FUTURE FRONTIERS ANALYTICAL REPORT

The Future of Work in Australia: Anticipating how new technologies will reshape labour markets, occupations and skill requirements

DR JOSHUA HEALY | DANIEL NICHOLSON | PROFESSOR PETER GAHAN

A report prepared for the NSW Department of Education

ABOUT THE AUTHORS

Joshua Healy is a Senior Research Fellow in the Centre for Workplace Leadership at the University of Melbourne. His interests are in employment relations and labour economics, with recent studies of the ageing workforce, skill shortages, and minimum wages. His work appears in leading academic journals and is regularly featured in the national media.

Daniel Nicholson is a Research Fellow in the Centre for Workplace Leadership at the University of Melbourne. He holds qualifications in political science, social policy, and social work. His research focuses on contemporary industrial relations and labour studies, with a particular interest in how current technological changes are affecting work and workplaces.

Peter Gahan is a Professor of Management and a Research Associate of the Centre for Workplace Leadership at the University of Melbourne. He has published extensively on aspects of employment relations, high-performance work practices, business innovation, and regulation. He has consulted widely on these topics for numerous governments and private-sector organisations.

ABOUT THE CENTRE FOR WORKPLACE LEADERSHIP

The Centre for Workplace Leadership was founded in 2013 as a partnership between the University of Melbourne and the Commonwealth Department of Employment. Its mission is to develop world-class leadership capability in Australian organisations, by bridging the gap between research insights and leadership practice. The Centre is committed to building the capabilities of current and aspiring leaders, sustaining high-performance workplace cultures, transforming workplaces through technology and innovation, and developing the new types of skills that will be needed to lead the organisations and workforces of the future.

EDUCATION: FUTURE FRONTIERS

EDUCATION: FUTURE FRONTIERS is an initiative of the NSW Department of Education exploring the implications of developments in AI and automation for education. As part of this initiative, the Department has commissioned background reports on future skills needs. The views expressed are solely those of the authors.

This report uses unit record data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The HILDA Project was initiated and is funded by the Australian Government Department of Social Services (DSS) and is managed by the Melbourne Institute of Applied Economic and Social Research (Melbourne Institute). The findings and views reported here, however, are those of the authors and should not be attributed to either DSS or the Melbourne Institute.

Executive Summary

Recent technological advances – in automation, robotics, artificial intelligence, and other areas – have provoked intense concern about the future of work. Perspectives range widely, from more enticing views of abundant leisure, to more disturbing visions of widespread unemployment and deepening social divisions. Almost daily, machines seem to acquire new capacities that again prompt speculation about where the jobs of the future will come from, whether they will be of good quality and fulfilling, and how future workers can best prepare to do them.

Our report offers a detailed Australian perspective on these issues. It reviews a large body of evidence about technological changes, and attempts to assess their likely implications for the Australian workforce and skill requirements in the coming decades. As an industrialised nation with strong international trade links, Australia's economy is shaped by global forces of technological change. This does not mean, however, that these forces have inevitable or identical effects in every location. Australia's particular context – its distinctive institutions and policy settings – will ultimately shape how common technological forces are manifest.

A central and recurring theme of our report is that Australian policy makers have choices about how, and how quickly, technology's effects are felt. While the pace of change can be confronting, technological progress is not something 'happening to us', but a process under our control. The challenging task for governments, social actors and the wider population is to gain some understanding of the forces at work, in order to harness the potential for good and, if possible, minimise the harmful consequences. This report contributes to building the knowledge base that is needed for informed choice and action.

Our analysis is presented in five main sections, each of which is briefly summarised below. The report's structure moves from more general, international content in early sections to more specific, Australian-focused conclusions in its later sections.

Section 1, 'Frontier Technologies', reviews the main current and emerging technologies that are having the most disruptive effects internationally on labour markets, jobs, and workers. We show that the pace and pervasiveness of technological change has increased, due to the convergence of several mutually enabling innovations, which together have brought about a 'paradigm shift' in how technology is applied in business and the labour market. While the displacement of some human workers is familiar in older industries such as agriculture and manufacturing, newer technologies also appear to be acquiring proficiency in more complex tasks that were previously thought to be 'safer' from similar effects.

Section 2, 'Employment Effects of New Technologies', examines how technological change is likely to impact on two distinct aspects of work in the future: first, the total quantity of work available for humans and, second, how that work is distributed. On the first point, we find no convincing evidence that work on the whole is disappearing, despite many new and old predictions that the 'end of work' is imminent. Most such accounts overemphasise the job destruction effects of technology, while ignoring or understating its equally important role in job creation. While today's advancing technological frontier may accelerate the rate at which old jobs are lost, it will also have offsetting effects that are difficult to predict, but that could conceivably equal or exceed the numbers lost. Historical evidence suggests that the process of economic development is surprisingly effective at generating sufficient new jobs, in unfamiliar fields, to maintain high levels of aggregate employment in the long term.

On the second point, however, there is strong evidence to suggest that the distribution of work is changing – and will in all probability continue to change – as technological progress gathers speed. Machines appear increasingly likely and able to substitute for humans in the performance of routine tasks, while complementing us in the performance of non-routine tasks. This 'routinisation' hypothesis is supported by empirical evidence from studies in a variety of developed countries, including Australia. The demand for humans to undertake abstract, cognitive tasks has increased strongly (and has been supported by a rapid rise in the proportion of workers with post-school qualifications), while the demand for workers to do routine tasks has fallen and is threatened further by technological progress. Importantly, this bias towards non-routine tasks is influencing the structure of employment both within and across occupations. Even in jobs that are not forecast to disappear, there is likely to be some transformation in job content, associated with a higher intensity of non-routine tasks.

Section 3, 'The Australian Context', examines specificities in the Australian economy, labour market and workforce that affect how the global technological paradigm shift will play out here. We see several grounds for optimism about the future when looking at how Australia has weathered the impacts of technological disruption to date. Compared with the United States, Australia's labour force participation rate has proven more resilient (for both sexes) and we have not experienced nearly the same extent of widening in earnings inequality (or, by some measures, in broader indicators of household income inequality). While there has been a progressive change in the underlying occupational structure towards jobs entailing more abstract task requirements, this shift in skill demand has not been accompanied by any substantial worsening in participation or inequality. These achievements are laudable, and suggest that Australia's institutions and policy settings continue to exert an important influence over how global technological and demand shifts are translated into outcomes.

We are sceptical of claims that Australia will lose 40 per cent of its workforce to automation. Our assessment, based on a careful reading of the evidence, is that this represents an upper limit to the likely changes we will see. While many Australian workers will be affected by impending technological change, for most the impact will be less dramatic than the loss of their entire job and livelihood. As in other developed economies, more Australians will be forced to alter how they spend their working hours, as machines become more proficient (and cost-effective) at a wider range of today's human tasks. We cannot anticipate exactly how far or how quickly this process will run, but on the best evidence it seems likely that competence in performing unstructured job tasks, especially those of a cognitive variety, will best serve the needs of the future labour market and provide workers with the greatest possible protection against job loss and redundancy.

It is encouraging to see the strong investments that have been made in recent decades to 'upskill' the Australian workforce and broaden access to formal post-school qualifications. Further investments of this kind are needed, and as far as possible this access to education should be extended equitably, to avoid exacerbating the tendency of technological changes to be polarising in their effects. Investments in technical skills should also be augmented by an increased commitment to providing future workers with a broader set of competencies – in areas such as communication, teamwork, and empathy – which remain uniquely human skills, and the foundation for our advantage over even the most sophisticated of machines.

Section 4, 'Possible Futures for Work and Skills in Australia', looks ahead and offers a fuller assessment of the likely future trends. We describe the main methods used to predict the labour market impacts of technological change, and evaluate the most prominent recent reports deploying these methods. The best evidence suggests that automation and artificial intelligence are having modest impacts on job destruction at the moment, and that this is unlikely to change dramatically in the near future. Predicting future employment growth is more difficult, but Australian projections point to the likelihood of further strong growth in industries like health and human services, professional, scientific and technical services, and education and training.

Scenario planning offers another useful tool for anticipating possible futures and can help policy makers both to envision and then to steer toward (or away from) certain directions. We examine four major recent scenario-based reports from Australia and other developed countries, and attempt to draw out their similarities and differences. Optimistic scenarios generally see a future of secure, meaningful work, with an emphasis on minimising drudgery and alienation. Australia is arguably well-placed to move in this direction, but will have to do much more to limit the negative individual and community effects of continuing routine job losses. Scenarios with a mixed outlook anticipate increased levels of labour market polarisation, and there are strong indications that Australia's future labour market will move further in this direction. Finally, pessimistic scenarios are consistent in predicting deepening social and economic inequalities, reduced labour protections, and fundamental weakness in the future labour market. Australia has not drifted far in this pessimistic direction, but there are signs of significant problems emerging, with persistent low wage growth, destruction of routine occupations, and extensive casualisation of the youth workforce. Policy intervention in these areas would help to avert the risk of Australia's future labour market moving closer to the more pessimistic scenarios.

Section 5, 'Conclusion', summarises our assessment of the available evidence, the nature of the policy challenge, and our views about the likely future course for labour market and job changes in Australia over the coming years.

Table of contents

Executive Summary....3
Table of contents....6
1. Frontier Technologies....7
1.1. - ICT as a driver of innovation....8
1.2. - Second-order innovations: New business models....10
2. Employment effects of new technologies....12
2.1. - Is 'the end of work' near?....12
2.2. - Changes in the distribution of work....15
3. The Australian context....23
3.1. - Work endures in Australia, too....23
3.2. - The changing distribution of work in Australia....24
3.2.1. - The supply side: Who wants to work?....24
3.2.2. - The demand side: What work is required?....27
3.2.3. - The practice: How is work done?....32
4. Possible Futures for Work and Skills in Australia....36
4.1. - The challenge of prediction....36
4.2. - Implications of the shifting technological frontier for future jobs and skills....37
4.2.1. - Implications for job destruction and transformation....37
4.2.2. - Implications for job creation....38
4.2.3. - Technology, automation and the diffusion of telework....39
4.2.4. - Implications for skill requirements....42
4.3. Future Labour Market Scenarios....42
4.3.1. - International Scenarios....44
4.3.2. - Scenarios for Australia's Future....47
4.3.3. - Key themes from the scenarios....47
5. Conclusion....49
References....51

1. Frontier Technologies

Periods of rapid technological change are typically accompanied by significant concern about their social and economic impacts. Mokyr and colleagues (2015) point out that apprehensions about the potential for technological unemployment, and consequences for human welfare more broadly, have accompanied technological advancement for centuries. Similarly, each wave of technological change is accompanied by a debate about the extent to which technology is driving progress: 'hard' technological determinists grant technology the agency to drive social and economic change, while 'soft' determinists argue that 'the history of technology is the history of human actions' (Marx and Smith, 1994: xiii).

While technological change is always a feature of economic development, many observers are increasingly convinced that the current wave of technological change is qualitatively different from previous phases. Every day, we are reminded of new technologies that promise to upend social and economic life. On waking in the morning, we are more likely to turn on a smartphone or tablet than to open a printed newspaper in search of the news. There, we encounter reports of robots taking jobs that were previously done by humans (Miller, 2017), the impending arrival of driverless cars and delivery drones (Wingfield and Scott, 2016), and stories of start-up businesses challenging long-accepted notions of work and consumption (Redrup, 2015).

This section describes some of the existing and emerging technologies that are spurring this renewed public interest, and that are likely to have disruptive impacts on the world of work in coming decades. We examine their uses and possibilities, and how these new functions are shaping how future work will be done, including a brief examination of the ways technology is radically impacting business models. It is beyond the scope of our discussion to exhaustively explore these topics. Instead, what follows is a brief overview of the technologies most likely to be disruptive for jobs and labour markets in the foreseeable future.

Technological change goes hand-in-hand with economic growth and is generally seen as a driver of higher productivity and living standards. It is also frequently 'disruptive' in the sense that it can enable the rapid displacement of incumbent workforces, businesses and work practices. For our purposes, 'technology' is a set of applied pieces of knowledge, both practical and theoretical, usually scientific or technical in nature, which may take the form of 'know-how, methods, procedures [or] experience of success and failure' (Dosi and Kogut, 1993: 249). There is broad agreement among academics and policy makers that recent developments in information and communication technology (ICT), computer-based technologies (CBT) and artificial intelligence (AI) have brought about a technological paradigm shift (Gahan *et al*., 2017). Such shifts occur when technological advances cause a substantial discontinuity in the underlying assumptions and beliefs that have previously informed the use and application of technologies (Ho and Lee, 2015: 129).

This paradigm shift — described by some as a 'second machine age' (Brynjolfsson and McAfee, 2014) or a 'fourth industrial revolution' (Schwab, 2016) — has not been driven by any one particular technology, but by the convergence of numerous, mutually-enabling technologies. A prominent example is Instagram, which created a photo-sharing social media app that was able to displace previous industry leader, Kodak. It managed to do this not because of any one technology, but because of network connectivity and high-resolution cameras converging in the form of smartphones (Leslie, 2014).

Brynjolfsson and McAfee (2014) argue that one of the central technological advancements enabling today's ongoing paradigm shift is the dramatic increase in the processing power of computers that has occurred over the last 50 years. The authors point out that the growth of computer capacities has closely followed the prediction encapsulated by 'Moore's Law': that the processing power of computing hardware would double approximately every two years. Moore's Law has proved a reliable predictor of the exponential growth in underlying computing capacity,[1] which has helped to facilitate rapid improvements made in areas like computer vision, machine learning and problem-solving capacities, and other elements of computer technology (Mitchell and Brynjolfsson, 2017). All of these developments have had a transformative effect on ICT and CBT and have begun to facilitate rapid advancements in AI.

1.1.- ICT as a driver of innovation

Both economically and socially, developments in ICT have had a particularly profound impact. ICT represents the 'converging set of technologies in microelectronics, computing (machines and software), telecommunications/broadcasting, and optoelectronics' (Castells, 2010: 30). Ford (2015) suggests that ICT is having such a profound effect for two reasons. First, it has evolved into a true general-purpose technology, meaning that it is not confined to one industry sector but can be applied in a myriad of contexts. Nor is it geographically bounded, as the technologies (generally) move quickly across borders. Second, ICT is enabling the development of other areas of technology, like the cognitive capacity of machines, to the extent that these can increasingly match or even outperform humans in undertaking more complex tasks.

These factors have allowed ICT to play a key role in driving innovations in all areas of the economy (Howcroft and Taylor, 2014). The impact of internet-enabled smartphones, for instance, is not isolated to one industry or occupation. Rather, these devices have facilitated new levels of connectivity and monitoring between employees and employers in all sectors (Bersin *et al*., 2016), and have driven innovations in business models that have displaced leading incumbent firms in a range of industries (Cohen and Kietzmann, 2014).

In recent decades, the disruptive impact of new technologies has perhaps been most visible in the robotisation and automation of jobs that were previously performed by humans. This process is most advanced in areas of manufacturing and administrative services, where many jobs previously consisted of routine tasks (Brynjolfsson and McAfee, 2014). Referred to as 'routine-biased technological change', this phenomenon occurs because computers can most straightforwardly substitute for workers in performing routine cognitive and routine manual tasks that follow explicit, codified rules (Levy and Murnane, 2004).

Since the arrival of automatic teller machines, for example, bank tellers perform far fewer transactional tasks, such as customer withdrawals, which are easily accomplished by a machine. More recently, transfers and other tasks are increasingly completed through internet banking. The role of a bank teller now consists more of sales and customer service tasks which cannot easily be performed by a computer (Hunter, 2001). Customer inquiries are increasingly managed through automated inquiry robotics deploying natural language programming, displacing the need to route such inquiries through call centres. In the manufacturing sector, assembly lines that previously employed hundreds of workers are now operated by machines with just a few people as overseers (Sherk, 2010).

Some emerging technologies, however, have begun to displace human labour in more complex cognitive and manual tasks that were previously thought to be impervious to automation. One of the technologies facilitating this phenomenon is the so-called 'internet of things'. This refers to the interworking of different physical devices through a series of internet-enabled sensors and electronics. These 'smart', connected devices consist of three elements: their actual physical parts (like the body of a drone, smartphone or car), smart components (such as data storage capacity or sensors) and connectivity

[1] Recent evidence suggests, however, that Moore's Law is facing a technological limit (Simonite, 2016).

capacity (wifi or network connectivity) (Porter and Heppelmann, 2015). Sometimes known as 'pervasive' or 'ubiquitous' computing, this phenomenon has wide-ranging implications for jobs. In the health sector, for example, internet-enabled devices like heart monitors can relay diagnostic information from patients to medical professionals automatically and in real time (Susskind and Susskind, 2015). Looking forward, major corporations such as Amazon and Google have begun to experiment with internet-enabled delivery drones and autonomous vehicles, both of which threaten to displace large workforces (Porter and Heppelmann, 2015).

Firms are also exploring applications of the internet of things in managing workers. A recent report suggests that employers can improve employee productivity by using the internet of things to monitor—through devices like 'smart' wristwatches— where workers are, who they are with and what they are doing (Bersin *et al*., 2016). Firms are increasingly investing in so-called 'people analytics', or the analysis of data from the internet of things, to gauge employee performance and inform decisions around recruitment and selection (Peck, 2013). These applications carry the potential for higher productivity, but also raise concerns about employee privacy and the possibility of invasive overreach (Bersin *et al*., 2016).

Internet-enabled devices collect and process unprecedentedly large amounts of data and are contributing to a new technology known simply as 'big data'. This term is used to describe the massive datasets that are captured from individuals' interactions with internet-enabled technologies. Big data analysis seeks to reveal patterns, trends and associations, especially relating to human behaviour and interactions (McAfee and Brynjolfsson, 2012). The analytic capacities of these computer programs exceed those of human beings and are still evolving; however, big data is already being used in a number of contexts. An example is vehicle manufacturers collecting data on customers' driving habits from their cars' on-board computers. This data is collated and analysed computationally, providing insights about how products can be better designed, built, and serviced (Porter and Heppelmann, 2015). In the retail sector, online stores enable firms to study what customers purchase, what they browse and how they are influenced by reviews and page layouts (McAfee and Brynjolfsson, 2012). In the future, Susskind and Susskind (2015: 59) suggest that big data will play a role in education, where progressively more complex datasets will be maintained on students, with a view to developing 'learning analytics' and individualised teaching plans.

