventional wisdom on education intervention, *Education Week* 26, March 21.

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On the one hand, employers have greater information about the required skills given their knowledge of sector or occupational specific technology and future investments. However, firms may worry about free-riding by rivals who can 'poach' newly trained workers without incurring the costs of producing those skills. On the other hand, the state faces significant informational constraints in seeking to subsidise skill development. For example, a long-standing problem in the UK is the inability of policymakers to distinguish between underinvestment due to a market failure and low investment in workplace skills that is in fact a rational decision made by employers in relation to their optimal product strategy and necessary work processes.

Consequently, government subsidies often go towards training that would have taken place anyway, or towards certifying existing skills, or to generating new skills which are not utilised, rather than towards encouraging firms to utilise higher levels of existing skills. Following this, a lesson for education policy for the future is that observing falling levels of training in any traditionally higher status occupations that become "digitally Taylorised" (as described before) and deskilled does not necessarily imply state intervention on the supply side of the market is sufficient, or even necessary. In order to be effective, education policy to raise skill supply would need to be coupled with other policies that raise the demand for, and utilisation of, skills within workplaces.[127] The route to achieving this may mean the development of a coherent industrial policy (see Keep and Mayhew, 2014),[128] or at the very least facilitating greater co-ordination between the education and training sectors on one hand, employers and the demand side of the labour market on the other and the state somewhere in between.

Technology can also affect the way education and training is given. This is already seen in platforms such as MOOCs

Of course, the effect of technology not only changes what the education sector needs to do in order to supply the labour market with necessary skills, it has the potential to also change the way this education and training is delivered. There are many reasons why costs of education have risen across many countries, but one is due to relative productivity growth. Education has typically been a low productivity growth sector as teaching methods are typically labour intensive and use limited technology – labour costs are liable to rise when wages in such sectors have to compete with those in other sectors where technology is raising productivity. In one sense, the rising share of national incomes spent on education is not a huge problem – the rising productivity and wages in other sectors allows societies to afford it (Baumol, 2011). On the other hand, it could be that there will soon be technologies which could be incorporated in the education system that could drive down costs and raise productivity. For example, digital technology allows for the costless replication of a single lecture to an unlimited number of students, and online teaching modules reduce the overheads incurred by schools, colleges and universities in physical locations.[129]

[127] This supposes that a more skill-intensive production process than would exist without direct intervention is, in fact, something that should be aspired to. It may be in terms of a number of social objectives, but may not be the case in terms of productivity. New technologies may in fact be superior to skilled labour as an input, suggesting a trade-off between the level of output and the way it is distributed as income.

[128] Keep and Mayhew, (2014), *Industrial strategy and the future of skills policy: the high road to sustainable growth*, London: CIPD.

[129] A different explanation for the rise of the cost of education is the huge increase in educational administrators and administration cost. It is striking that such administration costs in colleges and universities have grown at a time when many other sectors have automated many administrative functions. New technologies may eventually have the

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Various models exist, from incorporating such technologies into a traditional education setting to moving entirely out of the classroom through massive open online courses (MOOCs) and similar. At this stage, the biggest unanswered issue is whether the use of new technology offers a genuine like-for-like substitute in terms of educational quality, or whether the development of certain skills or aspects of knowledge require face-to-face interaction, demonstration and feedback.

same effect here, although of course such reforms may need to be implemented by the same administrators whose jobs would be under threat.

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Will Robot Laws Slow the Pace of Change? Privacy, Ethics and Liability Issues

Highlights

- Robots in the past have been separated from humans with the use of safety cages, however this is about to change, robots will be entering our home, controlling our cars and expanding into the military sector. Ethics, privacy and liability issues are at the forefront of this debate
- Ethical ramifications of robots used for elder care include a loss of privacy, potential reduction in human contact and the control of the robots themselves. Guidelines should be developed to guard against misuse
- Privacy issues from the use of drones and the collection of data when robots enter our home are also important issues that are being highlighted.
- Safety issues from the use of robots have been in place since robots have entered the workplace. However, now that robots will be working closely with humans, these need to be extended further. Liability issues with regards to who is responsible for mistakes or errors are highlighted especially in light of technology that could control our cars.
- Some guidelines/laws are already responding to the issues above such as the development of a Robot Ethics Charter, guidelines on regulating robots, ISO standards and establishing ethics committees in companies.

Elizabeth Curmi
Thematic Analyst, Citi

Regulation on the implementation of automation is one of the policy responses that could potentially offset some of the risks of automation. Robot laws are not new: in fact Isaac Asimov proposed the 'Three Laws of Robotics' in his short story 'Runaround'. Although fictional, these laws (1) a robot should not harm a human being; (2) a robot should always obey a human being; and (3) a robot should defend itself so long as it did not go against the first two laws, are currently being quoted in many articles such that they could actually be applied to today's world. Although these provide a useful departure point for discussion, they are, however, fictional and were not written to be used in real life.

The advancement of robots has led many academics, industrialists and others to discuss ethics, privacy and liability issues

The expansion of robots over the years has mainly been limited to tasks that are dull, dirty, dangerous or repetitive. Robots in many of these jobs have been separated from humans with the use of safety cages (Figure 100). This is about to change with the advancement of robots in military, service and health care sectors, where robots undoubtedly will have more direct contact with humans. This direct contact has led many researchers, technologists, philosophers, lawyers, governments, and others to discuss the important issues of ethics, privacy, liability, and safety issues surrounding the expansion of robots in different sectors. This chapter aims to highlight the main issues using examples from different areas, and discusses the principles, laws, and certifications that are being proposed that could help form some guidelines to the advancement of the use of robots in many sectors.

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Figure 100. An Automaker Robot with a Safety Cage

Source: Image taken from : http://www.presstv.ir/Detail/2015/07/02/418396/Germany-Baunatal-Volkswagen-Hillwig

Robot Ethics

Robot ethics is a growing interdisciplinary research effort trying to understanding the ethical implications and consequences of robotic technology. Many areas of robotics are impacted, especially those robots that interact with humans, ranging from elder care and medical robotics, to military robots and to all kinds of service robots.[130] We focus our discussion on the ethics of robots in the caring and military sectors, however similar issues arise in other sectors such as medicine and other service robots.

Robot Ethics and Ageing Populations

As described in the demographics chapter, the proportions of elderly people are increasing in many countries due to an increase in life expectancy and a decrease in fertility rates. This, together with a reduction in the number of caregivers in society has led several governments to consider the use of robots as caregivers, companions, and healthcare assistants. Japan is at the forefront of such technology; this is due to the fact that they are already feeling the effects of an ageing population. An example of such a robot is Robobear, which uses advanced technology to power its intelligent vision, has flexible movement, and has arms strong enough to lift a human off the ground (Figure 101) and is designed primarily to provide care to the sick and elderly. Robobear is the brainchild of Toshharu Mukai, a scientist who has been leading the Robot Sensor System Research Team at the Riken-SRK Collaboration Centre for Human Interactive Robot Research. The cost of the Robobear prototype is estimated at $168,000 to $252,000; however the manufacturers are hoping that the price will come down.[131] Other care robots include Paro, a therapeutic robot that helps relieve stress for the elderly and Care-Bot, developed by Genko Systems, which is programmed to assist senior care in a variety of real-life situations.

[130] Matthias Scheutz, What is Robot Ethics? IEE Robotics and Automation Magazine, December 2013.