Big data has helped to facilitate significant advances in AI. Arguably the most advanced area of AI is 'machine learning', or the capacity of computer programs to change or 'learn' when exposed to certain data inputs. For several decades, AI has gone through a series of 'hype cycles' followed by 'winters' when interest and funding ebbed, but many participants and observers believe this time is different (Knight, 2016; Walsh, 2017). Confidence has been buoyed by recent significant advancements: tasks that were thought to be safe from automation, such as describing what is in a photograph, discerning human emotions and judging the space in a room, are increasingly within the power of computers (Lee, 2017). The applications of these new capabilities are likely to have wide-ranging impacts: for example, the ability to judge the space in a room may soon give machines the capacity to replace human beings in tasks like cleaning an unfamiliar space or painting a wall. It is likely that these developments will continue, with Google, Microsoft and Amazon having pledged to make their machine-learning tools universally available. Lee (2017) notes that when other technologies have been made widely accessible in this way, rapid advancements have quickly followed (e.g., when Apple allowed third parties to create and distribute apps for its devices through the app store).

The corporations mentioned above plan to share their AI tools through their 'cloud computing' packages. Cloud computing allows data to be stored in a virtual architecture of remote servers via the internet (Bradlow, 2015). The data is managed by a hosting company that charges a client for on-demand data storage, which reduces costs significantly and frees the computer user from the need of a physical infrastructure. In addition to storage, hosting companies routinely provide data processing services. Cloud computing has already begun to facilitate increasingly flexible work arrangements, including 'telecommuting' and virtual working arrangements. In extreme examples, like tech companies Mozilla and Upworthy, organisations have done away with physical offices altogether and rely entirely on digital communication to coordinate their teams (Kane, 2015). These developments will require workers and firms to negotiate new arrangements for workspaces, computer hardware and software, and boundaries between work and non-work time (Holtgrewe, 2014).

Another emerging technology with potentially wide-reaching employment implications is the 'blockchain'. A recent CSIRO report described this as: '...both a database, recording transactions between parties, and also a computational platform to execute small programs (called 'smart contracts') as transactions... [it] is a distributed database, replicated across many locations and operated jointly by a collective' (Staples *et al.*, 2017: 3).

The blockchain was developed to support transparent, accountable transactions with online currencies like Bitcoin (The Economist, 2017). However, many new uses of the technology are being explored, including potential applications in areas from elections to orthodox financial transactions, and supply-chain monitoring. Staples and colleagues (2017) suggest that the blockchain could usurp the role that has traditionally been played by accounting and law firms in overseeing, facilitating and monitoring transactions and changes in legal documents. Governments have also begun to explore applications of the blockchain for collecting tax and administering social welfare payments (Walport, 2015).

Several other emerging technologies are also likely to have a disruptive impact on the world of work in coming decades. 3D printing (manufacturing techniques that create objects by printing in layers based on digital models) and unconventional energy storage (advanced items that store energy for later use) will have unforeseeable effects on the future makeup of the workforce and the labour market (Dobbs *et al.*, 2015). Next-generation genomics, or fast, low-cost gene sequencing and synthetic biology, is likely to have significant impacts on health diagnostics and treatments, as well as on agriculture (Dobbs *et al*, 2015). However, the technologies described in more detail above are those we consider likely to have the most profound impacts on future jobs, in part because they facilitate other related innovations. Again, no single technology has catalysed the current technological paradigm shift. Instead, the convergence of various technological advancements has led to the disruptions that are today spurring the renewed interest in the future of work.

1.2. - Second-order innovations: New business models

While it is imperative to understand how technology itself is evolving, second-order effects can be equally consequential. Before a new technology can disrupt jobs and skill demands, it must first be applied, via a new business model or process. For this to occur, businesses must believe that a technology will be more cost-effective than an existing process—or than human labour itself—in the long term. We thus consider briefly how new technologies are being commercialised, and how they are reshaping business models.[2]

Chesbrough (2010: 355) observed that 'a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model'. In some instances, technologies are adopted by firms that can use their existing business model to extract value from the new technology. In other cases, existing

[2] Here, 'a business model' is the set of decisions that together govern how a business brings in revenue, incurs costs, and manages its risks (Girotra and Netessine, 2014).

firms can change their business model in order to commercialise a technology and make it profitable (Chesbrough, 2010). However, in some cases the logic of a technology gives rise to entirely new business models, facilitated by or designed to meet (or both) the capacities of that technology (Cohen and Kietzmann, 2014).

Perhaps the most pervasive effects of technological business model disruption are seen in the rapid emergence of online labour markets. Some online labour markets, such as Seek and LinkedIn, connect workers to traditional employers. Others, such as Uber and Airtasker, connect workers to people and firms who want discrete, time-limited tasks completed. These 'gigs' range from unskilled, in-person services, such as delivering food or cleaning out a spare room, through to skilled tasks, such as software coding or graphic design. In the case of in-person or 'app-based' services (e.g., Uber and Deliveroo), new business models have been facilitated by the ubiquity of smartphones with integrated location, communication and payment capabilities (Moon, 2015).

However, some authors argue that media coverage and academic concern has focused too narrowly on the in-person 'gig economy' at the expense of understanding how a less visible online marketplace is reshaping skill demands (Bernhardt, 2016). In particular, scholars have raised concerns about the growth of 'North-South' markets for skilled tasks, whereby companies in developed countries commission tasks via online platforms to be completed by workers in developing countries (Agrawal *et al*., 2015). In this way, new technologies are facilitating the rise of a truly global labour market, whereby skilled workers compete for tasks irrespective of their location (Beerepoot and Lambgrets, 2015). This, in turn, raises concern about a 'race to the bottom' on labour standards or, as Dunn (2015: 67) put it, 'a global reverse auction for jobs'. These business practices have been enabled by the proliferation of computer and internet access in the developing world, software programs like Skype and Slack, and cloud computing, all of which have made collaborating with people over long distances more viable and productive (Baldwin, 2016; Beerepoot and Lambgrets, 2015).

Taken together, the technologies described here are having—and are likely to continue to have—significant disruptive effects on the job market, workforce, and skill requirements globally over coming decades. While the exponential growth in computer processing power has facilitated other technological innovations, no single development has proved a 'game changer'. Instead, we have argued that the convergence of many and varied technologies has been mutually-reinforcing. We next consider the impacts of these technologies on the quantity of human work available, and how the distribution of that work is changing.

2. Employment effects of new technologies

Recent years have seen an extraordinary burst of interest in the connections between technology, work and the labour market. The appetite for discussion of these issues seems near-inexhaustible at the moment, perhaps owing to the pace of change felt by many, and anxieties that the discourse has generated about where the jobs of the future will come from, whether they will be of decent quality, and whether enough of them will be available. The sheer volume of current discussion around these issues is itself contributing to the impression that momentous changes are underway.

In considering how today's technological developments are likely to impact on future work, two main issues require separate discussion, and these provide a structure for our review:

1. How do technological changes affect the *total quantity* of (human) work available? Will machines become so proficient that humanity can collectively and permanently reduce its workload?
2. How do technological changes affect the *distribution* of the available human work? This is a question about the types of work demanded, rather than its total quantity. Shifts in employment composition are a normal part of economic development, but there are concerns that these shifts may now be occurring in different ways, due to current and emerging technologies. The distributional consequences of technology are linked to concerns about growing inequalities in the labour market, particularly as related to changes in employment levels and earnings by education level or skill.

The changing nature of work has been studied from many different angles, and our review attempts to cover the best evidence from each of these perspectives. Some authors have studied changes in the overall occupational structure of employment or the demands for particular skill sets. Others look at changes in the task composition of particular jobs. Still others study earnings, to see how the labour market is rewarding different types of skills.

There are also important differences in the time period of focus for different studies. Some attempt to explain or interpret past changes. Such historical studies may provide guidance about future developments, even if this was not the original authors' intention. A different branch of the literature attempts more explicitly to predict future trends, by casting forward from the present with projections or forecasts. In general, such 'prospective' studies are less empirically robust than retrospective studies, and must be interpreted cautiously due to the risk of prediction errors. The appeal of prospective studies, however, is that they pick up on the latest technologies and can, within limits, inform thinking about whether their potential effects are likely to be substantially different from those observed in the past.

2.1 - Is 'the end of work' near?

The future of work literature has frequently included contributions prophesying an end to work itself. Titles such as The Jobless Future (Aronowitz and DiFazio, 1994), The End of Work (Rifkin, 1995) and, more recently, Why the Future is Workless (Dunlop, 2016) (among many others) have linked technological advances to the elimination of conventional human work. While the technologies of concern may have changed – from personal computers to robots and, most recently, artificial intelligence – the underlying message has not: we are entering, or are on the cusp of, a radical technological paradigm shift that will bring about an end to work as we have known it. While some authors clearly dread this prospect, others cheer it as an opportunity to remake contemporary economies, and break our dependence on work as a source of income, status, and meaning (e.g., Srnicek and Williams, 2015; Thompson, 2015).

Labour economists have usually been sceptical or dismissive about assertions that the end of work is near. They point out that there is no fixed quantity of work to be done (the 'lump-of-labour fallacy'), and thus automating one job or set of tasks does not lead to a permanent reduction in employment. Instead, the labour market is seen as dynamic: the expectation is that new (and often unforeseeable) jobs are created as old ones disappear.

In a major recent expression of this viewpoint, Autor (2015: 5) noted that debates about automation 'tend to overstate the extent of machine substitution for human labour and ignore the strong complementarities...that increase productivity, raise earnings, and augment demand for labour'. In other words, too much is made of the actual or potential job losses, and too little credit is given for the higher levels of output achieved through automation, and the corresponding new labour demand that is created elsewhere in the economy. The labour market's ability to adjust over the longer term is evident from the continued high level of employment today:

'...two centuries of automation and technological progress have not made human labour obsolete.' (Autor, 2015: 4)

Behind this observation is a cautious scepticism about the future of work. Impressive though they are, today's myriad technological advances may not be more likely than those of yesterday to instigate the end of work.

Part of the challenge in making a balanced assessment of technology's total impact on work is that job *destruction* is more prominent (and thus easier to observe) than job *creation*. The automation of a port or factory, and the consequent retrenchment of workers, is a visible sign of technology's job-destroying potential. But the countervailing effects of these same technologies – both the jobs that are newly created for technicians and engineers, and the flow-on effects from their earnings to additional services that they purchase – are much less readily apparent, and harder to quantify. Indeed, the job-creating effects of technology are sometimes ignored altogether, even in highly-cited analyses (e.g., Frey and Osborne, 2013).

When both sides of the ledger are accounted for, technology's long-term creative effects appear to exceed its destructive effects. Using 144 years of data for England and Wales, economists from Deloitte concluded that technology has been a net creator of jobs, even though the discussion of its effects tends to emphasise the destructive side (Stewart *et al*., 2015). By raising labour productivity, new technologies increase real incomes and, in turn, stimulate demand for new goods and services. Over long periods, these authors argue, this demand-inducing effect of technological change more than offsets the initial job losses, and society as a whole becomes more prosperous. A further benefit is that, by displacing human workers from jobs that are more hazardous to health, such as mining and farm labouring, technology can reduce the costs of work-related injuries and deaths (Stewart *et al*., 2015).

Atkinson and Wu (2017) also refute claims that contemporary technologies are unusually disruptive in their labour market impacts. Using historical United States Census data, they estimate the degree of occupational 'churn' for each decade from the mid-19th century to the present day. Their approach provides evidence of how stable (or volatile) employment growth patterns have been within and between broad occupational categories. Contrary to popular perception, they find that the United States is currently in a period of historically low occupational churn. The rate at which occupations are being created (and destroyed) has been on a downward trend in the United States since at least the 1960s. These authors also show that, since 1995, overall job security has improved: the rate of job loss relative to total employment has been falling (Atkinson and Wu, 2017: 17).

These results represent something of a 'double-edged sword'. On the one hand, current technological developments may not be having an unduly large and destabilising effect on jobs or workers. On the other hand, this low degree of occupational churn may itself be a problem: it implies the slowing of a dynamic that has fuelled previous cycles of economic growth. The study's authors call for a shift in focus:

'Instead of fretting about technology eliminating jobs, we should be worrying about how we are going to raise productivity growth.' (Atkinson and Wu, 2017: 23)

While historical perspectives on technological disruption are mostly reassuring, the notion that today we are approaching a very different sort of future – that 'this time is different' – has taken a hold of much mainstream discussion. The idea was popularised by Ford (2015) in his book, Rise of the Robots, which claimed that a variety of economic developments in the United States, including a persistent fall in the labour force participation rate since the early 2000s, had as their main cause: 'advancing technology – and the resulting automation of routine work' (p.51). By 2013, almost one in five Americans of 'prime age' (25-54 years) was outside the labour force, but population ageing and a severe recession were not fully responsible. Ford (2015) insisted that 'something beyond simple demographics or cyclical economic factors is driving people out' (p.43), and that the most compelling explanation was displacement caused by new information technologies (p.53).

Acemoglu and Restrepo (2017) conducted a more sophisticated econometric analysis along similar lines to the argument of Ford (2015). Their (unpublished) paper looks specifically at how the introduction of industrial robots – rather than automation more broadly – affected employment levels across the United States. For the period 1990 to 2007, these authors find that areas with higher exposure to robots also had lower employment. The estimated effect size is equivalent to 5.6 fewer workers (on average) for each new robot deployed, with the negative impacts being more strongly concentrated in jobs occupied by men (Acemoglu and Restrepo, 2017).

Although these sound like substantial employment losses, other authors emphasise that the aggregate effects of robotics are actually quite small when seen in a wider context. Mishel and Bivens (2017) contend that the effects of robotics implied by Acemoglu and Restrepo's (2017) results were dwarfed by the impacts of increased Chinese import competition, which in their estimation caused four times as many job losses in the United States. Moreover, Acemoglu and Restrepo's (2017) study suggests that technological investments *other than* in robotics are neutral or positive for overall employment. The implication for Mishel and Bivens (2017) is that, while robots may be detrimental to particular workers and locations, intimations about a looming 'robot apocalypse' are overblown and distract attention from more important underlying causes of unemployment and wage stagnation.

The question of whether 'this time is different' is resurfacing again in light of developments in artificial intelligence (AI) (see earlier discussion, in Section 1). Could AI be the technology that finally brings us to the end of work? There have already been two high-profile attempts to answer this question, both instigated in and focused on the United States. A report from the Executive Office of the President recognised that 'AI-driven automation' might be more of a threat to human employment than earlier technologies, since: '[it] has unique features that may allow it to replace substantial amounts of routine cognitive tasks in which humans previously maintained a stark comparative advantage' (The White House, 2016: 20). Further improvements in AI also mean that the spheres of work in which humans maintain a strong advantage are 'likely to erode over time'. However, this report falls well short of predicting an end to work. Government policies and institutions would continue to be pivotal, and:

'...ultimately, AI may develop in the same way as technologies before it...such that the bulk of individuals will be employed as they are today.' (The White House, 2016: 21)

Another report, written by a specialist committee under the auspices of the US National Academies of Sciences, Engineering and Medicine (2017), also stresses the indeterminate nature of AI's eventual impacts on employment. This uncertainty stems from the difficulty of predicting what new jobs and tasks might be created as the mix of technologies in use throughout the economy develops. As the committee noted:

'...it is easier to anticipate how new technologies will automate existing tasks than it is to imagine tasks that do not yet exist and how new technologies may stimulate greater consumer demand.' (National Academies of Sciences, Engineering and Medicine, 2017: 5)

This report does not foresee an imminent end to work, either. There would be continuing changes in workforce composition and skill requirements, as new technologies automate further tasks, but no net reduction in labour demand: 'shifts within and across occupations will likely be much more economically significant than changes in the overall level of employment' (National Academies of Sciences, Engineering and Medicine, 2017: 79). The committee further noted that outcomes for particular workers and for the wider economy depend not only on the technologies developed, but also on the manner of their adoption, with 'complex interactions among technologies, organizations, skills, institutions, markets, culture, and public policies' (National Academies of Sciences, Engineering and Medicine, 2017: 79).

As well as recognising the importance of other factors and policies that act in combination with new technologies, some leading commentators are also beginning to question the extent of 'disruption' that is actually occurring. An interesting alternative to the accepted wisdom is emerging to suggest that the current pace of technological change is, if anything, too slow. This argument hinges on evidence of mediocre recent productivity growth in the United States – a trend that is also evident in Australia.

Research from the Economic Policy Institute shows that the rates of average annual growth in labour productivity (and capital investment) are lower in the United States today than they have been for several decades (Mishel and Bivens, 2017). Similarly, but from within the highest levels of government, the former Chairman of the US Council of Economic Advisors said of artificial intelligence: '[My] biggest worry is that we will not have enough of it... we need to do more to make sure we can continue to make ground-breaking discoveries that will raise productivity growth' (Furman, 2016: 14).

Such sentiments recall the paradox attributed to Nobel laureate, Robert Solow (1987), three decades ago: 'You can see the computer age everywhere but in the productivity statistics'. Arguably, little has changed in the intervening years of technological progress. Thompson (2017) wrote: 'The US economy currently suffers not from too much automation, but rather from too little investment in the sort of technology that would raise the country's lacklustre productivity'. Similar arguments are made, even more stridently, by others (e.g., Weldon, 2017; Yglesias, 2015). What seems to unite all of these perspectives, regardless of how they view the current pace of technological progress, is an acceptance that human work in some form will remain a central feature of the economic and social order for the foreseeable future.

2.2 - Changes in the distribution of work

If we are not on the verge of an end to work itself, there is still the question of whether new technologies are altering the distribution of work, and threatening obsolescence for certain jobs or workers.

Among academic economists, it is now widely accepted that the labour market has become more 'polarised' in recent years, and that technological change has contributed to this process. As shown below and in the next section, this polarisation of outcomes is more pronounced in some countries than in others, but has been documented for most developed economies.

The idea of 'polarisation' implies a widening disparity in outcomes concentrated at the ends of a spectrum. In the case of the labour market, there have been gains for workers at both the upper and lower ends of the skills and earnings distributions, at the expense of workers located in the middle. The evidence of this change is most detailed in the United States but continues to emerge for other OECD countries. (We review Australian studies in Section 3.)

For the United States in the years from 1979 to 2012, Autor (2015) shows that employment levels generally grew in high-skill/wage occupations (e.g., technicians and professionals), as well as in low-skill/wage service occupations (e.g., personal care and cleaning), but declined in middle-skill/wage occupations (e.g., production workers and labourers) – consistent with the polarisation narrative.

Figure 1 depicts these trends for part of the same period (1980-2005), using the same three employment groups (high/middle/low) and data from the US Census reported by Autor and Dorn (2013). The graph shows how the share in total employment (based on hours worked) has evolved for the three broad skill groups since 1980, just prior to the largescale adoption of personal computers that initiated the previous wave of workplace technological change. Polarisation is clearly evident, with a redistribution of employment away from the middle-skill category, and toward the low and high categories (the latter, in particular). From 1980 to 2005, the share of total US employment in middle occupations shrank from 59 to 46 per cent. In terms of employment volumes, most of the offsetting gains went to the high-skill category, which expanded by 9 percentage points, to 41 per cent of employment by 2005. The low-skill category increased its share by less (3 percentage points, to 13 per cent) but grew at essentially the same rate as the high-skill category, given its smaller starting size.[3]

Goos and Manning (2007) document a similar tendency toward 'lousy and lovely' jobs, over the two decades from 1979 to 1999 in the United Kingdom. Like in the United States, there were increases in the shares of employment at the top and bottom of the wage distribution and declines in the middle. The strongest gains were made by workers at the top end of the distribution over this time, including in several highly-paid information technology jobs such as software engineers, data processing managers, and computer analysts and programmers (Goos and Manning, 2007: 124).

A major comparative study also confirms the broad picture of job polarisation in Western European countries from 1993 to 2010 (Goos *et al*., 2014). Across the 16 countries studied, employment shares grew by 5.6 and 3.7 percentage points, respectively, in high- and low-paying occupations, and fell by (the corresponding) 9.3 percentage points in middle-paying occupations. Almost without exception, polarisation had occurred separately in each of the 16 countries (Goos *et al*., 2014: 2515).[4]

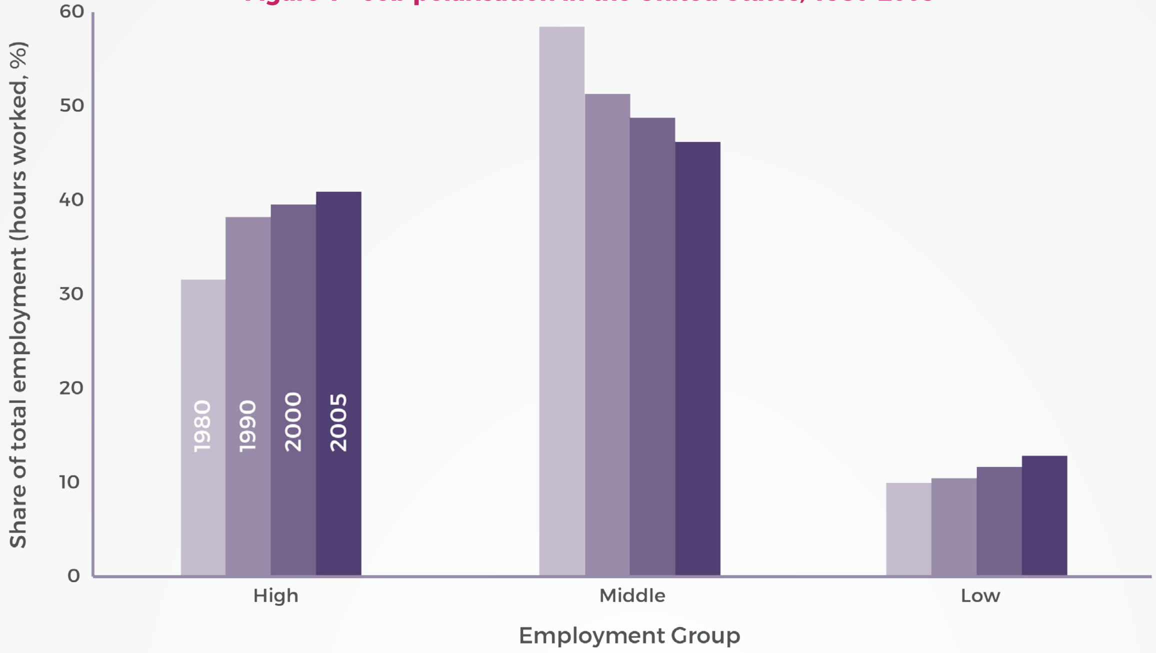
Most recently, the OECD's (2017) *Employment Outlook* shows that employment polarisation has been occurring in most developed economies, to varying degrees, including Australia. Figure 2 shows OECD data on the extent of polarisation by region in the OECD group of countries. Polarisation is widespread, but particularly marked in much of Europe compared with North America and Japan. Polarisation is also evident across industries, as shown in Figure 3. The process is most advanced in manufacturing sectors where, historically, secure and well-paid employment was available for workers with low-to mid-level technical skills.

Technological changes, particularly automation enabled by improvements in computer and information technologies, are frequently implicated as causes of employment polarisation. These explanations rely on a distinction between skills

[3] The change in total share for the high-skill category, from 31.6% in 1980 to 40.9% in 2005, corresponds to a 29% growth rate. The change in share for the low-skill category (9.9% to 12.9%) equates to a 30% growth rate.

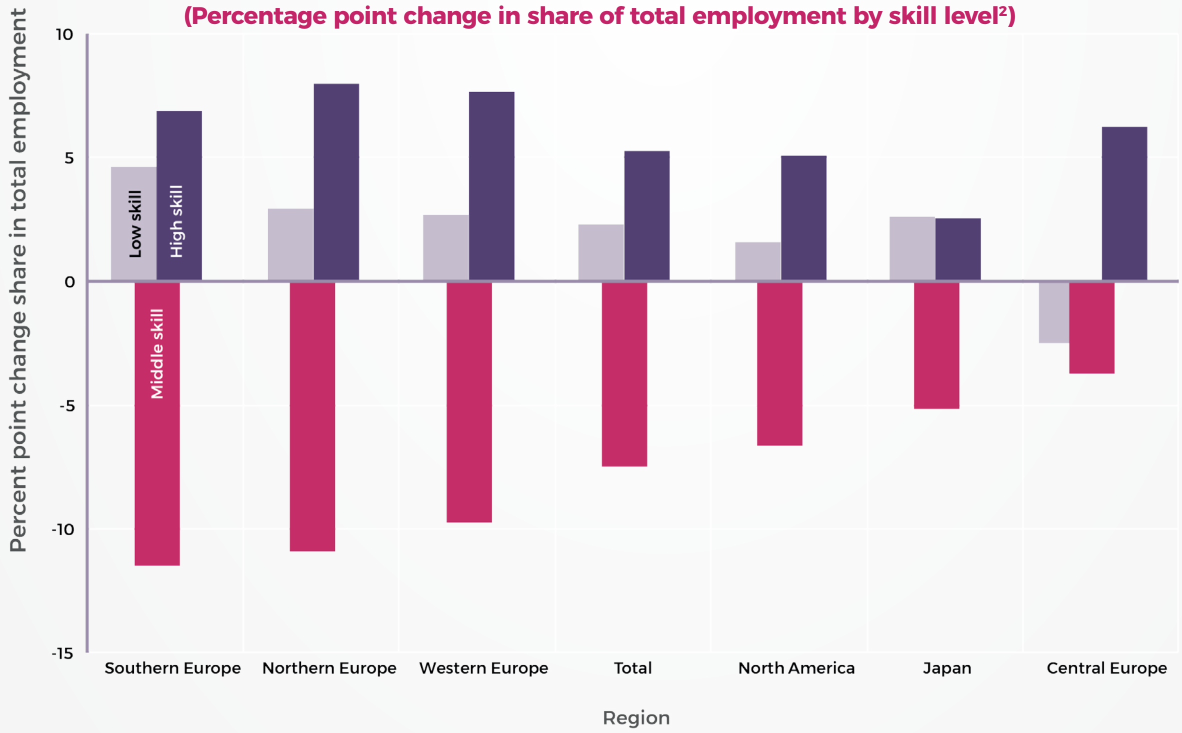
[4] The exceptions were small reductions in the shares of low-paying occupations in Finland and Luxembourg.

Figure 1 - Job polarisation in the United States, 1980-2005



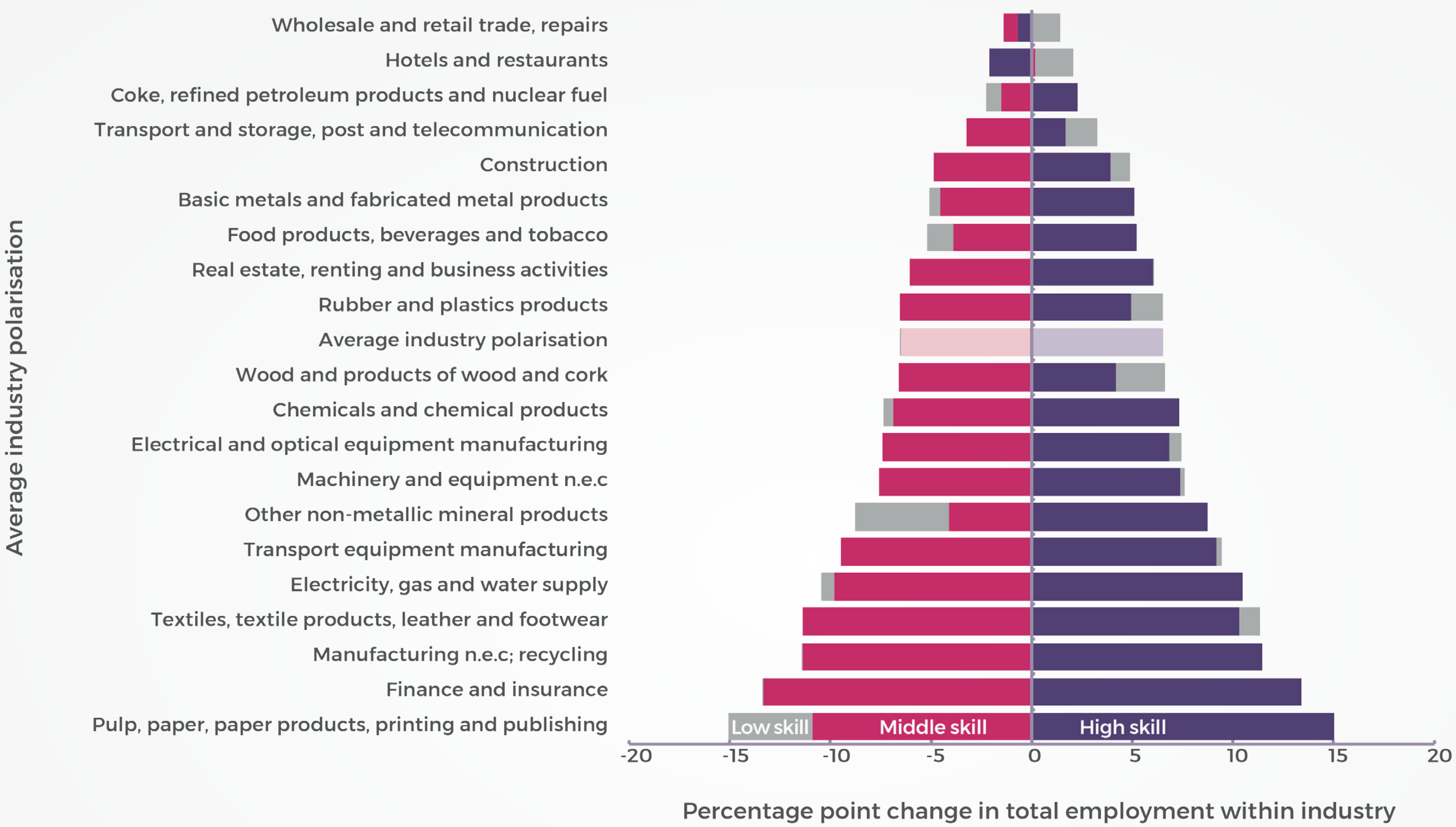
Source: Adapted from Autor and Dorn (2013, p.1556).
Notes:
1. 'High': Managers/professionals/technicians/finance/public safety;
2. 'Middle': Production/craft, transportation/construction/mechanics/mining/farm, machine operators/assemblers, clerical/retail sales;
3. 'Low': Service occupations.

Figure 2 - Job Polarisation in OECD selected countries, by region,[1] 1995-2015
(Percentage point change in share of total employment by skill level[2])



Source: OECD (2017) *Employment Outlook 2017*, OECD, Paris.
Notes:
1. Southern Europe includes: Spain, Greece, Italy and Portugal; Western Europe includes: Austria, Belgium, Germany, France, Ireland, the Netherlands, Switzerland and the United Kingdom; Central Europe includes the Czech Republic, Hungary, the Slovak Republic, and Slovenia; Northern Europe includes: Denmark, Finland, Norway, and Sweden; and North America includes Canada and the United States.
2. High-skill occupations include jobs classified under the ISCO-88 major groups 1 (legislators, senior officials, and managers), 2 (professionals), and 3 (technicians and associate professionals). Middle-skill occupations include jobs classified under the ISCO-88 major groups 4 (clerks), 7 (craft and related trades workers), and 8 (plant and machine operators and assemblers). Low-skill occupations include jobs classified under the ISCO-88 major groups 5 (service workers and shop and market sales workers), and 9 (elementary occupations).

Figure 3 - Job Polarisation Within Industries,[1] selected OECD countries,[2] 1995-2015



Source: OECD (2017) *Employment Outlook 2017*, OECD, Paris.

Notes:

1. The figure depicts changes in the share of low, middle- and high-skill jobs (by two-digit ISIC Rev.3 classification) within each industry across selected OECD countries. The results are obtained by pooling together employment in each industry across all the countries analysed. The average industry polarisation is a simple unweighted average of changes in the shares of low-, middle-, and high-skill jobs across industries.
2. The countries included in this chart are: Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, the United Kingdom and the United States.

and tasks that are either 'routine' (and thus readily substituted by computers) or 'non-routine' (and thus non-substitutable). This distinction relies on an understanding that computers are better suited to following a set of specific, pre-programmed (or at least identifiable) steps than they are at adapting to unpredictable events.

An important facet of the 'routinisation' hypothesis is its relevance to a broad spectrum of occupations. Many low-paid and conventionally 'unskilled' occupations nonetheless entail substantial non-routine elements, which complicates predictions about their susceptibility to automation. The routine/non-routine distinction allows a more nuanced understanding of jobs and skill requirements than a focus on earnings alone. The routinisation hypothesis also calls attention to 'tasks' as the building blocks of 'jobs'. In this framework, a job can be thought of as a series of discrete tasks, which are more or less routine, and hence more or less automatable. What determines the susceptibility of a particular job to automation is the ease with which its core tasks could be taken apart *in practice* (whether this is socially and industrially permissible) or, alternatively, whether these tasks are best kept 'bundled' into a coherent job.

There is ample evidence that routine tasks and jobs are declining in relative importance – a development consistent with predictions about 'routine-biased technological change'. An analysis for the United States by the Federal Reserve Bank of St Louis (Dvorkin, 2016) shows stark differences in employment growth patterns according to whether a job is classified as predominantly routine or non-routine. From 1983 to 2013, total employment in non-routine jobs roughly doubled. Importantly, this trend applied to all non-routine jobs, irrespective of where they were located on the wage distribution. Employment increased substantially for both 'cognitive' (mostly higher-paid) and 'manual' (mostly lower-paid) non-routine jobs. In contrast, employment levels were essentially flat over this thirty-year period for all routine jobs. The combination of these trends meant a substantial shift in employment shares away from routine and toward non-routine jobs in the United States workforce over recent years.

An Australian analysis undertaken by the Reserve Bank of Australia (RBA) produced similar results (Heath, 2016). Their approach involves a simple reclassification[5] of Australia's eight major occupations into four categories, based on their underlying skill content, as follows:

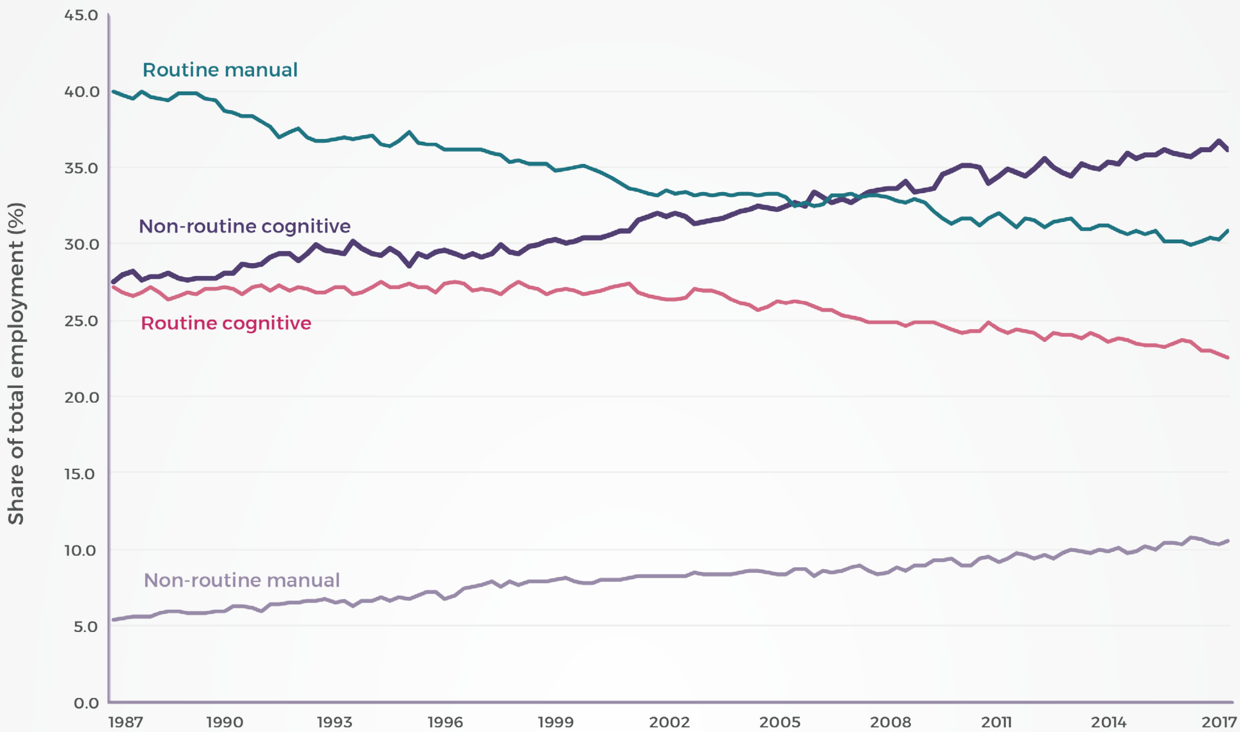
1. *Non-routine, cognitive: Managers, Professionals*
2. *Non-routine, manual: Community and Personal Service Workers*
3. *Routine, cognitive: Clerical and Administrative Workers, Sales Workers*
4. *Routine, manual*: Technicians and Trades Workers, Machine Operators and Drivers, Labourers

By applying this schematic to ABS Labour Force Survey data, the RBA analysis estimates how the shares of total Australian employment in the above four skill categories have changed over the past 30 years. Figure 4 reproduces the RBA analysis. The shift away from routine employment and towards non-routine employment is clearly shown. Routine jobs of both types (cognitive and manual) have been in decline, whereas non-routine jobs of both types have been expanding. The largest gains have been for non-routine, cognitive jobs while the largest losses have been for routine, manual jobs. Over the whole period shown in Figure 4, the share of Australian employment in non-routine occupations increased from 33 per cent to 47 per cent. The RBA suggested that 'the Australian workforce may have a comparative advantage in many occupations in the non-routine category because of our relatively high education levels' (Heath, 2016: 3).