[131] http://www.theverge.com/2015/4/28/8507049/robear-robot-bear-japan-elderly

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Figure 101. Robobear in Action

Source: Image taken from: http://www.theverge.com/2015/4/28/8507049/robear-robot-bear-japan-elderly

The issues with elder care robots include invasion of privacy, a reduction in human contact and issues of control

Whilst robots can bring benefits to elder care and the institutions that provide it, scholars have expressed concern about the ethical ramifications including: (1) the invasion of privacy (for example remote electronic surveillance of elderly people bathing or changing); (2) feelings of a loss of control; (3) potential reduction in the amount of human contact; and (4) the circumstances in which the elderly would be allowed to control robots. There are especially strong objections to robots being used as a replacement to humans and some have argued that robots should only be used as assistants. However, in certain countries there is a worry that there will not be enough young people to take care of the elderly and therefore robots can form part of the solution and provide an important service. They can be used to assist the elderly in their daily tasks, to help monitor their health and to provide companionship.[132] Sharkey and Sharkey in their article called 'Granny and the Robots: Ethical Issues in Robot Care for the Elderly' state that "it is not the use of robots in elder care per se that should concern us, but the ways in which they are used". They conclude that identifying ethical concerns regarding robots in elder care is a first step in ensuring that their introduction would not result in a deterioration of welfare of people exposed to them. Therefore developing appropriate guidelines on ways in which robots could be deployed in this sector could help guard against misuse.

[132] Sharkey A, Sharkey N , 2012, Granny and the robots: ethical issues in robot care for the elderly, Ethics Information Technology, Volume 14, Issue 1, pp 27-40

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Robot Ethics and Military

The issue of automated and autonomous weapons has been debated intensively over the years. In fact the use of aerial drones by the US in a range of different operations has increasingly been scrutinised[133] especially with regards to: (1) targeting killing; (2) the moral implications of injuries to non-combatants resulting from the extensive deployment of drones against terrorists; and (3) the fact that such weapons are unmanned and decisions are taken thousands of miles away from the action. In the UK the debate was ignited when it was announced in April 2013 that drones would operate from the RAF base in Lincolnshire. Since then they have been heavily debated especially with regards to targeted killing as shown in media reports when two radicalised British citizens were killed by a MQ- Reaper Drone in Syria.

Figure 102. MQ- Reaper Drone

Source: Image from Wikipedia

Even though the US government has stated that the use of force and individual targeting will be kept under human control, there is enormous pressure to use autonomous robots in warfare to reduce or eliminate the risk to human soldiers and to obtain better intelligence through surveillance operations. According to Prof Stuart Russell, the development of lethal autonomous weapon systems known as 'LAWS' have reached a point where the deployment of such systems could be feasible within years and not decades. These systems have been described as the 'third revolution in warfare, after gunpowder and nuclear arms.'[134]

Fast Lightweight Autonomy (FLA) and Collaborative Operations in Denied Environment (CODE) are two autonomous military projects that are being researched in the Defence Advanced Research Projects Agency (DARPA). The FLA project will programme tiny rotorcraft to manoeuvre unaided at high speed in urban areas and inside buildings, which could be an ideal drone for hostage situations. CODE aims to develop teams of autonomous aerial vehicles carrying out strike missions in a situation in which energy signal-jamming makes communication with a human commander impossible.[135]

[133] Rushton S, Kett M (2013), Killing Machines, The Journal of Medicine, Conflict and Survival, vol 29, No,3, 165-168.

[134] Stuart Russell,2015, Take a Stand on AI Weapons, Nature Vol 521, 28 May 2015.

[135] Stuart Russell,2015, Take a Stand on AI Weapons, Nature Vol 521, 28 May 2015.

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Ethical issues on the use of military robots include accountability, following of established war guidelines and others

There are several ethical questions that arise from the deployment of autonomous military robots including: (1) Who will be accountable if any errors are committed?; (2) Will autonomous robots be able to follow established guidelines of the Laws and Rules of Engagement as specified by the Geneva Convention?; (3) Will robots recognise the difference between military and civilians?; (4) Will they refrain from shooting if someone is wounded or retires from combat?[136] The potential lethal consequence of deploying certain military robots clearly illustrates the importance of the ethical dimensions of robotics. It is however important to distinguish between robots used as defensive weapons or other functions such as bomb disposal or landmine removal robots which perform life- saving operations, and robots that can be considered lethal.

The United Nations has had a series of meetings on LAWS; within a few years the process could lead to banning such autonomous weapons or else it could leave in place the status quo, leading inevitably to an arms race. In July 2015, an open letter was signed by approximately 20,000 AI and robotic researchers and other endorsers condemning the use of such weapons and suggesting that a ban could ultimately prevent such a military AI arms race.[137]

So Are We Living in 1984? Privacy Issues and Robotics

Robots by definition are equipped with the ability to sense (including vision capabilities), process and record the world around them[138] and therefore it is not hard to see how privacy could be an issue. The effects of robots on privacy could be divided into three main categories: (1) direct surveillance; (2) increased access; and (3) social meaning. Direct surveillance is already being used in the deployment of drones in the military as part of surveillance missions; however this new technology is presenting corporations and individuals with new tools of observation in different sectors such as marketing, e-commerce and security. The Federal Aviation Administration has recently given approval to a Washington DC-based company called 'Measure', to fly 324 commercial drones to collect data for a number of applications.[139] It provides its services to companies in several industries including agriculture, disaster relief and insurance, infrastructure and energy. Amazon is also planning to use drones for its delivery service by tracking the location of the person it is delivering to by pulling data from their smart phone.

The issue of privacy and drones in our public space is clearly demonstrated by a number of stories that have surfaced in the media, of people shooting down drones that fly over their property.[140] Whether this is legal or not is an issue for the US courts, however the question arises as to whether there is a loss of privacy and how do we feel about drones with long-ranging listening devices or drones that are hovering outside our property and taking pictures?

[136] Kernagham, 2014, The Rights and Wrongs of Robotics: Ethics and Robots in Public Organizations, Canadian Public Administration, Vol. 57, No.4.
[137] http://futureoflife.org/AI/open_letter_autonomous_weapons
[138] Ryan Calo, Robots and Privacy, in Robot Ethics: The Ethical and Social implications of Robotics.
[139] http://money.cnn.com/2015/09/01/technology/faa-commercial-drones-measure/
[140] http://edition.cnn.com/2015/09/09/opinions/schneier-shoot-down-drones/

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Regulators also worry that low cost drones, which are widely available for purchase, could ultimately pose a threat to commercial aviation and vital infrastructure. For example helicopters that were used for fire-fighting efforts in San Bernardino had to temporarily halt operations for fears of colliding with the drones that were hovering over the flames.[141] However companies such as Thales SA are working on a system that would use radar to spot the drone, a camera to identify it and sophisticated jamming tools that could take control of the system.

Figure 103. Prototype of Amazon Drone

Source: Image taken from http://www.leapfrogging.com/2014/08/30/google-and-amazon-want-to-give-you-wings-dont-be-their-drone/

When talking about privacy one cannot help but mention the issues that Google has and is currently facing. Many countries across the world have launched investigations into Google Street View. At the beginning of the debate, the arguments focused exclusively on the capturing, storing and displaying of images obtained by Google Street View cars. One example is the law suit that Aaron and Christine Boring filed against Google to remove photos of their Pennsylvania home which appeared on Street View. Google removed the photos of the Boring's residency, however since then it has also surfaced that through its Street View cars the company also obtained a huge amount of WiFi data including SSID information (the Wi-Fi network name) and MAC addresses (the Wi-Fi router unique number) from receivers in its vehicles. Google has stopped its collection of WiFi data; however this led to investigations in several countries, and several law suits have been filed against the company. In one case, Google agreed to pay $7 million to 38 states and the District of Columbia to settle the matter.