Whether or not this process of 'routine-biased' employment change has been *mainly* driven by technological developments remains a subject of debate. One of the leading adherents of the routinisation hypothesis notes that there are

[5] Correspondence with the RBA indicates that the analysis can be refined by using more detailed occupational classifications (e.g., sub-major group, minor group, or unit analyses). Doing so results in some minor changes to the shares of employment in each of the four derived categories, but does not alter the broad conclusions of the analysis.

Figure 4 - Change in share of total Australian employment, by skill type, 1987-2017



Sources: Reproduced from Reserve Bank of Australia analysis (Health, 2016) using latest data in ABS (2017c).
Notes:
1. Definitions of the four skill categories are provided in text.
2. Assignment to each category is based on the occupation of main job for employed persons.

complex interactions between technology and other business factors that 'make it both conceptually and empirically difficult to isolate the "pure" effect of any one factor' (Autor, 2015: 22). Baldwin (2016) makes a similar point, noting that advanced information and communication technologies have made it possible (and cost-effective) for firms headquartered in developed countries to outsource more parts of their production to low-wage developing countries. While this outsourcing certainly hurts many workers in developed countries, it is difficult to regard as wholly a 'technology effect'.

Despite the continuing controversy over technology's role in job polarisation, there is some emerging evidence of its primacy. In the same paper cited earlier, Goos *et al.* (2014) sought to measure the relative importance of technological changes and offshoring as drivers of job polarisation in Western Europe since the early 1990s. Their evidence suggests that 'routine-biased technological changes were much more important than offshoring' in explaining the hollowing-out of middle-skill employment opportunities across much of Europe (Goos *et al.*, 2014: 2510). Other studies using different approaches and sets of countries come to similar conclusions about the contributions of technological changes and offshoring to polarisation (Michaels *et al.*, 2014). This still-developing body of research supports a view of technology as one of the major factors affecting the distribution of employment. However, clearly there are some major puzzles yet to be resolved here, given the contention of Mishel and Bivens (2017) noted earlier that import competition from China has done significantly more harm to US workers than the adoption of robotics.

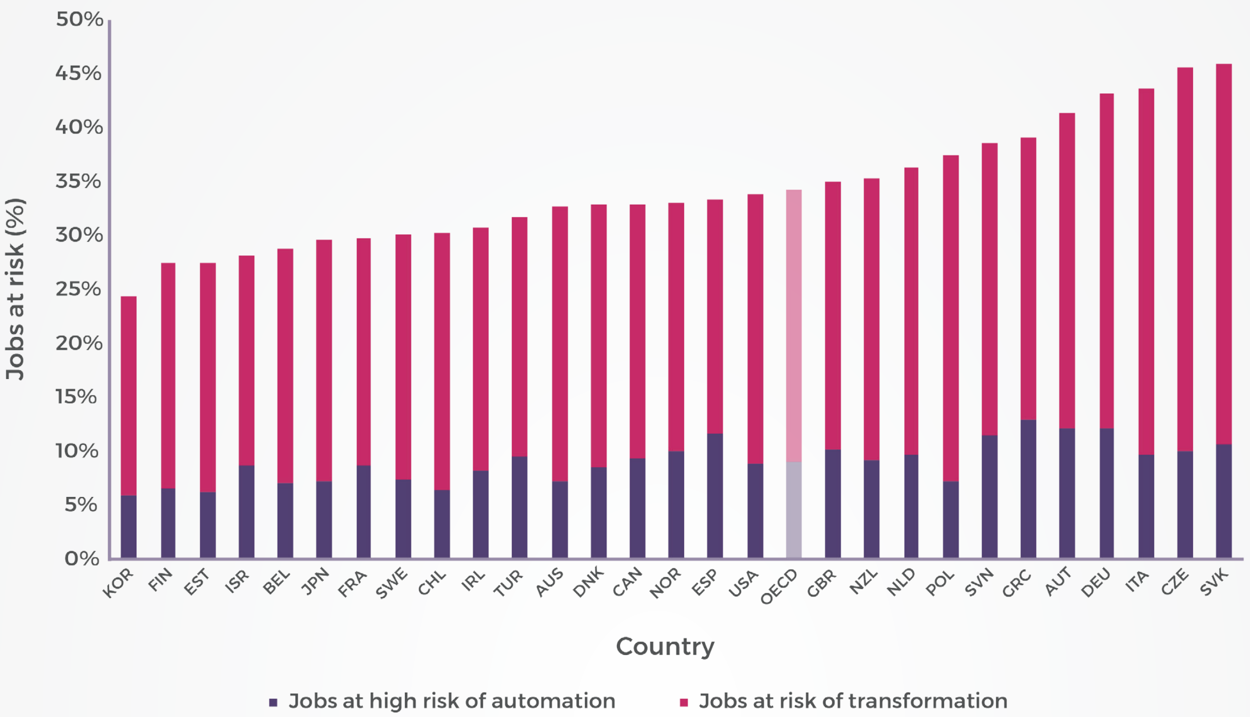
An obvious next question is whether today's emerging technologies will prolong or intensify earlier trends. Do the coming decades of technological change portend further polarisation and, if so, who will be the 'winners and losers' of this process?

By far the best-known and most widely-cited study of this kind is an unpublished paper by two University of Oxford academics (Frey and Osborne, 2013). Using data from the United States (rather than Britain), these authors calculate the 'probability of computerisation' for 702 detailed occupations, based on their inherent task content and expectations about how likely computers are to be able to do those tasks in a (vaguely-defined) foreseeable future – 'perhaps over the next decade or two' (Frey and Osborne, 2013: 44). The authors provide a probability of computerisation and a rank (out of 702) for each occupation. This probability ranges from near-zero (e.g., for therapists, surgeons and primary teachers) to near-certainty (e.g., for telemarketers and order clerks). Summing across occupations, the authors contend that 'around 47 percent of total US employment is in the high-risk category' – meaning their assessed probability of computerisation is greater than (the arbitrarily selected threshold of) 0.7 (Frey and Osborne, 2013: 38). While this conclusion has been widely repeated and relied on, the authors are clear about their own study's limitations, underlining that they 'make no attempt to estimate how many jobs will actually be automated', and stressing that a host of other factors will influence how quickly substitution of human workers by computers occurs in reality, including 'regulatory concerns and political activism' and 'engineering bottlenecks' (Frey and Osborne, 2013: 42-43).

The substantive finding of the Oxford paper – that nearly half of all US employment is at risk from computerisation – has also come under considerable challenge from later research. A study from the Organisation for Economic Cooperation and Development (Arntz *et al.*, 2016) uses data for 21 developed countries and finds a much lower risk of automation. On average across these countries, Arntz *et al*. (2016) estimate that just 9 per cent of all jobs (instead of 47 per cent) are likely to be at risk of automation over the timeframe suggested by Frey and Osborne (2013). There is little variation around this average on a country-by-country basis, with a maximum probability of 12 per cent (in Austria, Germany and Spain) and with most of the 21 countries having less than 1 in 10 of their overall workforces susceptible to imminent automation. The large disparity in the overall probabilities estimated by these two studies is a result of differences in assumptions about how the scope for automation of certain *tasks* translates into the displacement of whole *occupations*. While Frey and Osborne (2013) treat an occupation as 'at risk' if most of its inherent tasks could potentially be done by machines, Arntz *et al*. (2016: 8) argue that this overstates the immediate threat of displacement: 'most occupations contain tasks that are difficult to substitute at least in the foreseeable future'.

This returns us to a point introduced earlier, and discussed at length by Autor (2015), about occupations as 'bundles' of tasks. The organisation of discrete functions into coherent jobs recognises that certain tasks are complementary and related. Enabling one or more of these tasks to be automated does not necessarily mean that the entire job is under threat or likely to disappear. Instead, the more likely outcome is a *transformation* in job requirements, and a shift in workers' focus from older tasks to new ones. This potential for job redesign leaves some doubt about the high automation probabilities estimated by Frey and Osborne (2013) and others who use their method. There are confounding factors in the operation of labour markets and firms that their approach oversimplifies or ignores.

Figure 5 - Proportion of jobs at risk of automation and transformation,[1] selected OECD countries,[2] 2015.



Source: OECD (2017) *Employment Outlook 2017*, OECD, Paris.
Notes:

1. Jobs are at high risk of automation if the likelihood of their job being automated is at least 70%. Jobs at risk of transformation are those with the likelihood of their job being automated estimated at between 50 and 70%.
2. Country codes: Korea (KOR), Finland (FIN), Israel (ISR), Estonia (EST), Belgium (BEL), Japan (JPN), France (FRA), Sweden (SWE), Chile (CHL), Ireland (IRL), Turkey (TUR), Australia (AUS), Denmark (DNK), Canada (CAN), Norway (NOR), Spain (ESP), United States (USA), Great Britain (GBR), New Zealand (NZL), Netherlands (NLD), Poland (POL), Slovenia (SVN), Greece (GRC), Austria (AUT), Germany (DEU), Italy (ITA), Czech Republic (CZE), Slovak Republic (SVK).

The OECD study by Arntz *et al*. (2016) estimates that a significant proportion of employees are in jobs that will be *transformed* – rather than *destroyed* – by impending technological changes. For the United States, they estimate that 25 per cent of workers are currently in jobs at risk of transformation, compared with a much smaller figure (9 per cent) whose jobs are at risk of being automated entirely. Their analysis includes Australia (see Figure 5), for which the prospects of job transformation similarly exceed the threats of job destruction. In all countries, this job transformation process appears to be an under-recognised feature of technology's impact on the future of work.

3. The Australian context

Many of the emerging technologies described in Section 1 are essentially ubiquitous. Their disruptive effects are not confined by national borders or regulations, and indeed some of these technologies are facilitating more open borders. Labour markets are thus becoming more globally connected. Yet, at the same time, country-specific differences – including in population and workforce composition, labour market structures, and other institutions – continue to influence how (and how quickly) technological shifts are felt within particular locations.

This section examines the Australian context. It aims to establish how similar or different Australian trends have been to those documented in the previous sections for other major developed nations. We look at how the current technological paradigm shift is playing out for Australian workers, jobs and skill requirements. We highlight some distinctive Australian developments that do not seem to correspond with the patterns occurring elsewhere, and comment on why these differences may exist.

3.1 - Work endures in Australia, too

Human work, in one form or another, does not seem to have become any less important in the fabric of Australian economic life. Borland (2016a) calculates that, on a *per capita* basis, aggregate hours worked are similar today to what they were in the mid-1960s.[6] There have been variations due to the business cycle, but no long-term reduction that could be seen as the result of earlier technological changes. Notably, the introduction of personal computers to Australian workplaces in the 1990s coincided with a prolonged *increase* in working hours.

Still, Australian commentary has its share of contemporary 'end of work' prognostications. The most dramatic is a recent study published as part of a larger report by the Committee for the Economic Development of Australia (CEDA). Applying the methodology of Frey and Osborne (2013) to Australian data, this study estimates that around 40 per cent of today's jobs have a high probability of being automated in the next 10 to 15 years (Durrant-Whyte *et al*., 2015). However, by replicating the Oxford methodology and its inherent limitations, this Australian study opens itself to the same critiques discussed above. Most importantly, the estimate of a 40 per cent job reduction is not balanced by estimates of the future job growth prospects. As such, this study provides no information about the jobs that might emerge to replace the ones that are automated, or indeed how the task content of jobs might change to accommodate new technologies.

In another prominent Australian contribution, Dunlop (2016) also warns about the threat of widespread technological job destruction and the importance of adjusting public policy now to cope with its consequences. He argues that Australians should embrace new technology, but guard against its excesses and 'externalities', in part by debating the merits of radically different labour market and social-welfare policies, including ideas such as a universal basic income or portable learning accounts that support workers to gain bridging education at the point of transition between jobs and firms. Dunlop (2016) warns that, unless we build a new 'social contract' that is suited to the emerging technological paradigm, we will face the costs and damage to living standards of mass unemployment and extreme wealth concentration.

While the broad thrust of his prognosis holds, Dunlop's work might be criticised as largely taking at face value the international estimates as a good indicator of what is in store for Australia. Moreover, it is not clear whether his general prescriptive analysis

[6] This is mostly a result of increases in labour force participation over time. In a related article, Borland (2016b) shows that average hours *per worker* have fallen by about 14 per cent since the mid-1960s. But this has been more than offset by a 25 per cent increase in the labour force participation rate over the same time. The joint effect of these two forces is small net rise in aggregate hours worked *per capita*, the measure referred to here.

provides a sufficiently detailed 'road map' for how best to respond to these *global* challenges in a way that reflects the *domestic* economic and policy context that Australian policy makers and social actors face.

Our assessment, informed by the cross-national OECD analysis discussed earlier (Arntz *et al*., 2016), is that estimates such as those in Frey and Osborne (2013) represent an upper limit to the immediate change we are likely to observe. Once the likelihood of job transformation is taken into account – recognising that many jobs are likely to be impacted by automation, but not destroyed – the threat of automation-induced job losses is more subdued. While we do not doubt that a substantial proportion of Australian jobs and workers will be affected to some extent by impending technological changes, for most the impact will be different from and less dramatic than the elimination of their entire job and livelihood. We anticipate that many more will have to adjust to and cope with some shift in task responsibility and focus as machines become more proficient and cost-effective at certain tasks that humans do today.

Perhaps the best overarching advice is that we should try to imagine a very different kind of working world, without catastrophizing or presuming that 'worst-case' scenarios are inevitable. Finkel (2015) reminds us that, despite the extraordinary rate of technological change (and the comparatively slow pace of policy change), pessimistic visions of mass technological unemployment have been wrong time and time again. This view remains consistent with the Australian and international evidence, with national economies having by and large continued to generate sufficient (net) employment consistent with maintaining low levels of unemployment.

3.2 - The changing distribution of work in Australia

While the Australian evidence does not support claims about work disappearing, interesting changes have been occurring in how the work is distributed. There are changes in terms of who works, what is done, and how that work is rewarded. We attempt here to summarise the major changes, showing where possible how Australia compares, either to the US or to the group of developed economies in the OECD.

3.2.1 - The supply side: Who wants to work?

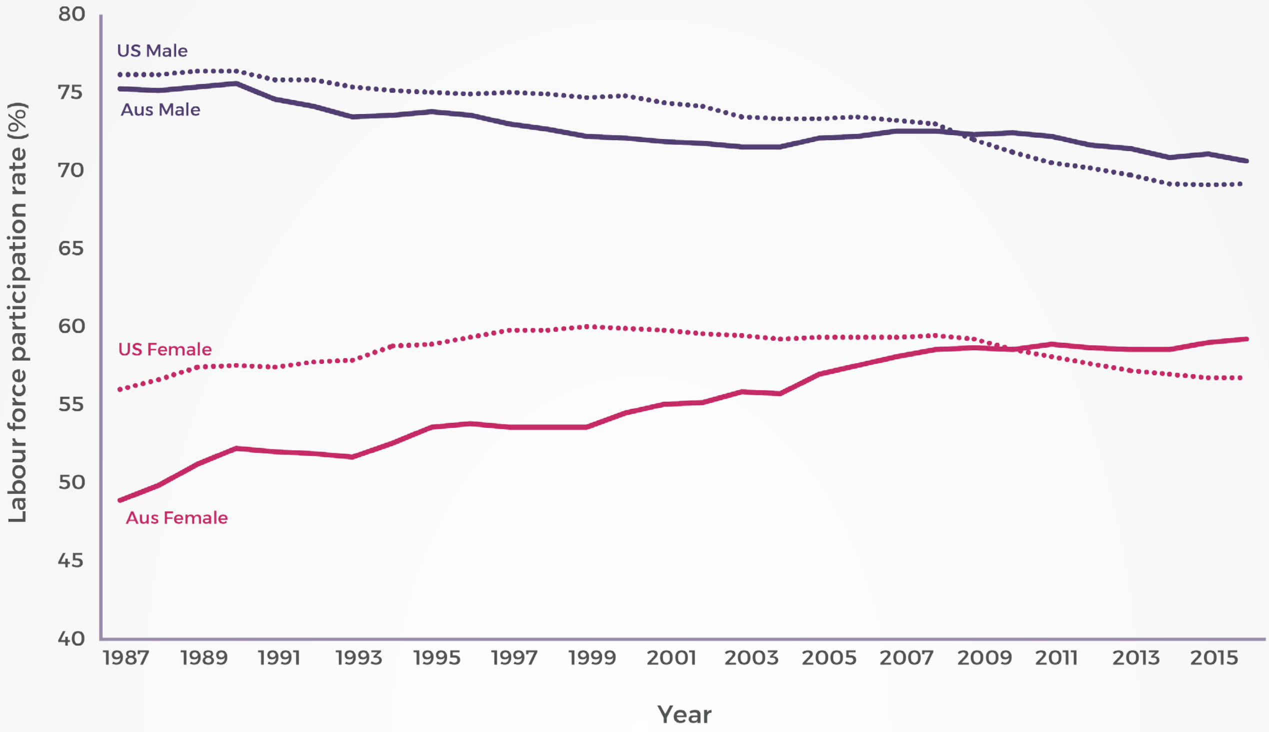
Work has enduring importance for well-being, but access to work is not evenly shared. Measures of how different population groups are participating in (or being excluded from) the workforce – and how these patterns may be changing – provide an indication of how technological changes and other forces are affecting economic opportunity.

The first question is whether the labour market is changing in ways that make accessing work more challenging for certain groups. In the US, Ford (2015) and others have called attention to a steep decline in the labour force participation rate (the percentage of the population employed or actively looking for work), as *prima facie* evidence that technology is reducing the overall demand for labour. Although it is difficult to be definitive about the causal connection made by Ford, other research in a similar vein has noted that this decline in participation is especially concentrated on men (in the US), suggesting that it may be related to the structure of industry and the increasing capacity of machine technologies to automate blue-collar jobs that were male-dominated (e.g., Autor and Wasserman, 2013).

To what extent has Australia followed the US trend of declining labour force participation? Figure 6 presents comparative data for both countries over the last 30 years, with men and women shown separately.

There are noticeable differences between the Australian and US experiences. For men, the fall in participation is especially pronounced in the US, and appears to accelerate after the Global Financial Crisis. Since 2013, the participation rate of US men has been below 70 per cent; in other words, three out of ten American men are outside the labour force today. The participation rate has also declined, but more gradually, for Australian men over this

Figure 6 - Labour force participation rate, by sex, Australia and the US, 1987-2016



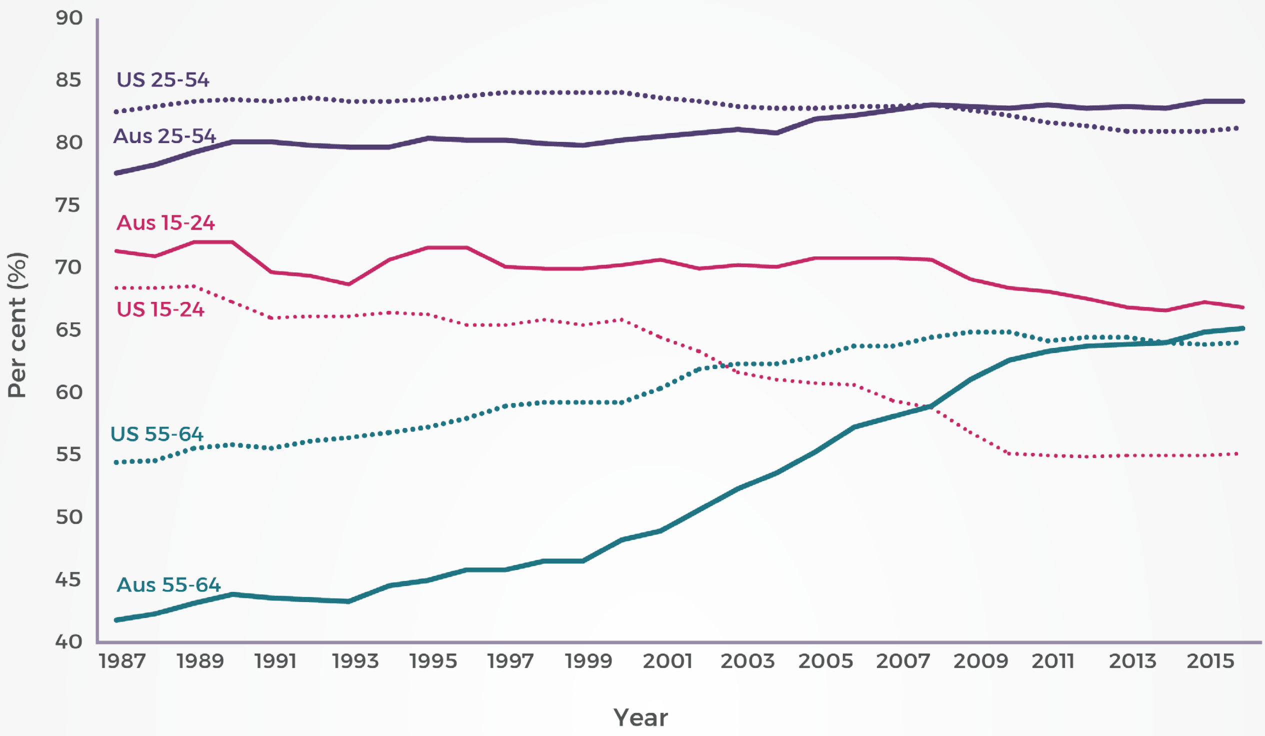
Source: OECD.Stat (2017b).
Notes:
1. Figures shown are labour force participation rates (the civilian labour force as a percentage of the civilian resident population) for persons aged 15 years and over.
2. The group of OECD countries has changed over time, but OECD.Stat advises that: 'In order to facilitate analysis and comparisons over time, historical data for OECD members have been provided over as long a period as possible, often even before a country became a member of the Organisation'.

period (by 4.7 percentage points, to 70.6 per cent in 2016). To illustrate the difference, if Australian men had the participation rate of their US counterparts, there would be 130,000 fewer men in Australia's labour force today (assuming a constant population size). Further challenges lie ahead for men in both countries, if some of the forecast impacts of robotic technologies on male-dominated areas of work eventuate (Kaplan, 2015).

The differences for women are even more striking between the two countries, with Australia again comparing favourably. Rising female participation rates in the US plateaued in the mid-1990s and then began to fall in the GFC. By comparison, in Australia women have continued to enter the labour force in large numbers and their participation rate is now at a historical high (59.2 per cent in 2016).

Of course, labour force participation rates are also changing with respect to characteristics other than gender. Among the most important is age, with longer life expectancy and better healthcare leading to new opportunities for older work engagement

Figure 7 - Labour force participation rate, by age group, Australia and the US, 1987-2016



Source: OECD.Stat (2017b).
Notes:
1. Figures shown are labour force participation rates (the civilian labour force as a percentage of the civilian resident population) for persons in each of the three age groups.
2. The group of OECD countries has changed over time, but OECD.Stat advises that: 'In order to facilitate analysis and comparisons over time, historical data for OECD members have been provided over as long a period as possible, often even before a country became a member of the Organisation'.

(Gahan *et al*., 2016). In contrast, younger jobseekers face more difficult transitions into the labour force, with rising expectations relating to qualifications and work experience, and the fracturing of traditional career-entry pathways (Healy, 2015, 2016; Susskind and Susskind, 2015).

The legacies of these developments are seen in Figure 7, which shows the past 30 years of labour force participation rates by age in Australia and the US. Three broad age groups are chosen to illustrate the changes: younger (15-24 years), prime-age (25-54 years), and older (55-64 years).

The largest changes have occurred at younger and older ends of the age-participation spectrum. The participation rate of older Australians rose by more than 20 percentage points in the past 30 years, with most of the increase happening since the turn of the century. In 2014, the participation rate of older Australians overtook the comparable US rate for the first time, and has since continued to climb (to 65.2 per cent in 2016).

In contrast, participation rates have been retreating for the young. In the US, this decline began earlier and has been steeper than in Australia, although the

US losses appear to have stabilised in recent years. In Australia today, participation rates are very similar for younger and older people. In part, this reflects a preference – or, perhaps, the necessity – for young people to spend time acquiring formal qualifications in order to compete in an increasingly challenging job market. We discuss in the next section how employment opportunities have shifted with respect to educational attainment.

Overall, what emerges from these comparisons is that for the past three decades Australia's labour market has generally outperformed the US. Where there were gains, Australia's have been larger; where there were losses, Australia's have been less severe. These comparisons suggest that the trajectory of Australian developments cannot be assumed to reliably follow the US path. For now, Australia seems to be weathering the effects of technological changes on labour supply better than the US – and is better placed to withstand further disruption, if and when it arrives.

3.2.2 - The demand side: What work is required?

The leading narrative about how technological changes influence employment outcomes is the 'polarisation' hypothesis discussed earlier. This posits a distinction between two main classes of tasks (routine/non-routine), which have different susceptibilities to displacement. The theory appears to be well supported by US empirical evidence showing a 'hollowing out' of the occupational structure in recent decades: employment growth has occurred for jobs that are non-routine, accompanied by a declining share of routine jobs (Levy and Murnane, 2013).

Australian evidence on the occupational and skills composition of employment over recent decades has produced somewhat more mixed results – which Wooden (2001) attributes largely to methodological issues. Nonetheless, the most recent of these studies suggests that our workforce has also been 'hollowed out' in a pattern similar to that experienced in other industrialised economies, albeit in a less pronounced fashion, and with the growth in employment tilted more toward high-skill jobs (Borland and Coelli, 2015).[7]

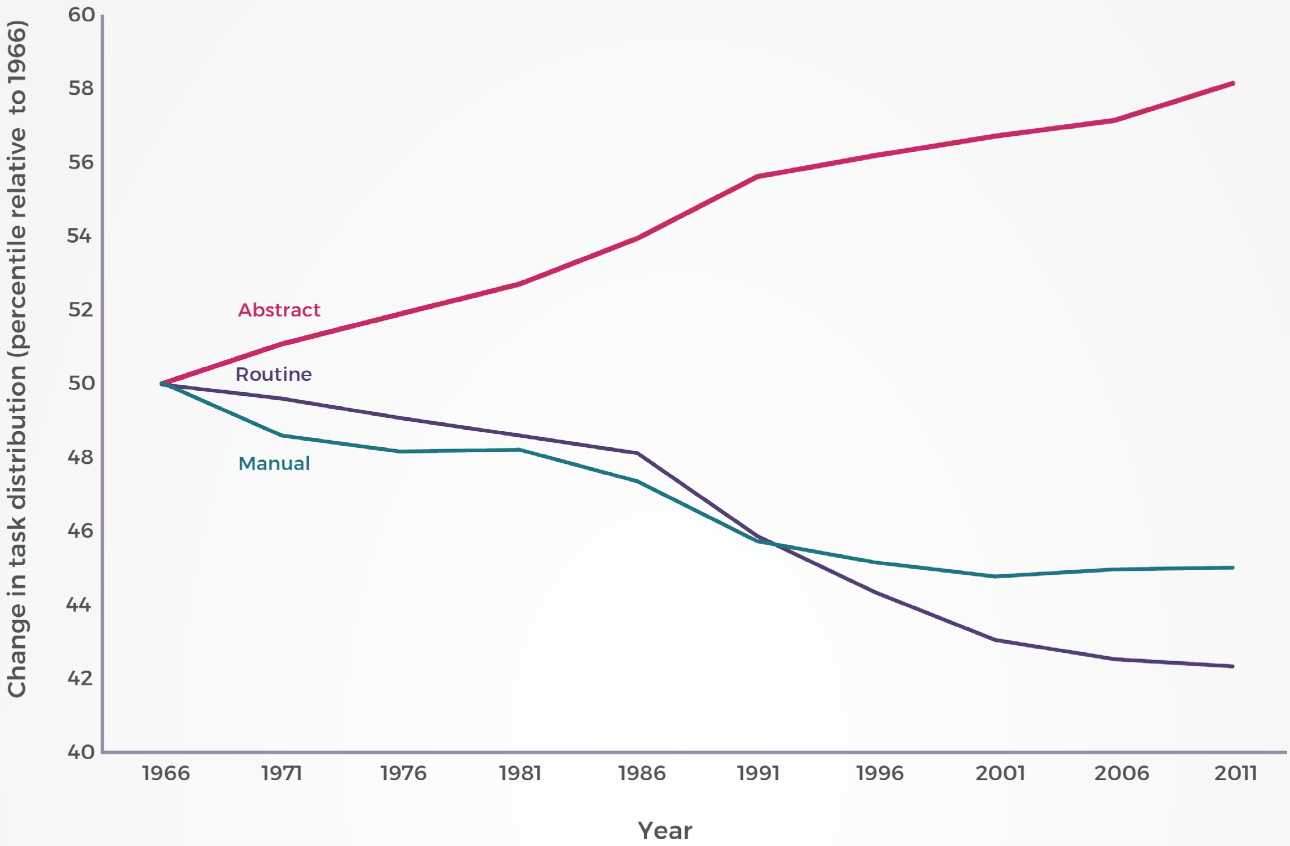
The composition of the Australian workforce has also shifted decisively away from routine jobs and towards non-routine jobs, especially non-routine, cognitive jobs – as documented in the analysis by Heath (2016) reproduced earlier, in Figure 4.

Another important Australian analysis of these developments has been published recently by Coelli and Borland (2016). For reasons of consistency and comparability, these authors match the Australian workforce structure to the detailed descriptions of skills required in different occupations from the comprehensive US Dictionary of Occupational Titles (DOT). This approach allows occupations to be ranked on the extent to which each requires three sets of tasks: *abstract* (analytical reasoning and interactive tasks); *routine* (manipulative or mental tasks undertaken within set limits or standards); and *manual* (unstructured physical tasks requiring bodily coordination). These three broad task categories are compatible with the four categories delineated by Heath (2016): with 'abstract' tasks matching non-routine, cognitive tasks; 'routine' tasks covering both manual and cognitive forms of this work; and 'manual' tasks standing for Heath's (2016) non-routine, manual category of occupations.

Coelli and Borland (2016) then trace changes in the relative importance of their three task categories in the Australian workforce, using Census figures on employment by occupation dating back to 1966. They interpret changes in the occupational structure towards or away from particular task specialities as evidence of the changes in underlying labour demand for those tasks. Figure 8 reproduces the key graph from Coelli and Borland's (2016) study, using their own estimates. It shows the trajectories of change in the measures of abstract, routine and manual task intensity, beginning from a common

[7] In companion studies for Australia, Borland and Coelli note that the polarisation hypothesis does not assume symmetrical growth at both ends of the skills distribution. In most countries, the pattern has the appearance of a J-curve rather than a U-shaped curve, reflecting the tendency for net job growth in low-skilled occupations to be muted by comparison with high-skilled occupations (Borland and Coelli, 2015; Coelli and Borland, 2016).

Figure 8 - Changes in measures of occupational task content, Australia, 1966-2011



Source: Reproduced from Coelli and Borland (2016: 14). The authors made their data available for download as 'supporting information' to their published article (dx.doi.org/10.1111/1475-4932.12225).

Notes:

1. Definitions of the three task categories are provided in text.
2. The data in this graph was calculated in the following way:
   Each 4-digit occupation was given a percentile ranking (from 1=lowest to 100=highest) for abstract, routine and manual. An average percentile score for each task measure was then determined from the occupational structure of employment in 1966. These were all set to 50. Following this, the average percentile scores were calculated for each Census year relative to 1966. An increase from 50 implies that the employment structure has shifted towards occupations requiring above average level of the task, a decrease means that it has shifted away.

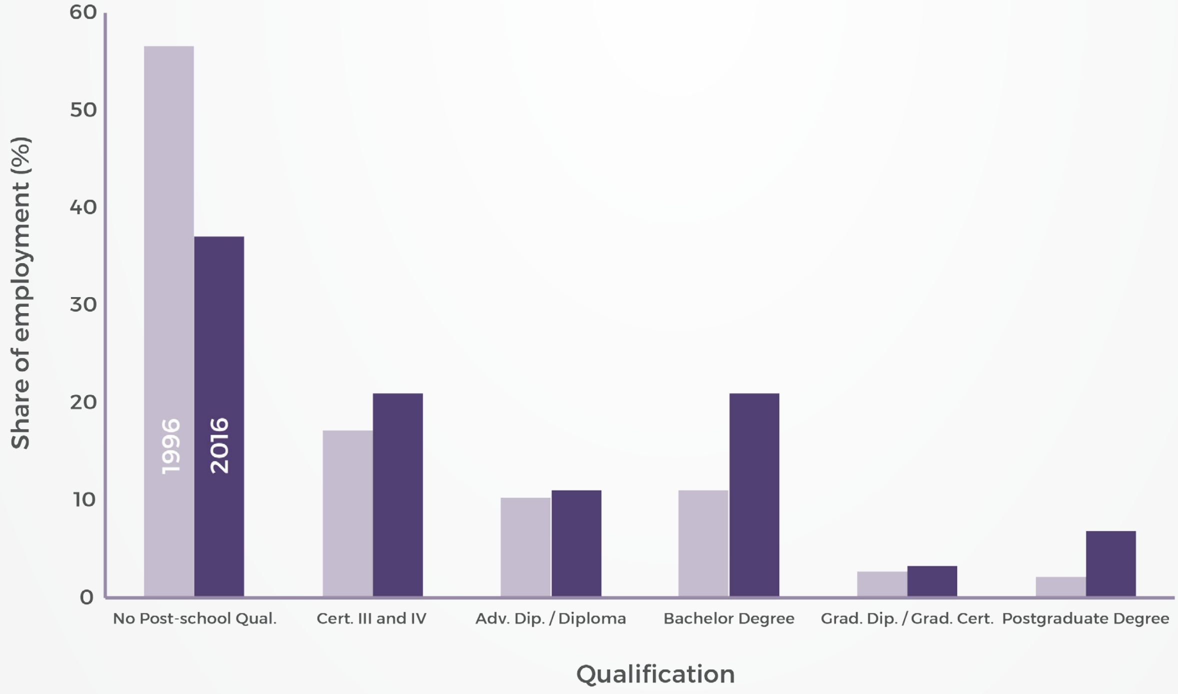
base in 1966 up until the last available figures in 2011. An increase (decrease) from the baseline implies stronger (weaker) demand for a task category.

The analysis suggests that occupations with high abstract task content grew substantially in importance, at the expense of occupations with high routine task content – a finding that is in line with other Australian evidence (Heath, 2016) and with US studies discussed earlier. However, in contrast to Heath's (2016) evidence of a growth in non-routine, *manual* jobs, Coelli and Borland (2016) report a net reduction in the 'manual' task category since 1966 – although this decline seems to have halted since 2001. These differences leave us with some uncertainty about how the demand for non-routine, manual skills and workers has changed in the Australian labour market since the start of this century. While both the Heath (2016) and Coelli and Borland (2016) studies agree that there has been strong growth in demand for non-routine, *cognitive* tasks, the latter study offers less encouraging evidence of how non-routine, *manual* tasks and workers have fared. Neither study settles the debate, and further analysis is needed of how the demand for manual labour responds to continued technological change.

There is little doubt, however, that attaining a formal qualification has become increasingly important for gaining entry to the Australian workforce. Twenty years ago, the majority of employed Australians did not have a post-school qualification – this was true even of those working full-time (ABS, 1996). Today, the composition of the workforce has changed dramatically, with increasingly higher levels of educational attainment, and substantially lower proportions of workers without post-school qualifications of some kind. Underlying skill demands have changed to the extent that it is now significantly more difficult for those who do not continue their education beyond secondary school to compete for work. As a result, these less-qualified Australians make up an increasing share of the population outside the labour force: people without a post-school qualification accounted for almost two out of three (65 per cent of) working-age Australians who were not participating in the labour force in 2016 (ABS, 2017a).

Figure 9 represents these trends graphically, using data from the ABS Survey of Education and Work collected twenty years apart in 1996 and 2016. The figure compares the share of employed Australians (aged 15-64 years) whose highest completed qualification is at each of the levels shown in these selected years. The shares of all post-school qualification types increased between 1996 and 2016, while the corresponding share without any post-school qualification declined sharply. In 1996, for instance, some 16 per cent of Australian workers

Figure 9 - Composition of the Australian workforce by highest educational attainment, 1996 and 2016



Sources: Authors' calculations from ABS (1996, 2017a).