[141] http://www.wsj.com/articles/next-step-for-drones-defending-against-them-1437645600

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Google believes that with today's satellite image technology complete privacy does not exist. However with robots entering our home the issue of privacy becomes an important issue

Visible drones manning a city, whether it is to provide a commercial service, for surveillance purposes or for other issues, or cars driving around taking pictures and collecting data, invoke George Orwell's 1984, where surveillance was at the forefront of the world described in the book. In its court documents against the Borings, Google stated that 'Today's satellite-image technology means that even in today's desert, complete privacy does not exist'.[142] This statement opens up another debate into whether privacy can actually be maintained or still exists in today's world.

Other issues relating to privacy include access to private spaces and activities such as our home. With the internet of things coming into force and connecting our appliances and devices together it will permit guesses about the interior life of a household such as what time a person gets home and what habits they may have such as playing video games or watching television. The issue of robots entering our home is a different matter. With costs decreasing, personal or home robots are rapidly expanding, in fact 28% more service robots were sold in 2013 when compared to 2012 (this includes vacuum and floor cleaning, lawn-mowing and entertainment and leisure robots).[143] Applications for home or service robots are potentially infinite and can occur in areas such as elder care (described above), education, entertainment, and home security. Home robots can come equipped with sensors, GPS systems and cameras and in some cases they can also connect wirelessly to the Internet to either relay messages or images or sometimes to update their programming. The mere fact that a machine is making extensive, unguided record of events in a home could represent a privacy risk.

The question also arises as to who will have access to this data and what will become of some information. Recently a US consumer rights group called Epic has claimed that Samsung breached the privacy of its users by allowing its smart TVs to record private conversations without informing its users. This campaign will definitely not end here, and such discussions demonstrate the complexity of this technology entering the home and the lack of consumer understanding of what it is doing and how it works.

Cyber security is also another issue which should be taken seriously

Hacking (and viruses) is also a concern especially when millions if not billions are spent by companies on cyber security every year. Robots could be particularly at risk especially when they rely on communications over public networks.[144] It can affect privacy issues, for example in the case of personal and home robots and can also be a safety concern. For example Stuxnet, a 500-kilobyte computer worm, infected software of at least 14 industrial sites in Iran including a uranium-enrichment plant. It targeted Microsoft Windows machines and networks and then sought out Siemens Step 7 software and used it to program industrial control systems that operate equipment. Whilst a human operator of an oil rig, nuclear plant and other industrial processes can be susceptible to coercion, influence, bribery etc., it is unlikely to be as dangerous or as scalable as a virus affecting a robot that is controlling the industrial process.

[142] Google accused on privacy views, Maggie Shield, BBC news, 1 August 2008.
[143] International Federation of Robotics (IFR), World Robotics 2014 Service Robots.
[144] http://www.technologyreview.com/view/537001/security-experts-hack-teleoperated-surgical-robot/

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Safety, Errors, and Liability Issues

A number of workplace fatalities related to robotics have taken place over the years, however many of the incidents were related to either repairing the robot and/or entering a controlled space such as a safety cage. The latest episode occurred at a Volkswagen plant in Germany in which a robot unfortunately crashed a technician against a metal plate. The incident occurred during installation and involved a fast moving first generation robot designed to operate inside a cage, away from humans. The VW case was a factory accident rather than a fault in the robotic system; however, in a world where people will be interacting with robots on a daily basis, safety and liability issues must be even more at the forefront of the advancement of robotics. Collaborative robots or co-bots such as Baxter or Sawyer are designed to work with humans in manufacturing without safety-fencing. No fatalities have been reported from the use of co-bots, however they have only started to infiltrate the market; the co-bots have been programmed with safety features that let them detect and react to nearby humans.

Figure 104. Baxter Working Directly with Humans Without Any Safety Nets

Source: Image taken from http://sputniknews.com/science/20150409/1020641124.html

ISO safety standards provides specific guidelines for industrial robots

With robots, the safety issue is with their software and design, and for anyone whom has written any software code, one would know that somewhere in the millions of lines of code sometimes written by a team of people, there could be mistakes or errors. However in robots, particularly robots that interact directly with humans, a tiny software flaw could potentially be fatal. Currently there is a safety standard for industrial robots called ISO 10218-1 'Robots and robotic devices-safety requirements for industrial robots' which provides specific requirements and guidance for the assurance of safety in the design and construction of the robot itself. Recently a new standard was issued for safety in personal care robots, in particular for three types of personal robots -a mobile servant robot, physical assistant robot and personal carrier robot called ISO 13482.

Liability is also at the forefront of the discussion, this is particularly relevant to driverless cars

Linked to the risk of mistakes or errors is the problem of liability — who is responsible if something goes wrong? The responsibility question is particularly pertinent to military robots as anyone across the supply chain could be made responsible including the manufacturer, programmer, the military procurement officer, the robot's handler and even the President of the United States.[145] There have been several liability cases that have been filed in court relating to accidents involving industrial robots. The case of Jones vs Automation Inc. showed the complexities of such issues. The court stated that GM was at fault for the injury to the plaintiff when he was struck by a robot gantry loading system used in the auto plant. GM's modification to the system was the apparent cause of the accident and not the manufacturers of the robot as there was no evidence of a defect to the system.

Another interesting case on liability involved a driver who hit a pedestrian while making a left hand turn in his car. The lawsuit against the driver was dismissed as he (the driver) did not have a chance to avoid the accident. Even though this case had nothing to do with robots or automation systems, the court in its judgement stated that 'A human being, no matter how efficient, is not a mechanical robot and does not possess the ability of a radar machine to discover danger before it becomes manifest'. Could this decision raise the possibility that once we have autonomous cars, the courts might raise the standard of care for manufacturers to avoid collisions, since robots can act more accurately than humans? [146] In the coming years autonomous vehicle liability (the question of who is responsible if something goes wrong) is certain to be a topic of continuing interest in the legal community and among companies working to develop the technology. Sixteen states in the US have already passed some legislation related to autonomous vehicles mostly related to safety, testing and licensing. There is some mention of liability in some states such as Colorado, where it retains liability for damages with the driver who may or may not use autonomous 'guidance technology' while other states such as Hawaii absolve manufacturers of liability where a car has been retrofitted by a third party.[147] However, there is no clear legislation as to who is responsible when something bad happens (whether it is the driver, manufacturer etc.). The discussions in this field will definitely continue and specific legislation for liability with regards to autonomous cars and other autonomous robots might need to be enacted if it is deemed that the current legislation available is not appropriate.

Principles, Standards, Certification, Rules of Robots

The establishment of a new federal robotics agency could help the law catch up with the rapid advancement of robotics

Some laws are already responding to the issues mentioned above. Several US states have laws governing autonomous cars, whilst others have laws concerning drones. The Food and Drug Administration is actively monitoring robotic surgery, whilst the Federal Aviation Authority is currently responsible for drone permits. However some argue that since robotics and automation are changing very quickly and these organisations that are in charge or partially in charge are not talking to one another, a new federal robotics agency should be set up. This agency could help the law catch up, serve as a place of expertise in new technology, and help the public, law makers and others understand such transformative change.[148]

145 Lin P, Abney K, Bekey G, 2011, Robot Ethics: Mapping the Issues for a Mechanized World, Artificial Intelligence, 175 , 942-949.

146 Stephen S. Wu, Summary of selected robotics liability cases, Cooke Kobbick & Wu, July 12, 2010.

147 Rand, Transportation, Space and Technology Program, 2014, Autonomous Vehicle Technology, A guide for policy makers.

148 Calo R, 2014, The Case for Federal Commission, Brookings September 2014.

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Other governments are also discussing these issues. The South Korean Government has published the Robots Ethics Charter[149] which sets ethical guidelines concerning robot functions, a move which anticipates a time when service robots are part of daily life. The Japanese Government in its Robot Strategy has emphasised the importance of establishing internationally compatible regulations and standardisation. The EU has also funded a project through its FP7 Framework programme called RoboLaw which produced guidelines on regulating robots using case-studies in different sectors. This is particularly important for the EU legal system but some of these guidelines could be implemented in other countries. The UK's research council EPSRC has together with different academics also produced five principles of robotics mainly focused for designers, builders and users of robots which aim to provide modern rules for robotics that capture issues such as privacy, liability and ethics as described in this chapter. Companies are also getting on board; in fact according to Google Deepmind's CEO, Google is also setting up an ethics committee.[150]

There have been some interesting debates over the last few years on these issues and several ethics committees and organisations have been set up. Further international standards are also being proposed including a standard for cooperating robots, a safety standard for robot devices and nursing care and a modularisation of software and hardware that move on wheels.[151] However in a digital, globalised world, important issues such as ethics, privacy, liability and safety need designed institutions, incentives, laws about what information flows should be permitted or prevented,[152] international guidelines on how to operate in homes, standardisation for safety issues and laws on ethical and legal consideration of autonomous weapons. The quicker such standards are developed, the quicker the advancement and adoption of robots will happen in different sectors, however such standards may indeed arrest, rather than accelerate, the advancement and adoption of robots. Whether you agree with this expansion or not is another matter, however at least we will have some sort of protection. What is definitely clear is that in an age when the discussion on automation and the loss of jobs has reached sky high, and technology is moving at such a fast rate, the people who might gain from all this (besides the people working in AI) are lawyers who will be needed more than ever to cover issues such as privacy, liability, safety and ethics in a world deemed by two MIT Professors the 'Second Machine Age'.[153]

AI and robotics are not actually the problem — it is the way we use them that is the issue. Demis Hassabis, the head of Google's $565 million machine learning programme states that "Artificial intelligence is the science of making machines smart,"…. "If we're able to imbue machines with intelligence then they might be able to help us as a society to solve all kinds of big problems that we would like to have a better mastery of — all the way from things like disease and healthcare, to big questions we have in science like climate change and physics, where having the ability for machines to understand and find insights in large amounts of data could be very helpful to the human scientists and doctors."[154]

[149] https://akikok012um1.wordpress.com/south-korean-robot-ethics-charter-2012/
[150] http://www.bbc.com/news/business-34266425
[151] Japan's Robot Strategy, Vision Strategy, Action Plan.
[152] Brynjolfsson, E., McAfee, A., 2014, The Second Machine Age.
[153] Brynjolfsson, E., McAfee, A., 2014, The Second Machine Age.
[154] http://www.bbc.com/news/business-34266425

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Yanis Varoufakis (the former finance minister of Greece) views technology and automation in a different way to Hassabis. In an interesting discussion with the music producer Brian Eno, he stated that the issue with automation is ownership, and whether the ownership of the machinery will get even more unequal: “The way I try to express my own fear of, and hope for, the future is that we have our choice, which is between Star Trek and the Matrix. Star Trek is this: we’re all sitting around having philosophical conversations like in the ancient Agora in Athens and the slaves are not human. There are holes in the walls on the Starship Enterprise; you ask for something and it comes up. Fantastic. So then you can explore the universe and talk to Klingons. That’s one choice — the utopia. The dystopia is The Matrix, where the machines are being fed by our own energy. We are plugged into a false consciousness that the machines have been created to keep us happy. We think we are leading a perfectly normal life, but all along we are the slaves of the machines. So these are the two extremes. And the choice whether we go to Star Trek or The Matrix is ours. It’s a political choice.”[155]

[155] The Guardian, 28 November 2013, ‘Brian Eno meet Yanis Varoufakis: ‘Economists are more showbiz than pop stars now’.

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Will Keynes Prediction of a World of Leisure Prove Correct?

Highlights

- Keynes predicted that technology was an opportunity for us to enjoy more leisure time. Technology has reduced the cost of leisure, from travel to TVs. It also allows people to work flexibly.
- Evidence shows that the number of working hours has decreased over time whilst wages have also increased. There are however differences between countries with people in Nigeria working the longest hours, and people in Australia working the shortest number of hours per week.
- Average leisure time has increased when compared to the 1960's; however this differs between countries. A case study in the US shows that leisure time also differs between people who have different educational attainment and earnings, with professionals working more than 50 hours per week.
- Technology has also changed our leisure activities, and also our work practices. Millennials would like to shift their work hours, while countries like China are reducing their working weekly hours to increase spending in leisure, whilst Sweden is moving to a 6 hour work day to increase productivity in the workplace.
- One of the least commitment paths for policy makers to deal with the expansion of automation in the workplace could be to follow Keynes suggestion; however, work creates additional benefits such as personal worth and social attachment.
- The worry is that the 15 hour week that Keynes referred to would become a reality for people who are under-employed or un-employed, squeezed out by machines. However, if leisure time does increase for all, then the ultimate winners would be the media and leisure sectors.

Elizabeth Curmi
Thematic Analyst, Citi

Living in a Star Trek world, as described in the previous chapter, could lead to a world with more leisure time. Keynes in 1930 had already predicted that ongoing technological advances could displace workers. He viewed this as a huge opportunity rather than a concern. He looked at technological unemployment as a way of mankind solving its economic problem and in his essay called 'Economic Possibilities for our Grandchildren'[156] predicted that by 2030 the average work week would shrink to 15 hours per week allowing humans to enjoy more leisure time. "Thus for the first time since his creation man will be faced with his real, his permanent problem-how to use his freedom from pressing economic cares, how to occupy the leisure, which science and compound interest will have won for him, to live wisely and agreeably and well."

Could automation allow us all more leisure time whilst also keeping a good standard of living?

[156] John Maynard Keynes, Economic Possibilities for Our Children, 1930.

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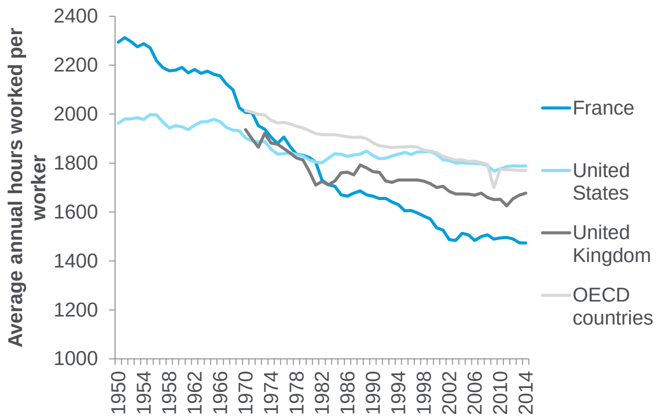
How Long are We Currently Working and How Much Leisure Time do We Currently Have?

Actual hours worked have decreased over time

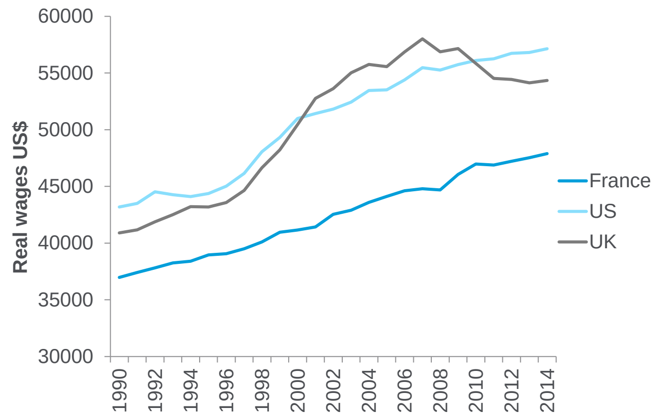
Evidence from the OECD shows that the annual hours actually worked per year per person has decreased over time (Figure 105). This is calculated by dividing the number of hours worked per year by the average number of people in employment per year. They include actual regular work hours of full-time, part time and part-year workers and exclude time taken off because of public holidays, annual leave, sick leave etc. The data is intended for comparisons of trends over time, rather than the level of average annual hours of work for a given year. The results show that for example in France and in the US the average annual hours worked per person has reduced by 35% and 10% respectively in 2014 when compared to 1950. Real wages have increased over the same period (Figure 106).