Notes:

1. The figures are for employed persons aged 15-64 years.

had a bachelor degree qualification or higher. By 2016, this proportion had almost doubled, to 31 per cent.[8] By far the largest increases occurred in terms of completed university-level qualifications: the proportion with a bachelor degree rose from 11 to 21 per cent, while the proportion with postgraduate degrees (Masters and Ph.D.) rose from 2 to 7 per cent. These developments suggest that the Australian labour market increasingly demands and rewards post-school qualifications, particularly university degrees, which is consistent with evidence of the occupational structure shifting towards more non-routine, cognitive jobs and tasks.

Shifts in educational and occupational demands arising from technological change and job destruction will also affect the distribution of earnings among those who remain employed. The US is distinctive for high earnings inequality – in large part a by-product of limited state intervention in regulating wages and employment conditions. Any ‘skill-biased’ effects of technological change will be amplified in such an environment, where workers with lower-level skills are unlikely to benefit from significant government assistance to bolster their living standards. The same technological effects, however, may be less strongly evident in Australia’s case, where major institutions and more extensive labour market regulation intervene in various ways to influence the final outcomes of market forces, even though here too we have seen the less-qualified portion of the workforce declining as a share of total employment.

Figure 10 examines two measures of change in the earnings distribution for Australia and the US over the last 30 years[9]. The lines on the graph show two ratios, representing changes in the lower and upper halves of the distribution. First, the ‘50/10 ratio’ compares earnings for a worker at the median of the distribution (the middle or 50th percentile) with another at the 10th percentile (i.e., near the bottom). This ratio indicates to what extent the low-paid have kept up with or fallen behind the growth in earnings for an ‘average’ worker. Second, the ‘90/50 ratio’ looks at changes in the upper half of the distribution. This ratio indicates whether the average worker’s pay increased in line with that of an already well-paid worker near the top of the distribution (i.e., the 90th percentile).

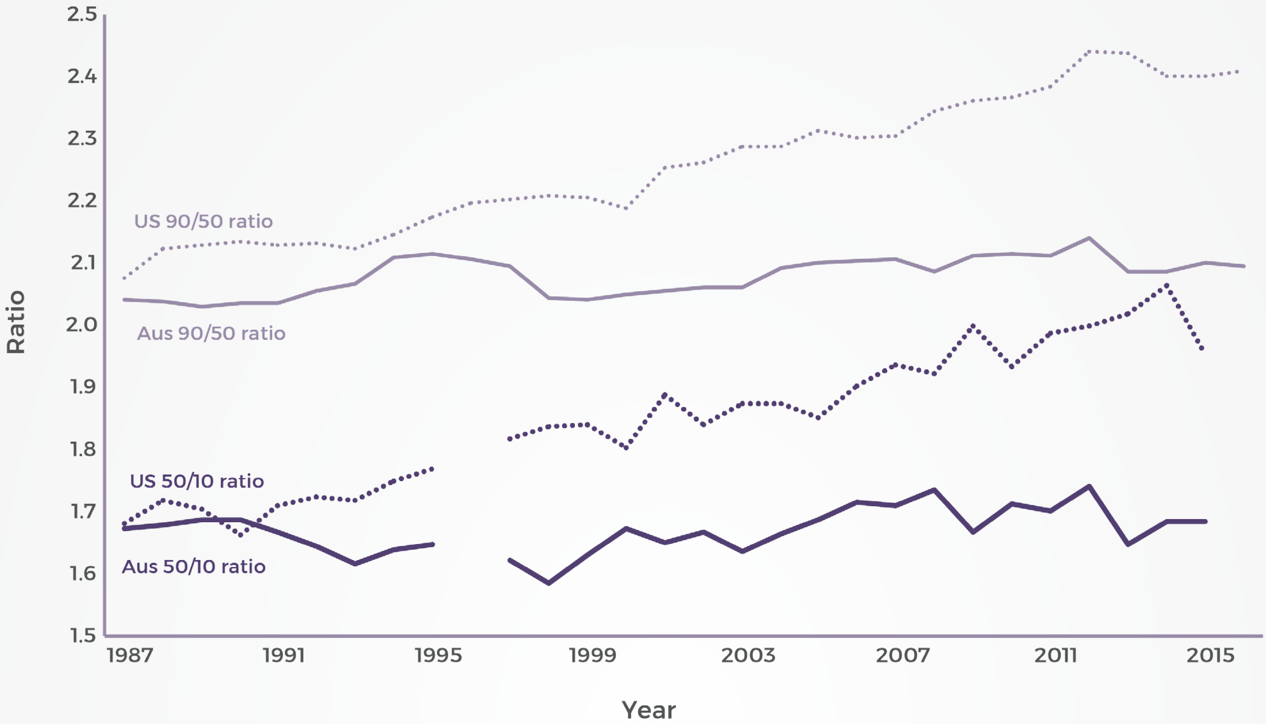
The rise in US earnings inequality is clear from Figure 10. Consistent with the polarisation narrative, this rise occurred in both halves of the US earnings distribution. The earnings of well-paid Americans increased ahead of those in the middle, who in turn gained ground on those near the bottom. The result is a ‘fanning out’ of the distribution, with advantaged workers capturing a steadily growing share of total employment compensation in the US.

By comparison, the Australian experience indicates that earnings polarisation here has been largely kept in check. Over the past 30 years, there was some increase in top-half inequality in Australia (the 90/50 ratio), but nothing like the extent of change seen in the US. Perhaps even more importantly, there has not been any net change in *bottom*-half inequality (the 50/10 ratio). In the Australian workforce, in contrast to the US, full-time low-paid workers have not seen their earnings fall further behind the pack.

[8] The trends are similar in the full-time workforce. Between 1996 and 2016, the share of full-time workers with a bachelor degree or higher doubled from 17 to 34 per cent.

[9] The data are gross (pre-tax) weekly earnings for full-time workers. This measure gives an incomplete view of the earnings distribution, but avoids the complication of having to adjust earnings for differences in the hours worked by part-timers. The focus on earnings also ignores broader sources of inequality in non-market income (e.g. capital gains) and wealth. Whiteford (2017) discusses these different approaches to measuring inequality.

Figure 10 - Earnings ratios for full-time workers, Australia and the US, 1987-2016



Source: OECD.Stat (2017a).

Notes:

1. Calculations are based on estimated weekly earnings for full-time employees.
2. The two ratios shown illustrate the degree of earnings dispersion in (a) the top-half of the distribution (the 90th / 50th percentile) and (b) the bottom-half of the distribution (the 50th / 10th percentile).
3. Australian estimates are missing for 1996 because the source data (from the ABS Survey of Employee Earnings, Benefits and Trade Union Membership) were not collected in that year.
4. The group of OECD countries has changed over time, but OECD.Stat advises that: 'In order to facilitate analysis and comparisons over time, historical data for OECD members have been provided over as long a period as possible, often even before a country became a member of the Organisation'.

Broader measures of *household* incomes (as opposed to individual earnings, in Figure 10) tend to confirm the picture of lower and better-contained levels of inequality in Australia than in the United States. The 'Gini coefficient' provides one measure of inequality, ranging from 0 to 1, where 1 represents the highest possible level of inequality (all income accruing to one household). Using this measure of inequality, the latest results from the Household, Income and Labour Dynamics in Australia survey (HILDA) indicate that there has not been any widening of household income inequality for the last 15 years, with the Gini coefficient remaining stable at approximately 0.3 (Wilkins, 2017). This figure is substantially lower than the equivalent for the United States (0.4), although a longer time series using ABS income survey data does show Australian household income inequality increasing gradually since the early 1980s (Whiteford, 2017).

The trends in Figure 10 – and in other analyses of income inequality – further highlight the limitations of assuming that US trends apply to Australia. While both countries have similar levels of technological sophistication, their labour market outcomes are quite different, and Australia has not seen the same extent of growth in employment or earnings inequalities as in the United States. This suggests that Australia's institutions and regulatory environment can still substantially 'mediate' the effects of technological and demand shifts on labour market outcomes. These local institutions potentially include a wide array: minimum labour standards, social welfare policies, education and training systems, and so on. Whatever the individual effects of these institutions, their cumulative effect has seemingly been to curb any tendency toward wider disparities in outcomes, thus slowing the emergence of a more divided society.

The effects of new technologies are also experienced differently – or expected to differ – according to geographical location. Technological progress presents both an opportunity and a challenge for regional Australia. The opportunities stem from increased potential for connectivity, productivity and competitiveness of businesses and workers outside the cities (Regional Australia Institute, 2015). In one study of businesses in regional Queensland, for instance, participants saw better connectivity as an opportunity for workers to interact remotely and for businesses to access resources and markets outside of their immediate local 'catchments' (Smidt *et al*., 2015).

But while technological changes undoubtedly present opportunities to the regions, there are hurdles to overcome before these prospects can be fully realised. Access to fast, reliable and affordable digital infrastructure remains a problem in the regions, and this may restrict economic opportunities. A recent study reported that almost half of respondents in rural and regional Australia considered their internet access to be either 'very poor' or 'inadequate' (Vidot, 2016). The Regional Australia Institute (2016) reports that 'digital literacy' in parts of rural and regional Australia is significantly lower than in the cities, meaning that workers and businesses in these areas may be less equipped to seize the opportunities presented by some newer technologies.

There is also evidence to suggest that the automation of routine tasks will have a stronger impact on certain industries—including mining and agriculture—that have in the past provided significant employment in regional areas (Finkel, 2015; Smidt *et al*., 2015). The CEDA study noted earlier (Durrant-Whyte *et al*., 2015) suggests that the looming threat of automation for regional jobs is, in general, much higher than in cities. While some 40 per cent of all Australian jobs were found to be at high risk in this study, the figure for regional and rural areas is 60 per cent. Unless offset by strong employment gains in new industries, automation-related job losses on this scale would severely harm the economic viability of some Australian regional and rural centres.

3.2.3 - The practice: How is work done?

The future of work discourse is full of conjecture about how work practices and work organisation – the ways in which we work – are changing. However, particularly in Australia, discussion by labour economists, informed by aggregate statistical data, has tended to be sceptical about many of these claims. We have earlier cast doubt on headline-seeking speculation about 'the end of work', but even some other, less dramatic claims about changes in work practices have been found wanting for convincing statistical support.

Wilkins and Wooden (2014) review changes in the Australian labour market over two decades from 1993 to 2013 and call attention to several popular misconceptions about the nature and extent of change. A number of their findings are relevant for evaluating how technological changes may be reshaping Australian work practices. Among other things, they conclude that:

- Self-employment has not grown in prevalence over recent years – indeed, it has declined – as a share of the total workforce, relative to conventional 'dependent' employment. ABS

(2017b)[10] data show that employees have accounted for a steadily rising proportion of employment (from 80 per cent in 1991, to 83 per cent in 2016), and thus the share of all employed people who are owner-managers has declined. This evidence suggests that Australians today are not more likely than they were in the past to eschew employee jobs for self-employment. Many Australians do this, but they do not represent a growing share of our workforce.

- Among employees, the prevalence of 'casual' work arrangements (defined as the absence of paid annual and sick leave) appears to have stabilised since the turn of the century, at approximately one-quarter of employees (24 per cent in 2013, the latest figures available, compared with 25 per cent in 2000) (ABS, 2014). The more stable casual employment rate is somewhat at odds with claims about a continued rise in Australian job insecurity. For some employee groups, including women, the casual share has declined since the turn of the century (Wilkins and Wooden, 2014), although – as we discuss further below – it has continued to grow in other parts of the labour market, principally for young workers. As we show below, alternatives to casual jobs have become increasingly scarce for young Australians seeking to work, and this development reflects the loss of many entry-level, unskilled jobs consistent with past patterns of 'routine-biased' technological change.
- There is no evidence that Australian working practices (or employer expectations) are evolving to enable more workers to use advanced communication technologies to work more frequently from home ('tele-working'). Instead, the latest data suggest that the incidence and 'hours-intensity' of tele-working has declined in Australia. We return to this evidence in Section 4.

[10] This data source determines each worker's 'status in employment' according to their main job – i.e., that in which they worked the most hours. Workers who supplement their main employee job with some additional hours in their own business enterprise are therefore not counted among the 'self-employed' on this measure.

Thus, although Wilkins and Wooden (2014) described the 1993-2013 period as 'two decades of change' for the Australian labour market, some important working practices have in fact been remarkably unaffected by broader economic and technological developments. Indeed, our extrapolations from the most recent ABS data indicate that the trends they describe for these two decades hold true for the subsequent period since 2013.

Two of the points made by Wilkins and Wooden (2014) deserve further examination. The first is their observation about the mix of employees and self-employed workers in the workforce. How do we reconcile their finding of a *shrinking* self-employed share with the almost-daily popular media coverage of a supposedly expanding 'gig economy'?

The gig economy attracts attention in part because of its major operators' insistence on engaging their workers as 'independent contractors' or 'freelancers', not as employees. Major platform companies, especially Uber and Deliveroo in Australia, have repeatedly defended the distinctiveness of their business models, the flexibility that this supposedly affords their drivers, and the need for their operations to be exempt from existing labour standards (including minimum wages, superannuation, and paid leave entitlements). The forthright way in which leading gig-economy firms challenge established labour practices would account for some of the strong interest in this segment of the workforce, even if it remains for the moment a relatively minor feature of the wider labour market landscape.

Another argument that is made is that major labour force surveys and related data sources simply do not adequately measure, and thus underestimate, the total volume of gig-based work. In Australia, this might occur because standard questions focus on respondents' *main* job (that in which they do the most hours), potentially overlooking other work done 'on the side' for supplementary income, which is common for gig economy participants (Minifie and Wiltshire, 2016).

As part of a broader effort to link its employer and employee data, the Australian Bureau of Statistics recently released 'experimental' data on the prevalence of multiple job holding. The results (ABS, 2015) suggest that many Australians – some 1.9 million in the 2011-12 financial year – work several jobs concurrently. Some half a million workers (among those 1.9 million) had at least three concurrent jobs. Looking at working patterns across an entire year gives a different picture from the typical 'snapshot' of a week or month's activities.

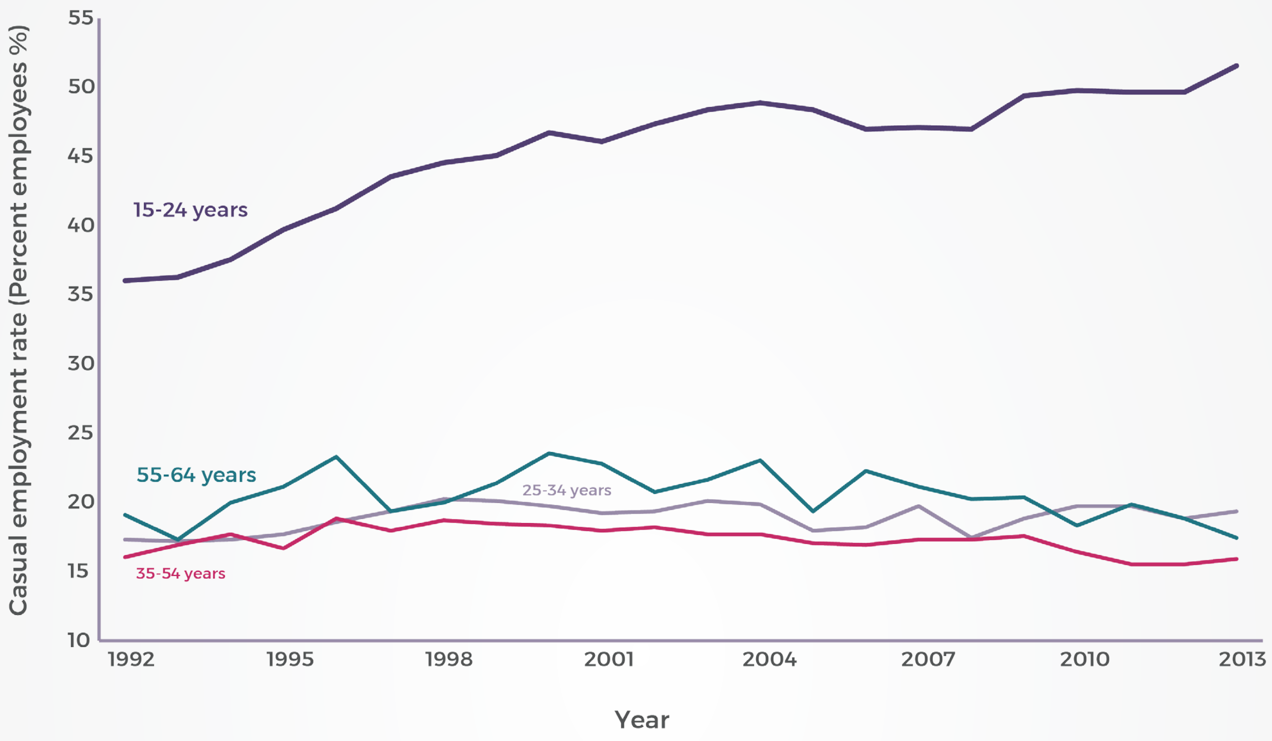
While it is too early to judge the scale of the gig economy from these experimental figures, more evidence of this kind needs to be assembled and monitored on a consistent basis to gauge whether this new kind of working is gaining a foothold in the Australian economy. It would be of particular interest to know more about the characteristics of gig workers and their earnings. Evidence of this kind could then be related to other findings about the jobs and workers displaced by automation and robotics – to see if gig-based work provides an avenue back into the workforce for those adversely affected by technological change.

The second point of interest in Wilkins and Wooden's (2014) findings is that, following an extended period of growth as a proportion of total employment, casual employment has not become more prevalent in recent years. Since 1996, the casual share has remained at between 23 and 25 per cent of all employee jobs (ABS, 2014) (the latest available data are for the year 2013). Casual work has thus become a sizeable and entrenched component of the Australian workforce, but appears to have recently reached a plateau in its overall use.

While the observation of a stabilising casual share holds true for Australia in the aggregate, Rayner (2016) shows that it is not correct when the data are subdivided by age, as shown in Figure 11. This additional level of detail reveals the extent to which casual employment has grown specifically among young workers. By the end of the period shown in Figure 11, more than one in two young Australian workers (aged 15-24 years) were employed in casual jobs.

This development is of considerable importance and may herald a permanent change. The casualisation of work for young Australians is different from other trends, in that it has not been closely tied to the business cycle. Nor does it seem to be a response to any particular technological change, given that the increase has been steady and long-term. In part, the trend may reflect the extension of formal education later into life for more young people, and their preference to combine study with casual work. However, the increased reliance on casual workers may have deeper technological roots, if it reflects ongoing changes biased against routine, entry-level jobs. The loss of these jobs may have closed off some pathways into more stable employment for young jobseekers, leaving them with fewer alternatives to starting out in some form of casual job. For instance, the disappearance of many blue-collar factory jobs has left more young people who do not go on into post-school education with a limited set of choices between casualised work and welfare dependence. Even higher up the skill hierarchy, opportunities are shifting and narrowing for some young jobseekers as hiring processes adapt to new technologies. The legal profession is a well-known instance of firms scaling back their demands for entry-level graduates, whose former work locating reference documents and preparing case files can now be done by purpose-built algorithms (Susskind and Susskind, 2015).