Figure 105. Average Annual Hours Worked Decreasing from 1950 to 2014



Source: OECD, Citi Research

Figure 106. Real Wages ($US- 2014 constant prices at 2014 USD exchange rates) Increasing From 1990-2014



Source: OECD, Citi Research

On average people in Nigeria work the longest hours whilst people in Australia work below the global average

If we look at an average working week, we see that that in 2014, people in Nigeria worked the most hours (48.2 hours/week), followed by people in Ghana who worked on average 47.8 hours/week. People in the US worked on average 44.5 hours per week (8.9 hours/day); this is based on employed persons aged 25-54, who live in households with children under 18.

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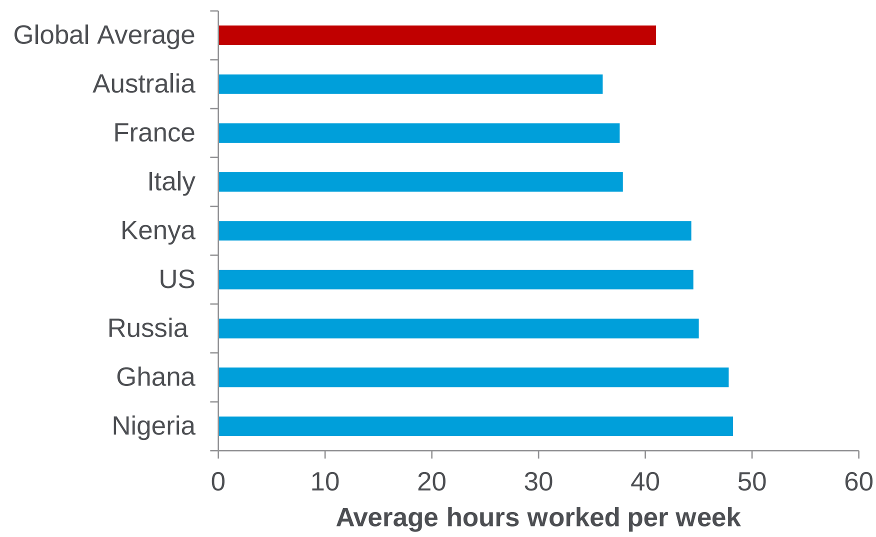
Figure 107. Average Hours Worked Per Week in 2014



Source: InterNations (2004)[157], BLS (2014)[158], Citi Research

How Much Leisure Time Do We Have?

Leisure time has increased for both men and women. For women the technological innovation in the household reduced the time spent on household work and has enabled women to enter the workforce

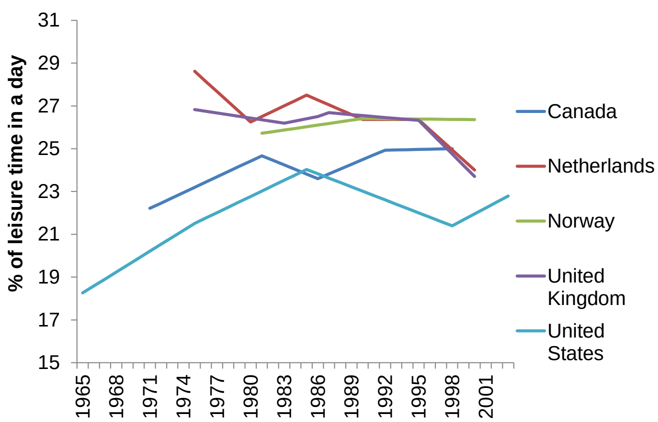
It is estimated that on average in the US, leisure time for men increased by 6-8 hours per week (driven by a decline in market work hours) and for women by 4-8 hours per week (driven by a decline in home production work hours) from 1965 to 2003.[159] Valerie Ramey provides lower figures when compared to the Aguiar and Hurst analysis; she estimates that leisure time has increased by 1-4 hours for men and 3-5 hours for women over the same period. The technological revolution in the home such as the introduction of washing machines, electric or gas cookers, vacuum cleaners etc. have reduced the amount of time that needs to be spent on cleaning the household and this amongst other things has enabled women to enter the workforce. In fact it is estimated that the introduction of household appliances accounted for 40% of the observed increase in married women's labour force participation rates during the 1960s.[160] A study done by Tiago et al. (2008)[161] has estimated that in the UK the decline in the price of home appliances accounts alone for about 10 to 15% of the increase in female labour participation rates from 1975 to 1999. However even though women did replace time spent on household chores with labour, their leisure time also increased. Aguiar and Hurst estimate that home appliances reduced time spent on home production by roughly 11 hours per week between 1965 and 2003 — this more than offset women's 5 hour per week increase in the labour market.

[157] InterNations, Balancing Work and Life abroad.
[158] Bureau of Labor Statistics, (2014), American Time Use Survey.
[159] Mark Aguiar and Erick Hurst (2006), Measuring Time Trends in Leisure: The Allocation of Time over five decades.
[160] Coen-Pirani, D., Leon, A., Lugauer, L., (2008), The effect of household appliances on female participation: Evidence from micro data, Carnegie Mellon University.
[161] Tiago, V., de V Cavalcanti and Jose Taveres (2008), Assessing the 'Engines of Liberation': Home Appliances and Female Labour Force Participation, The Review of Economics and Statistics, Vol 90, pp81-88.

Different countries experience different evolutions in leisure time over the years

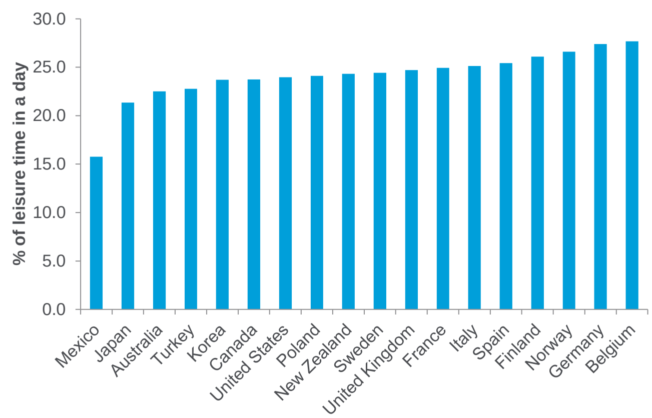
Data from the OECD provides a different picture. Figure 108 below indicates that over the past 40 years, different countries have experienced different evolutions in terms of shares of time dedicated to leisure. The share of time dedicated to leisure in the Netherlands seems to have fallen from the mid-1970s to 2003, with a similar pattern of decline in leisure in the UK. In the US and Canada rising amounts of leisure are seen over time albeit at a lower base (especially in the US) than European countries. This raises the discussion of whether a decrease in hours worked over time necessarily means a symmetrical upsurge of available leisure time. The OECD believes that it doesn't. For this analysis the OECD used a narrow definition of leisure, by extending the definition to include a % of personal care (defined as sleeping, eating and drinking and personal services) this extends the time spent on leisure activities in different countries. This shows the complexity in measuring time spent on leisure activities. Figure 109 below compares the leisure time in different countries, with Mexico having the lowest time dedicated to leisure and Belgium the highest.

Figure 108. Time Trends in Leisure From Time-Use Surveys (narrow definition of leisure)



Source: OECD[162], Citi Research

Figure 109. Annual Leisure Time in Different Countries (using a broader definition of leisure)



Source: OECD, Citi Research

The American Time Use Survey estimates that in 2014 on an average weekday, men and women spent 5.1 hours and 4.5 hours, respectively, on leisure and sports activities. This reduces to 3.3 hours for full time employees and 4.7 hours for part-time employees. The majority of this time is spent watching TV (average of 1.8 hours for full time employees), followed by socializing (0.5 hours). For more information on the media eco-system including revenues of different media sectors refer to Citi's GPS report '*The Curtain Falls- How Silicon Valley is changing Hollywood*'.

[162] OECD, (2009), Special focus measuring leisure in OECD countries.

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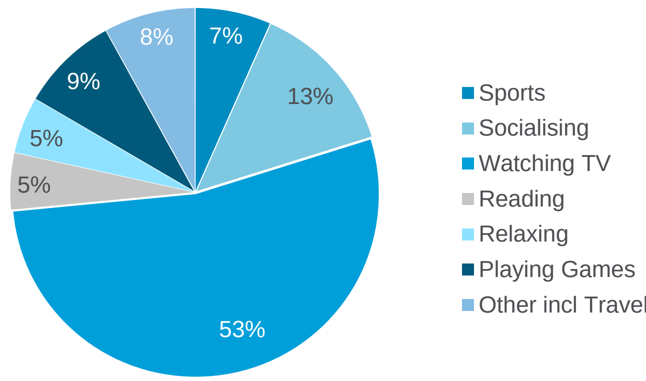
Figure 110. Leisure Time Spent on Different Activities on an Average Weekday for Employed people (both full and part-time)



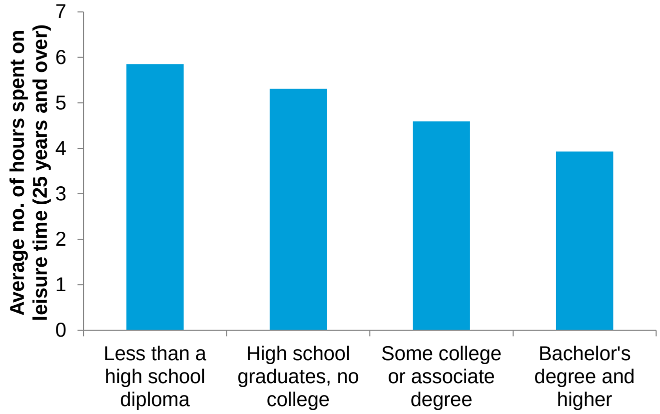
Source: American Time Use Survey 2014, Citi Research

In the US leisure time also differs between educational attainment and income levels. Higher earners have less leisure time available when compared to lower earners.

Higher earners and people that have a higher education have less leisure time available when compared with lower earners and people that have a high school diploma or less (see Figure 111 and Figure 112 below). There are many factors that account for this leisure time-gap. Part of this has to do with the structure changes to the labour market, where low-skilled jobs are often poorly paid and unsatisfying. So the value of working more hours amongst the under-educated is fairly low and therefore the rise in leisure increases. Also many well-educated people like what they do, so the reward of working extra hours goes beyond the financial incentives. A Harvard Business survey of 1,000 professionals in the US has found that 94% of the respondents work at least 50 hours per week and almost half work more than 65 hours a week, which is above the global average of 41 hours per week. A more recent survey undertaken by the Centre for Creative Leadership[163] has found that 60% (out of 483 professionals, managers and executives surveyed) who use a smartphone for business, work between 13.5 to 18.5 hours/day. The analysis does state however that smart phones allow flexibility, where managers are able to leave early, for example for family related events, all while being able to keep abreast of what is going on at work. Many high earners would potentially like to work less for somewhat (proportionally) less pay and would like more flexibility allowing them to work remotely and have more of a work/life balance (see a discussion on the PwC employee survey found in the next section).

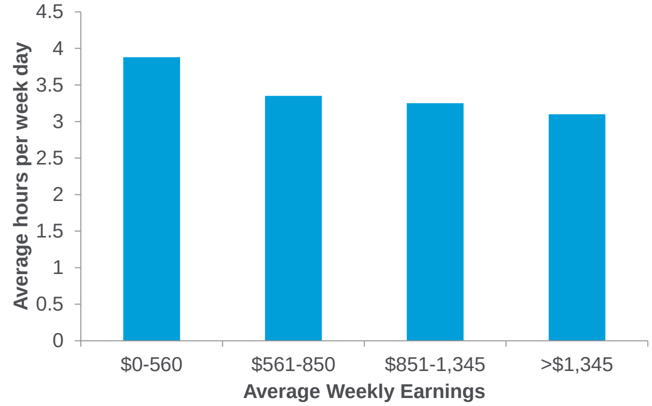
[163] Jennifer Deal (2015), Always On, Never Done? Don't blame the smart phone, Center for Creative Leadership.

Figure 111. Average Leisure Time by Education Attainment (25 years and over) in the US Weekdays



Source: Citi Research

Figure 112. Average Leisure Time by Earnings (single job holders only) in the US

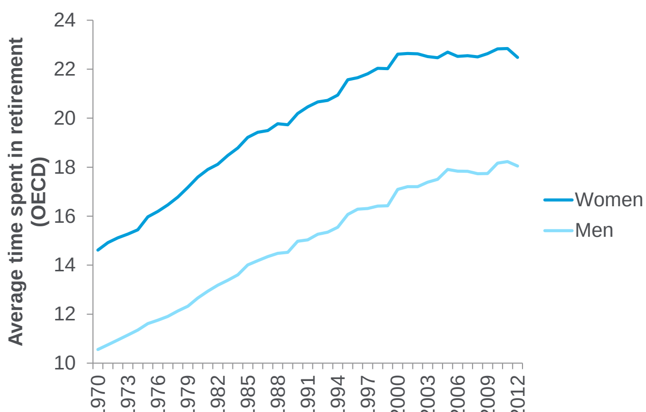


Source: Citi Research

Since we are living longer the cumulative time that people spend on leisure has increased over the years

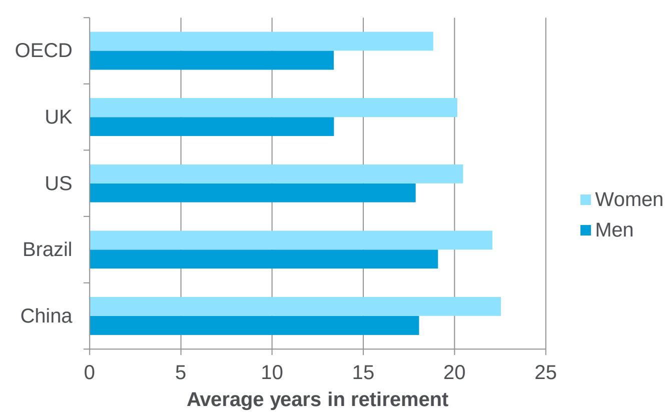
However, even if in some high earning occupations the amount of hours worked is above the global average as described above and leisure time available is less than the average worker, the cumulative time that people spend on leisure has increased over the years. This is due to many factors, but one in particular is that we are living longer and spending more time in retirement. Figure 113 below shows that on average men and women spend an additional 7.1 and 7.9 years in retirement in 2012 when compared to 1970. Figure 114 shows the average time spent in retirement in 2012 in different countries. Average time spent on leisure activities in the US in 2014 for people aged 65 to 74 years and 75 years and over is 6.6 hours and 7.9 hours respectively, which is more than double the amount of time spent in leisure during employment; coupling this with the extra time in retirement, and one can see that cumulative leisure time has actually increased over the years. Ramey and Francis (2009) in fact estimate that a person who was born in the 1930's had a cumulative leisure time of 113,000 hours, this increased to 143,000 hours for someone who was born in the year 2000.[164]