Figure 11 - Casual employment rate in Australia, by age, 1992-2013



Source: ABS (2014).

Notes:

1. Casual employees are defined as those without paid leave entitlements.
2. The casual employment rate is calculated as the proportion of employees in each age group without paid leave entitlements.
3. Calculations exclude employees who are owner-managers of their own enterprises.

4. Possible Futures for Work and Skills in Australia

4.1 - The challenge of prediction

A key challenge for policy makers, organisations and individuals is understanding how the future will unfold, and what its likely consequences will be. For social scientists, the task of predicting the future stretches accepted approaches to evidence and analysis that underpin the rigour with which retrospective data are used to test theoretically-derived hypotheses. Thinking about the future is problematic for this approach, since that there is no data about the future on which to draw. As a consequence, futurists and social scientists interested in understanding what the future might look like draw upon an array of methodologies – from trend analysis to examination of market leading technologies and trends, identification of 'megatrends', and scenario planning – as ways to bring some discipline to the difficult task of looking ahead.

Prospective analyses have been part of social science for a long time. Demographers, for example, project population growth over extended periods, which provides valuable information that helps governments plan investment in public infrastructure, housing, education and health. These projections require assumptions to be made about a range of factors likely to shape the actual trajectory of population growth, including birth and death rates, immigration, geographical mobility, and so on. City planners often face the challenge of projecting the future across a more diverse range of factors that shape the growth of cities, from population growth to investment flows and changing attitudes and lifestyle preferences.

Social scientists seek to overcome a number of different challenges in making predictions about the future (Schwartz, 1991). As we have noted, the absence of data and traditional forms of evidence is fundamental. Even with a finely-tuned approach to generating projections about future trends, predicting the future of an economy is extremely challenging, even over relatively short timeframes (Stewart and Williams, 1998). As the example of demographic projections suggests, one important reason why the future is so hard to predict with any accuracy is that it is shaped by intersecting forces. The greater the number and the more diverse are these forces, the larger the number of potential ways in which they can conceivably combine to create different possible outcomes. In the absence of any further means to discriminate between these alternative futures, some of which vary markedly from the present or from other possible futures, choosing the 'most likely' future entails an increasing degree of uncertainty (Godet, 2000).

Timeframes also pose a problem: predicting the future over more ambitious timeframes entails greater uncertainty and ambiguity about likely developments and outcomes. Time frames present inevitable trade-offs between the concreteness (or detail) with which it is possible to make future predictions and the confidence with which we can make them. For example, the available evidence and techniques for predictive inferences may allow us to extrapolate the probabilities with which particular general classes of jobs (or occupations) might be susceptible to automation, but predicting whether more specific classes are likely to be automated – let alone when, or in what locations – will introduce a higher probability of being wrong (Mietzner and Reger, 2005).

The upshot of these initial observations is that the available 'evidence' about the impact of technology (and other factors) on jobs into the future is based on assumptions and implicit uncertainty about the margin of error within which these projections are made. As we have seen, for example, with estimates of the likely impact of automation on the destruction of existing classes of jobs, these projections vary markedly and, over time, as the methodologies used to generate them have been refined, initial estimates have been adjusted significantly.

With this in mind, our conclusions about the implications of technology for jobs and skills are contingent on the best evidence available today. We have sought to weigh and judge this evidence, giving higher emphasis to the most robust information that is relevant to Australia. Our conclusions are themselves marked by some inherent uncertainty. For this reason, we consider the likely future trends at a general level, rather than attempting to make detailed projections.

4.2 - Implications of the shifting technological frontier for future jobs and skills

Guided by the available evidence, we can draw some broad conclusions about how new technologies, from robotics to AI, are likely to impact on four critical areas of the labour market. These are:

1. job destruction and transformation;
2. job creation, including job quality and the location of job opportunities;
3. how work is likely to be organised; and
4. the sorts of skills required to do jobs and to negotiate labour market transitions.

4.2.1 - Implications for job destruction and transformation

The question of how technology is likely to impact on job destruction has been the focus of both international and Australian research. The work of Autor *et al*. (2003) and Frey and Osborne (2013) has provided the foundational approach internationally, with subsequent studies drawing heavily on their work – both for the purpose of retrospectively estimating the past impact of technology on jobs, and prospectively to generate projections about its likely consequences in the near future.

These first estimates suggested that automation would have a highly destructive impact over a relatively short period of time. As discussed in Section 2, Frey and Osborne (2013), for example, estimate that 47 percent of workers in the United States were employed in occupations at high risk of automation – where 'high risk' was defined as an occupation which consisted of a bundle of tasks where more than 70 per cent could be automated. These authors estimate that a further 19 per cent of employees worked in occupations at medium risk of automation, defined as where between 30 and 70 per cent of tasks in the occupation could be automated. These estimates have, we noted, been replicated in the Australian context, and have influenced the perspective taken by both policy makers and other stakeholders interested in pre-empting and responding to the consequences of such changes. Ensuring these estimates reflect the reality of changes happening is thus critical.

Subsequent estimates produced by Arntz *et al*. (2016) suggest that a significantly smaller proportion of jobs are at high risk of automation. These new estimates seek to account for more detailed analysis of tasks within jobs, as well as variation between individuals in the bundle of tasks undertaken within a particular job category. For the United States, Arntz *et al*. (2016) estimate that slightly less than 10 per cent of workers are currently employed in jobs at high risk of automation – while around 25 per cent are at medium risk. These jobs, they note, were more likely to experience significant transformation, whereby some tasks which could be automated would be 'unbundled' from existing jobs, and the remaining task content of those jobs would be reconfigured – without the job in its entirety disappearing.

Arntz *et al*. (2016) provide estimates for OECD countries, including Australia. Currently, their estimates offer the most robust indication of the likely effects of AI and automation on patterns of job destruction in Australia. As Figure 5 above shows, they estimate that around 7 per cent of Australian workers are in jobs at high risk of automation, while a further 26 per cent are at medium risk. Again, these estimates are significantly more modest than earlier estimates reported for Australia. They are, however, consistent with the research estimating current rates (and patterns) of job destruction and creation reported in Section 3, which indicate a high degree of continuity with prior episodes of economic disruption and restructuring.

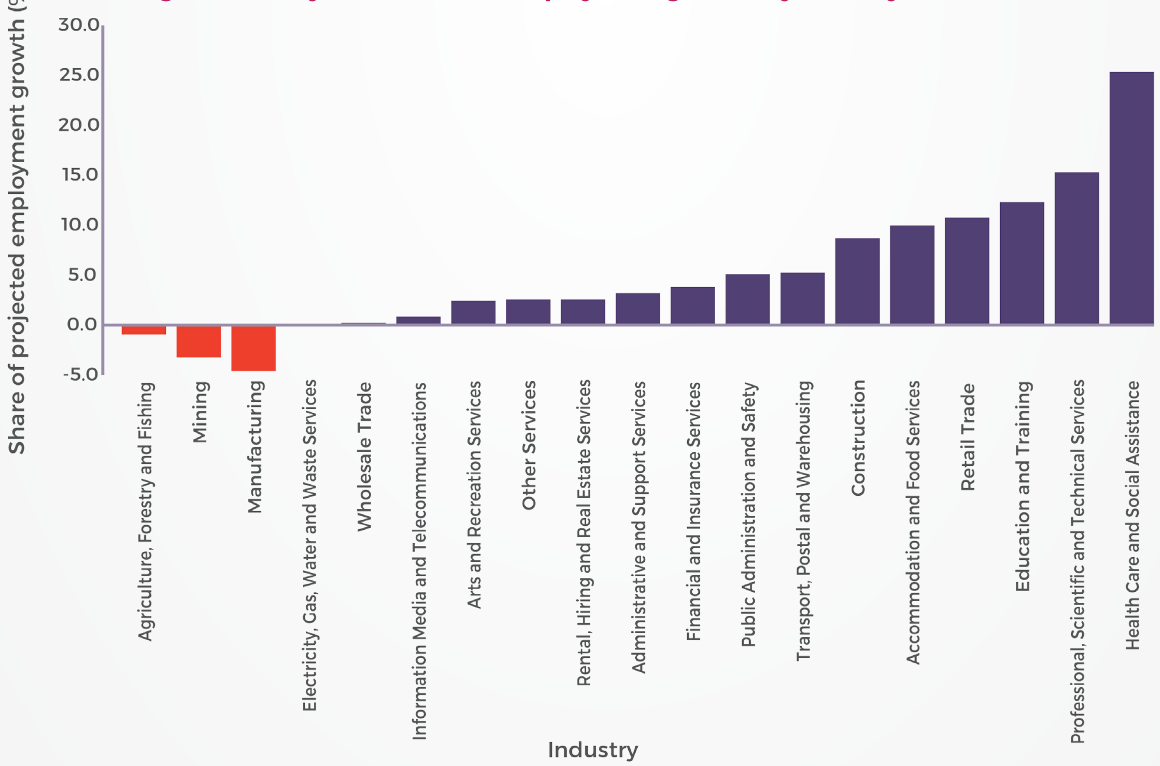
Overall, then, the evidence indicates that, at present, AI and automation have had modest impacts on the *rate* of job destruction. The estimates reported by Arntz *et al*. (2016) – the most reliable attempt to estimate the likely future impact on jobs – suggests that this is likely to be sustained in coming years, with a modest but discernible increase in the rate of job destruction, at worst. Although this is difficult to estimate with any certainty, the current *rate* of destruction – and perhaps the pattern of job destruction – associated with automation may alter as AI develops. At this stage, though, there is no basis on which this change can be estimated.

The available evidence is consistent with a conclusion that there is a more marked impact on the overall *pattern* of job destruction. However, the evidence does not suggest that there is a linear relationship between skill and the risk of automation, as is often assumed, with the probability of destruction decreasing with higher levels of skill required. Coelli and Borland (2016) describe the relationship as 'J-shaped', with automation being associated with a significant net increase in employment in higher-skilled jobs and a more modest net increase in low-skill employment.

4.2.2 - Implications for job creation

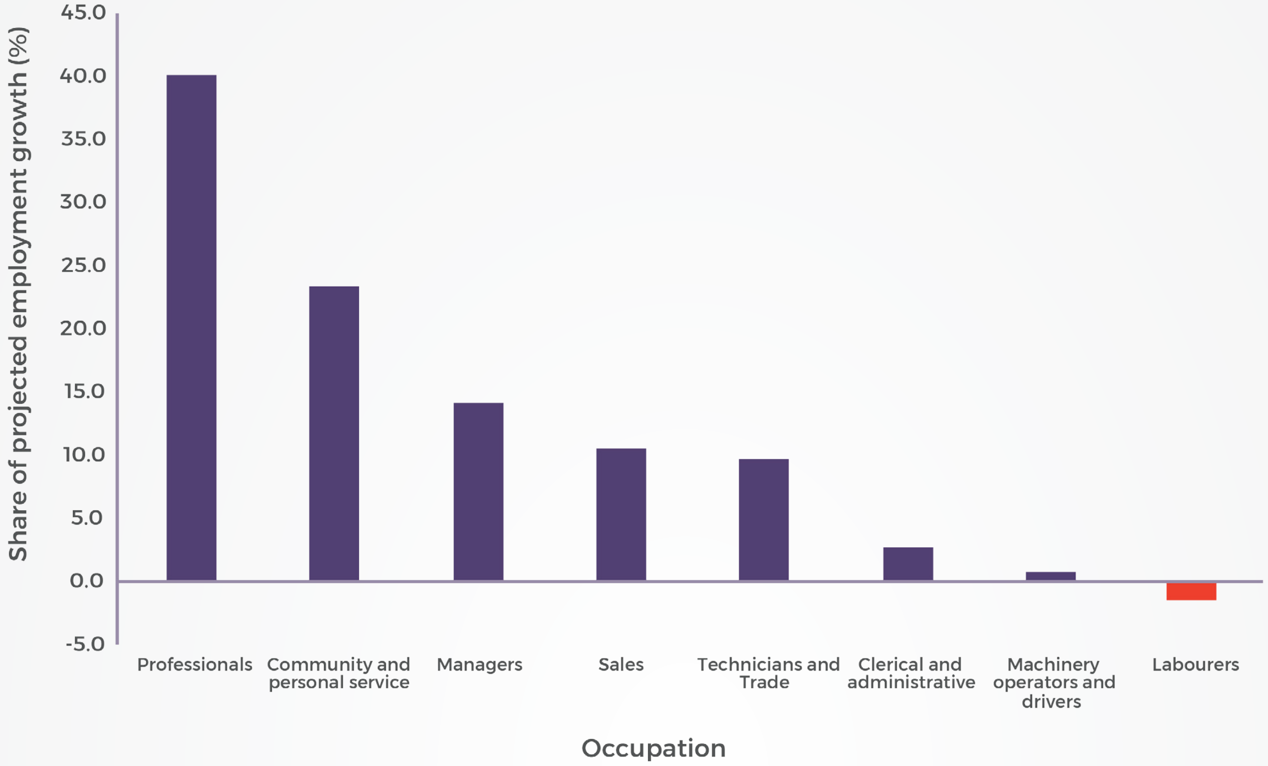
The implications for job creation are much more difficult to quantify and have been subject to more limited consideration. Nonetheless, official projections on employment growth provide some indication as to the industries, occupations and regions that are likely to generate job growth in the near future. Below, we report the most recent projections for shares in employment growth (i.e., the proportion of new growth accounted for) by industry and occupational group in Australia over the five-year period to 2020 (Figures 12 and 13).

Figure 12 - Projected shares in employment growth, by industry, 2015-2020



Source: Department of Employment (2016) *Employment Projections*, available at: lmip.gov.au/default.aspx?LMIP/EmploymentProjections (accessed 13 July 2017).

Figure 13 - Projected shares in employment growth, by occupation 2015-2020



Source: Department of Employment (2016) *Employment Projections*, available at: lmip.gov.au/default.aspx?LMIP/EmploymentProjections (accessed 13 July 2017).

Projected shares in employment growth vary widely across industries (Figure 12). Most of the employment growth is expected to be generated in a small number of industries, the most important of which include: Health and human services; Professional, scientific and technical services; Education and training; Retail; Accommodation and hospitality; and Construction. Negative job growth, as a share of total projected growth, is expected to occur in Agriculture, forestry and fishing, and in Manufacturing. Those industries where employment growth is projected to be concentrated are not all 'hi-tech' or technologically intensive sectors; rather, they are a mix of advanced and service settings where personal service is a critical element of delivery. Nor are all these industries viewed as ones with a high concentration of skilled jobs; instead, they contain a mix of high and lower skills jobs.

A similar pattern emerges when considering job growth by occupational group (Figure 13). Here, we report projections at the most aggregated level; however, each of the occupation groups can be viewed as a proxy for skill levels, with skills requirements generally declining from the category of Managers down to Labourers. Although these projections suggest that higher skilled occupations will, on average, contribute a large share of the total employment growth, growth is nonetheless projected to come from a broad mix of occupations and skills (except for the final group, Labourers).

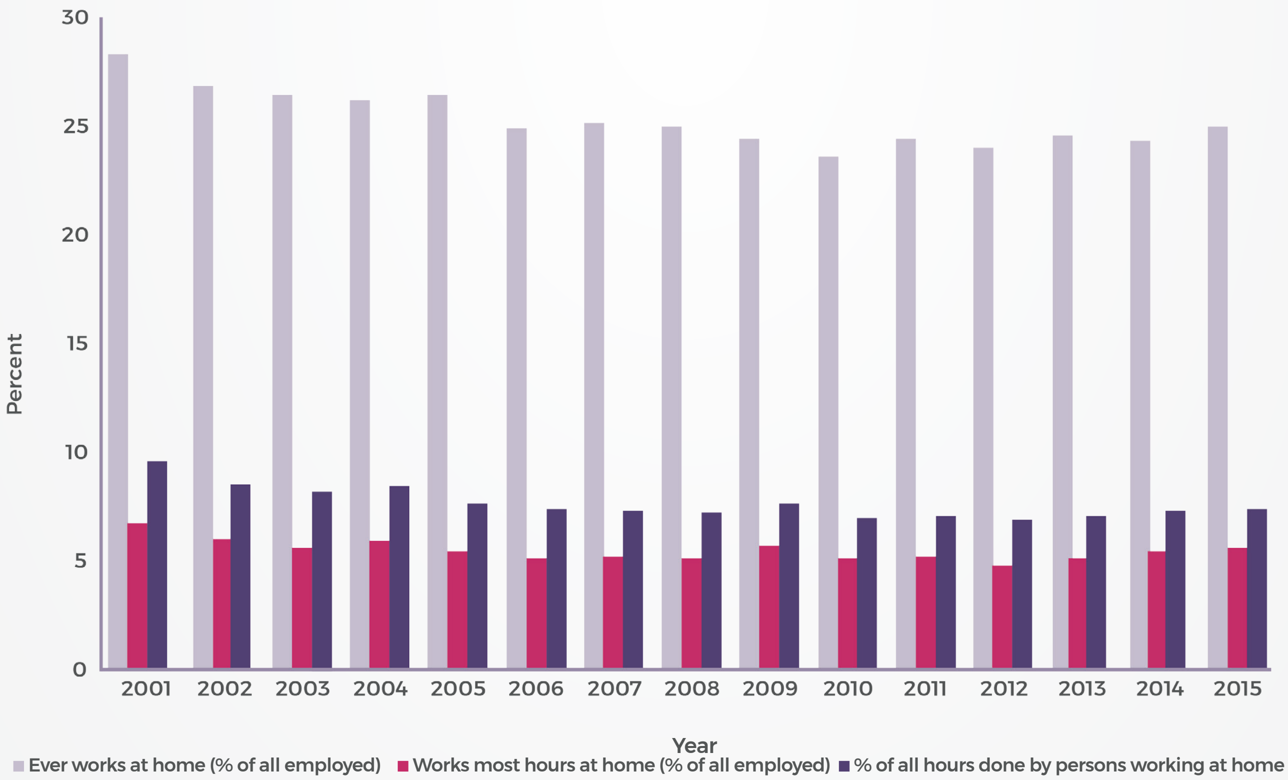
4.2.3 - Technology, automation and the diffusion of telework

Virtual work arrangements emerged in the mid-1970s, typically in the form of 'teleworking', but their diffusion was limited by technological and other constraints. Gallup's annual work and education survey in the US indicated that the adoption of teleworking remained low until well into the 1990s. In 1995, just 9 per cent of the US workforce reported having used telecommuting at any stage of their working lives. However, in the subsequent decade, this figure rose to around 30 per cent; and the latest Gallup Work and Workplace survey (2016) estimated that 37 per cent of US workers telecommute for at least some part of the working week.