Figure 113. Average Time Spent in Retirement From 1970 to 2012 in OECD Countries



Source: OECD, Citi Research

Figure 114. Average Time Spent in Retirement in 2012 in Different Countries



Source: OECD, Citi Research

[164] Ramsey V.A, Francis Neville (2009), A century of work and leisure, American Economic Journal, pp 1889-224

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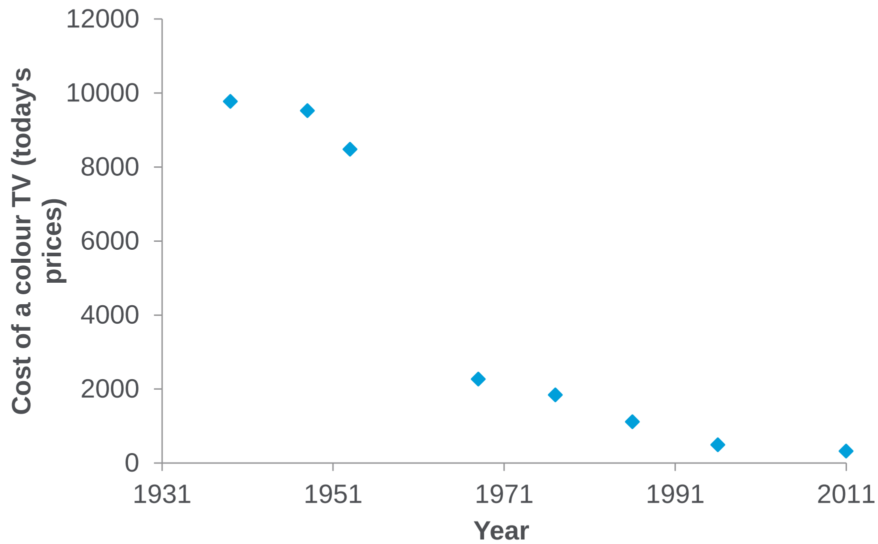
How has Technology Affected our Leisure Activities?

Technology has also reduced the costs of leisure over time, for example the costs of a TV has reduced from $8,480 in 1953 to $320 in 2011

Over the last decade we have seen extraordinary changes in technology. It has changed the type of leisure activities that we value today and also decreased the costs over time. For example the cost of airline tickets has decreased over 50% in the last 30 years.[165] There are many factors that contribute to this such as deregulation; however technology also played a part. From fuel saving technologies that reduce costs for airline companies, to computers that are used to move prices around and enable us to shop for the lowest prices, to purchasing tickets directly from the Internet rather than the airline itself or a travel agency; all of these developments have encouraged more people to fly over the years and reduce the costs in the process. The cost of a TV has also declined over the years. The first compatible colour TV set sold for $1,000 in 1953 (or $8,480 adjusted on today's terms), the price decreased in the 1970s when a 25 inch colour TV cost $530 (or $1,840 adjusted), and in 2011 one could purchase a colour TV for as little as $320[166] (see Figure 115 below). Today you don't even need a TV; you can streamline television programmes just by using your computer through services such as Netflix, BBC I-player and others. Technology has changed the way we socialise, the way we read books, watch TV, play video games etc.

Figure 115. Cost of Colour TV Over Time



Source: Cox (2011), Citi Research

[165] The Atlantic (2013), How airline ticket prices fell 50% in 30 years (and why nobody noticed).
[166] Brent Cox (2011), How much more do televisions cost today?

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Can Automation/Technology Reduce Working Hours Further and Increase Leisure Time Without Compromising the Standard of Living for All?

The eight hour day hasn't changed very much since Henry Ford first adopted a five-day, 40-hour week for his workers in his factories. He reduced the work week from 6 to 5 days arguing that every man needs more than one day a week for rest and recreation. He stated that "It is high time to rid ourselves of the notion that leisure for workmen is either 'lost time' or a class privilege."[167] He however did admit that the five-day work week was instituted in order to increase productivity as even though workers hours decreased, they were expected to expend more effort when they were at work. He also stated that people need to have more leisure time available to find uses for consumer products, including automobiles.

64% of Millennials would like to change the way they work

However, could the 40-hour week (traditionally worked between 9am and 5pm) be coming to an end? PwC together with the University of Southern California and London Business School have surveyed tens of thousands of employees of PwC firms around the world to explore the thinking and mind set among its younger employees (Millennials born between 1980 and 1995). They found that 64% of Millennials would like to occasionally work from home and 66% of respondents would like to shift their work hours.[168] They believe that productivity should not be measured by the number of hours worked at the office but by the output of work performed. In our previous chapter on jobs we also highlighted that 53 million people in the US were working in some sort of freelance capacity. According to the Freelancers Union the two most common reasons for going freelance were (1) to earn extra money and (2) to have flexibility in their schedule. Workers especially young workers would like to see more flexibility in their working hours, enabling then to achieve a better work/life balance.

Policies regarding the working hour week are also changing in China and Sweden

We are also seeing such policies being implemented on a national scale. The Province of Chongqing in China which is home to 30 million people has begun implementing an official policy for a 4.5-day working week as part of an effort to increase domestic consumption and leisure spending. Other provinces such as Hebei and Jiangxi are also considering implementing such a policy measure. Domestic tourism generated nearly half a trillion (US$) for China's economy in 2014, and the extended weekend will give workers more opportunities to travel and spend more within China.[169] Sweden on the other hand is moving to a standard 6-hour work day with the aim of increasing productivity in the work place, with businesses across the country already implementing the change. It is too early to determine whether such measures will be successful in improving productivity, however there are many studies that have discussed how an 8-hour day is not as effective as one would think and to stay focused on one particular task for 8 hours is a huge challenge.

Could technology change the working hour week further?

With the rapid increase in automation and technology, could it be that the working hour week would reduce even further when some of our work tasks become automated which could possibly increase our leisure time in the process? Could Keynes theory of working a 15-hour week actually become a reality?

[167] Ford Factory workers get 40-hour week (www.history.com).
[168] PwC, University of Southern California & London Business School (2013), PwC's NextGen: A global generational study, 2013.
[169] World Economic Forum (2015), Is China heading towards a 4.5 day week?

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Andy Haldane from the Bank of England in a recent speech did argue that that one of the paths requiring the least commitment from policy makers to deal with automation in the workforce would be to relax and follow the path Keynes charted in the 1930 — ‘a world of progressively shorter working weeks, where mini-breaks become maxi-breaks’. However, Haldane states that work delivers other benefits besides money- it creates a sense of personal worth and social attachment. Keynes does address this and states that “Yet there is no country and no people, I think, who can look forward to the age of leisure and abundance without dread. For we have trained too long to strive and not to enjoy.” He argues that a 15-hour week would be sufficient to satisfy our need for work. So the question arises whether people would actually enjoy more leisure time or consider this as being idle or feeling useless.

Working shorter weeks could be a potential solution to the negative effects of automation on the labour market. The worry is that this would become a reality for the under-employed

Automation could improve productivity and allow the opportunity (or not, depending how you view work) for people to work less hours. Working shorter weeks could be a potential solution to alleviate some of the negative effects that automation could have on the labour market and increase our leisure time in the process. The worry is that the 15 hours a week that Keynes refers to, would become a reality for people who are under-employed or unemployed, squeezed out by machines replacing their job tasks and made to work shorter hours, reducing their wages in the process. Maybe automation and technology would enable us to work less whilst also maintaining a good standard of living. History has shown us that average working hours have decreased over the years (at least for some professions and some countries) whilst average wages have also increased over time. If this happens, then the media and leisure sector would be the ultimate winner, benefiting from a huge increase in leisure time available. However, you never know: with time on our hands, we could actually start enjoying science, painting, writing and reading, leisure activities that were valued in the 1930s.

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Conclusion

In the words of the famous author Elbert Hubbard —- "One machine can do the work of fifty ordinary men, No machine can do the work of one extraordinary man." With technology advancing at a rapid pace, could Hubbard be right? Do we need to be extraordinary for technology not to take our job?

Over the last few years there have been many academics, industrialists and others that have highlighted, analysed and debated the rapid expansion of automation in the workplace. In our previous Citi GPS report Technology at Work, we concluded that 47% of the jobs in the US are susceptible to automation. In this publication we extend this analysis to other countries and regions and conclude that jobs in developing countries are also susceptible to automation. Due to technological advancement low-wage regions which have traditionally attracted manufacturing firms will not have the same possibility of achieving rapid growth by shifting workers from farms to higher-paying factory jobs -therefore they would need to find a different path to prosperity.

Our analysis also extends to cities, and we conclude that in the US, cities that are more specialised in a certain industry are at high risk of automation, whilst others that have a more diversified industry are more resilient to the expanding scope of automation. Work by Oxford Martin School researchers shows that the cities most at risk include Fresno and Las Vegas, whilst cities least at risk include Boston, Washington D.C and New York. The best way for cities to reduce their exposure to automation is to upskill their workforce.

New jobs are also emerging with forecasts suggesting that there will be 9.5 million new job openings and 98 million replacement jobs in the EU from 2013 to 2025. However our analysis shows that roughly half of the jobs available in the EU would need highly skilled workers, something which is emphasized in both the previous chapters.

In the US, the digital economy is also creating some new jobs, whilst other sectors such as the green economy and industrial sectors are also increasing their job openings. Over 4 million jobs are expected to be created in the health sector alone. This is not surprising given that we are living longer. In fact it is estimated that in advanced economies, the population over 65 years old is expected to increase, whilst at the same time the working age population is expected to decrease — 26 million additional workers would be needed over the next 20 years. Could automation and innovation help offset these macro-effects of demographic change? Embracing automation has been amongst the strategies being pursued in a number of countries including Japan and China. Incremental productivity gains through automation could plausibly offset the demographic developments in a number of countries.

Automation should lead to productivity improvements. However this is not yet evident. Across the advanced economies and in many emerging markets, measured productivity growth is low in historical comparison. We offer three explanations for this: (1) productivity is not measured correctly, (2) changes in composition of production have taken place that imply a wider distribution of productivities amongst different companies and workers; and (3) rapid changes in technology will require significant adaptation to develop their full productive potential. We also conclude that technological change is re-enforcing a low-inflation environment and consequently interest rates are likely to remain lower for longer.

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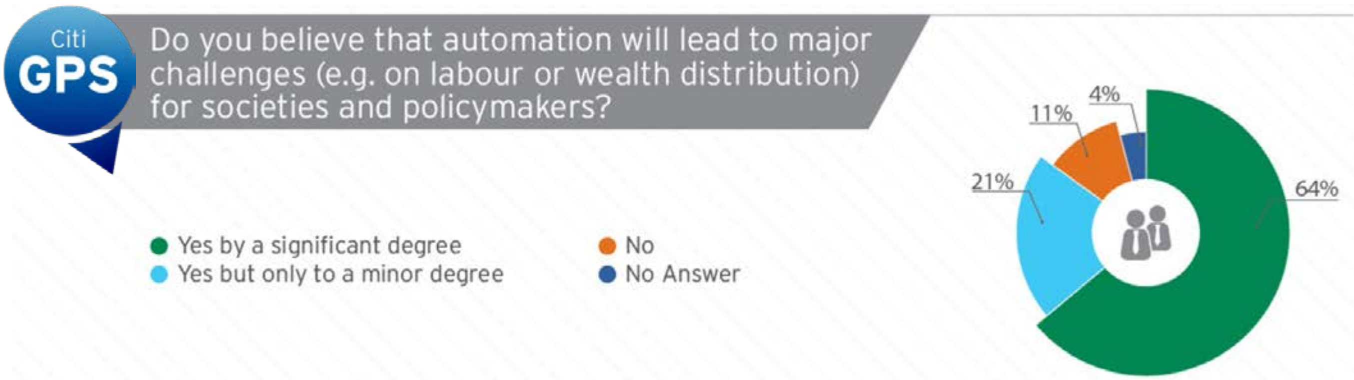
While most studies have focused on long-term susceptibility to automation, Citi's analysts have already seen automation and computerisation occur in a number of different sectors such as the food industry, call centres, warehouses and others. With robots getting cheaper and wages increasing in certain countries like China, other sectors which have traditionally been slow at integrating robots into their manufacturing process are now changing. There remain some barriers, especially to SMEs which pride themselves on their fixed to variable ratio, however with the introduction of co-bots these barriers could decrease over time.

It should be evident that a world in which innovation is accelerating and abundant is preferred to a world in which it is lacking. But this report highlights the potential disruption that technological changes could cause for jobs in different regions and cities. If technological advancement is left unmanaged or poorly managed these changes could create significant disruptions to society. In fact 85% (64% by a significant degree, 21% to a minor degree) of the respondents to our survey believe this to be true (see figure below).

Figure 116. 85% of Respondents Believe that Automation will Lead to Major Challenges for Societies and Policy Makers



Source: Citi Research

In the last part of the report we highlight a number of different measures that could be taken to reduce this disruption. These include policy responses such as Earned Income Tax Credits, job placement services, regulations, investment in education etc. We also highlight the importance of principles, standards, certification, guidelines and laws that should be developed to ensure some sort of protection for society. In the last chapter we discuss the least commitment path that policymakers could take, which is to reduce working hours and increase leisure time. The question is whether an increase in leisure time would become a reality for people who are under-employed or unemployed, squeezed out by machines replacing their job tasks. However, you never know: using the words of Varoufakis, we could live in a Star Trek world, where machines will enable us to have time to sit around and have philosophical conversations, where you ask for something and it appears, and where we have time to explore the universe and talk to Klingons. Maybe it is not all doom and gloom — 76% of respondents to our survey state that they are techno-optimists and only 21% are techno-pessimists.

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Figure 117. 76% of Survey Respondents are Techno-Optimists

Source: Citi Research

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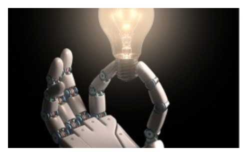

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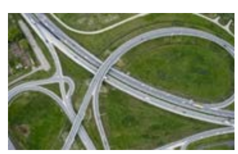

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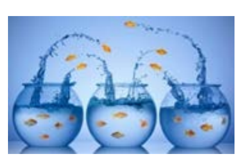

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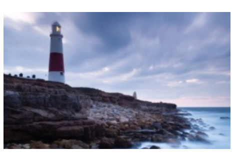

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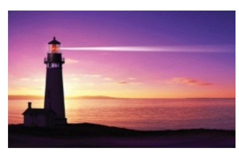

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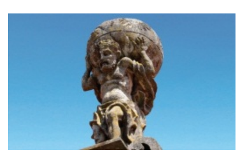

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