Based on a larger representative sample of the US workforce, the American Community Survey conducted by the US Census Bureau (2015) reported that around one quarter of American workers engaged in some form of telework, with around 3.7 million workers (2.5 per cent of the workforce) working at least half their week from home. Notwithstanding the growth in virtual work practices, the evidence also suggests that the diffusion of such practices remains well below the possible virtual work arrangements that are offered by organisations. In other words, many employees feel hesitant to engage in virtual work. Analysis of the American Community Survey suggests that more than half of all US jobs are amenable to some form of telework. This gap between the potential and actual practices requires empirical research in order to better understand from the employee perspective the facilitators of and barriers to implementing virtual work practices.

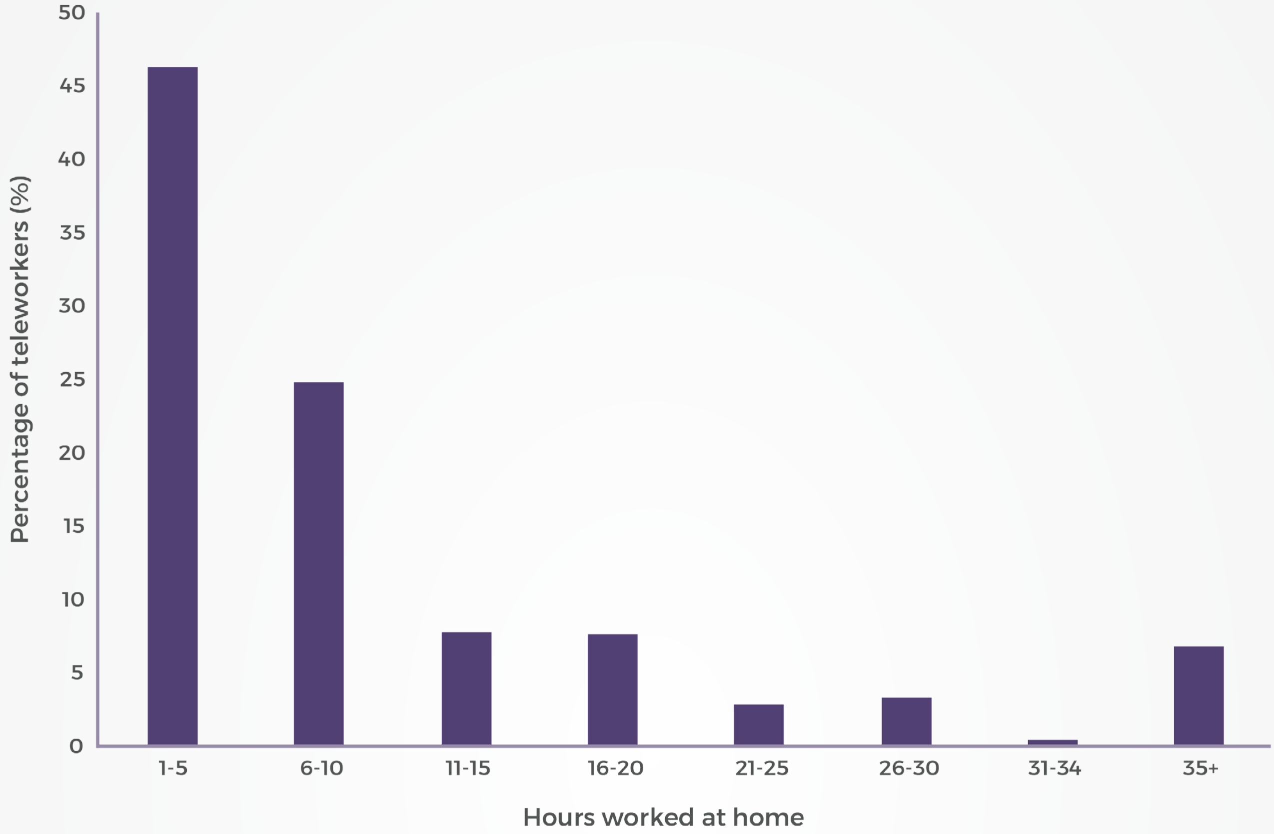
There are fewer sources of Australian data on telework, with the best evidence coming from the Household, Income and Labour Dynamics in Australia (HILDA) survey. Figures 14 and 15 show aspects of the HILDA evidence on telework, drawing on all the available waves of data spanning the past 15 years.

Figure 14 - The incidence of working from home, 2001-2015



Source: HILDA survey data, 2000-2015

Figure 15 - The distribution of usual weekly hours worked at home, 2015



Source: HILDA survey data, 2015

Notes:

1. Figures are the proportions working the number of hours in each category, among those who work at least one hour per week at home. For instance, 46 per cent of these workers work 1-5 hours at home.

The first point of note (shown in Figure 14) is that there has not been a recent increase in the incidence of telework consistent with any widespread shift in working patterns. In 2001, some 28 per cent of Australian employees reported ever working some of their hours from home. By 2015, this proportion had changed little, at 25 per cent. Nor has there been a surge in the proportional importance of teleworking when expressed in terms of working hours. On the latest HILDA data, approximately 7 per cent of all working hours were done at home in 2015, a slight reduction from the estimated 10 per cent done in 2001.

The second main point (represented in Figure 15) is that the majority of workers who do some telework do relatively few of their few hours at home. In 2015, according to HILDA, nearly half (46 per cent) of all teleworkers did 1-5 hours at home, and another substantial proportion (25 per cent) did 6-10 hours at home. The proportion of teleworkers doing full-time hours (i.e., 35 or more) appears to be quite low (about 7 per cent in 2015).

While these figures suggest that teleworking is an enduring and non-trivial feature of the Australian labour market, they do not lend any weight to suggestions that this variety of work is becoming more prevalent in Australia over time – or that it is somehow displacing more conventional workplace-based arrangements and expectations. Only a minority of Australian workers enjoy the flexibility to work from home, and even these workers appear mostly to work a small number of their hours at home. For most, the expectation to attend a workplace outside their place of residence remains.

4.2.4 - Implications for skill requirements

Our analysis suggests that much of the public discussion of technology's impact and threat has been fuelled by speculation about the rate of change and disruption that is perhaps unwarranted. Given both the current trends we observe and more recent estimates, the immediate impacts of AI and automation are likely to be more modest than is widely supposed. This suggests then that the consequences for what types of skills are likely to be required by employees into the future need to be considered against the actual trends and these more modest expectations of change.

There is limited evidence on how AI and automation are likely to alter skill requirements for specific jobs or occupations. Generally, however, the evidence indicates that it will have mixed effects (Cunningham *et al*., 2016). Some technological developments are leading to increased demand for higher-order technical skills across a broader range of jobs, especially 'STEM' skills (science, technology, engineering and mathematics). There are also new demands for the range of skills associated with the HASS disciplines (humanities, arts and social sciences), including problem solving, and interpersonal and relationship skills associated with working in teams. Yet, for other jobs – especially those in which particular tasks are subject to automation – technology is leading to deskilling.

In an innovative approach to establishing what types of skills are required to undertake different types of jobs, the Foundation for Young Australians (FYA, 2016) examined the skill requirements sought by employers when seeking to fill new positions. This study analysed the content of more than 2.7 million job advertisements posted in Australia between July 2014 and June 2016, covering 625 detailed job categories for which at least 50 jobs were advertised over that two-year period.[11]

From this analysis, FYA identified seven 'job clusters', with each having a common set of core technical and enterprise skills (see further descriptions in Table 1). Interestingly, of the seven clusters, FYA projected that 'carers' have the strongest employment prospects and the lowest risk of automation, consistent with the view that the future labour market will place a higher value on interpersonal and human-to-human skills.

FYA concludes that these common sets of skills imply a capacity of individuals to be highly mobile across jobs *within* a job cluster, and varying levels of immobility between jobs in different job clusters. The identification of common skill sets *across these clusters*, however, also suggests that the barriers to moving between jobs in different clusters may not necessarily require individuals to gain an entirely new qualification. This observation suggests considerable scope for using recognition of skills gained through prior learning and experience to enable individuals to shorten the periods of formal training required to gain a mandatory or job-relevant qualification. The scope for workers to move laterally across broad job clusters also suggests that there is likely to be growing demand for (and value in) modular or 'micro' forms of qualifications that can be reconfigured and augmented to fit with emerging skill requirements in related or entirely new (but compatible) occupations.

4.3 - Future Labour Market Scenarios

For most of the preceding discussion, we have looked back at technological and workforce changes in the past to draw plausible inferences about what lies ahead. We now attempt to gaze more explicitly into the future, using the technique of scenario planning to imagine and contrast multiple potential futures simultaneously. Scenario planning is a widely-

[11] While this is clearly a large sample, the online marketplace does not cover the field of job advertisements. One of the largest players, Seek, claims to account for one-third of all job matches in Australia (Seek, 2015), implying that many people find jobs through other means.

Table 1 - Job clusters in the Australian economy and the requisite skills used intensively

Job cluster	Occupations	Technical skills	Enterprise skills
'Generators'	Sales reps, retail supervisors, café managers, hotel managers, bank managers, entertainers, interpreters, airline crew.	Business development and sales support, managing sales relationships, customer relationship management, contract management.	Communication skills, building effective relationships, customer service, planning, time management, digital literacy.
'Artisans'	Machinery operators, landscape gardeners, electricians, crop & livestock farm workers, plumbers, and carpenters.	Workplace health and safety, machinery operation, first aid, inspection, contract management, forklift operation, hand and power tools operation, welding, plumbing, carpentry.	Detail-orientation, planning, problem solving, digital literacy, capacity to train others, communication skills, team work.
'Carers'	GPs, social workers, childcare workers, fitness instructors, surgeons, counsellors and beauty therapists.	Screening, first aid, patient care, cleaning, occupational health & safety, data entry, case management, clinical experience, rehabilitation, child protection, psychology, therapy.	Communication skills, team work, teaching, customer service, problem solving, research, planning, time management, detail-orientation.
'Co-ordinators'	Bookkeepers, printers, fast food cooks, bus drivers, furniture removalists, law clerks, receptionists and car park attendants.	Data entry, contract management, word processing, invoicing, scheduling, food safety, cooking.	Time management, detail-orientation, digital literacy, communication skills, team work, customer service.
'Designers'	Architects, electrical engineers, clothing patternmakers, food technologists, building inspectors, product testers, industrial engineers, geologists and draftspersons.	Contract management, procurement, inspection business process, scheduling, civil engineering, concept development, construction management, estimating, computer-aided design.	Problem solving, digital literacy, planning, quality assurance, project management, time management.
'Informers'	Primary and secondary school teachers, economists, intelligence officers, accountants, policy analysts, physicists, solicitors, organisational psychologists, museum curators, and HR advisers.	Data analysis, report writing, financial analysis, risk management, policy development, curriculum development, lesson planning.	Communications skills, written communication, teaching, problem solving, creativity, research, detail-orientation, project management, digital literacy.
'Technologists'	Programmers, software engineers, database administrators, web designers and ICT business analysts.	Programming, coding, designing, analysis	Communication skills, customer services, team work, detail-orientation, planning, quality assurance, project management.

Source: Adapted from FYA (Foundation for Young Australians) (2016), Exhibits 2, 4 and 5.

used tool that has the advantage of opening its assumptions to scrutiny. This transparency is intended to foster discussion and to avoid the biases associated with some other forms of prospective analysis.

Several recent scenario-based studies provide relevant information. Rather than developing our own separate scenarios here, we attempt instead to provide a discussion and synthesis of the following selected, key studies that have described possible futures for jobs, skills and the labour market.

We first outline the findings of three major international reports from different jurisdictions:

- From Europe: *The future of work: The meaning and value of work in Europe* (Méda, 2016) – a report prepared under the auspices of the International Labour Office (ILO);
- From the United Kingdom: *The Future of Work: Jobs and Skills in 2030* (UKCES, 2014);
- From the United States: *Shift: The Commission on Work, Workers, and Technology* (Shift, 2017)

These reports each contain a number of scenarios: some are optimistic, some more mixed, and some pessimistic. Table 2 summarises and compares these scenarios. We discuss each in further detail below, categorised (in our judgment) as optimistic, mixed, or pessimistic.

We then attempt to bring the discussion closer to Australian circumstances, by considering the scenarios from a notable recent report by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2016), entitled *Australia 2030: Navigating Our Uncertain Future*.

These four reports differ slightly in their purposes. Some offer scenarios for the quantity of work that might be available in the future and how workers might be engaged to do it, while others are concerned with what kinds of industries might dominate and how they would shape the future labour market. Nevertheless, there is enough overlap in these reports and their scenarios—all of them emphasising the impacts of technology on the economy and the labour market—to provide a basis for useful comparisons.

4.3.1 - International Scenarios

Optimistic scenarios

Both the Méda (2016) and Shift (2017) reports contain scenarios that are largely optimistic. In the first case, this scenario is called 'Ecological Conversion' and describes a world in which full employment, quality work and environmental stability have become mutually enforcing ideals. This scenario proposes that, contrary to some suggestions, widespread job losses and dramatic increases in prices are not the necessary corollary of environmental sustainability. Instead, it imagines a labour market that has been remade with an emphasis on worker autonomy and more personalised economic relationships, like those described by Crawford (2009). In this scenario, the world of work is transformed, so that:

'...our guiding light will no longer be the indicator calculating in exclusively monetary terms the greater amounts produced and the added human value, but physical, biological and social markers of the goods produced to satisfy social needs, framed in social and environmental norms compatible with the reproduction of society.' (Méda, 2016: 21)

There is some overlap between this optimistic scenario and the one from the Shift (2017) report. Titled 'Go Economy', this scenario describes a world in which there is sufficient work and where jobs, rather than fragmented task-based 'gigs', form the basis of how that work is done. In these ways, the jobs and labour market envisaged in the 'Go Economy' would be similar to those described in the 'Ecological Conversion' scenario: secure, meaningful work with an emphasis on minimising any sense of alienation workers may experience from their labour.

These two scenarios have different emphases, however. 'Ecological Conversion' describes a world in which environmental sustainability has been achieved through a more craft-based, artisanal labour market. In contrast, 'Go Economy' stresses the importance of technological advancement

Table 2 - Scenarios of the future: a comparison of major reports

Report (Country)	Scenario outlook for the future: Optimistic		Mixed		Pessimistic
***Shift: The Commission on Work, Workers and Technology* (US)**	***Go economy*** *A technology-driven economy in which people embrace connectivity in every area of their lives and look for ways that machines can extend their capabilities through data platforms, electronic devices and virtual reality.*		***Jump Rope economy*** *A strong economy creates an abundance of opportunities for work, but in the form of discrete tasks, not ongoing employment in jobs.*	***Rock, Paper, Scissors economy*** *A community-based, local, and sustainable economy that prioritises work in person-to-person interactions. Overall, the quantity of available work has declined, but it is allocated as more discrete, paid tasks, not jobs*	***King of the Castle economy*** *An economy dominated by large corporates, where fewer quality jobs are concentrated, thereby accentuating the economic and social divide between the "haves" and the "have nots".*
The Future of Work: The Meaning and Value of Work in Europe (Eur)	***Ecological Conversion*** *Environmental sustainability is prioritised, growing trend towards niche forms of production, 'green' products & services, and job sharing. Will also involve significant transition costs as some unsustainable sectors are shut down or significantly diminished, some sectors are transformed, and new, more sustainable sectors are created.*		***Technological Revolution*** *The acceleration of technological advances has disruptive effects but ultimately triggers economic growth and a profound change in the way work and production is organised.*		***The Deregulated Economy*** *Economic forces and technological disruption generate growing pressure to deregulate markets and, in particular, dismantle labour law protections, to drive economic growth in an uncertain world.*
The Future of Work: Jobs and Skills in 2030 (UK)		***Skills Activism*** *Technological innovation drives the automation of professional work, leading to large-scale job losses and political pressure prompting an extensive government-led skills programme*	***Forced Flexibility*** *Greater business flexibility and incremental innovation lead to modest growth in the economy – but this flexibility often results in less opportunity and weakened job security for the low skilled*	***Innovation Adaptation*** *Against the backdrop of a chaotic global economy with faltering trade, and a stagnant economy, productivity is improved though a systematic implementation of ICT solutions*	***The Great Divide*** *Despite robust growth driven by strong hi-tech industries, a two-tiered, divided society has emerged, reinforcing the divergence in the economic position of the 'haves' and 'have nots'.*
Australia 2030: Navigating Our Uncertain Future (Australia)	***Digital DNA*** *Australia experiences a dramatic shift towards digital services and a knowledge-driven economy made possible by the exponential growth of computing power and an increasingly connected world, and the wide range of new technologies this enables.*	***Clean and Lean*** *Decoupling of economic growth and environmental sustainability has led countries to simultaneously pursue both objectives. Consumers seek out healthier lifestyles and Australia works with other economies to address carbon abatement, resource efficiency and sustainability.*	***Mining and Dining*** *Australia's economy benefits from a 2nd wave of the resources boom driven by growth and urbanisation in developing economies. Minerals, energy and food represent the majority of Australian exports and are the underpinning wealth generators for the economy.*		***Weathering the storm*** *Global geopolitical instability increases, driven by climate change and regional conflicts over access to land, food and water. Tensions threaten to destabilise trade alliances and disrupt global supply chains, leading to prolonged global economic stagnation.*

and artificial intelligence and the increasing interconnectedness of workers at a global level.

Mixed scenarios

Across the four reports reviewed in this section, we consider most of the scenarios to be neither optimistic nor pessimistic but mixed in outlook. Indeed, we do not regard *any* of the scenarios in the UKCES (2014) report as optimistic. In our view, three of their scenarios are mixed. The first of these is called 'Skills Activism'. This scenario foresees a world in which technological change has driven the automation of work, including of skilled jobs, to the point of widespread technological unemployment. As a result, political pressure—which takes the form of 'skills activism'—mounts on government to rebuild the labour market, which it does through significant investment in a skills programme. So, while this scenario shows a beneficial outcome in the long run, it is characterised by significant medium-term social and economic upheaval.

A number of scenarios share a concern for the continued fragmentation of jobs into tasks. In its 'Rock, Paper, Scissors Economy' scenario, the Shift (2017) report envisages a decline in the overall quantity of work, and increasing reliance on time-based tasks ('gigs') rather than jobs. This scenario is not wholly pessimistic, however; it also anticipates a more sustainable economy of community-based local networks appearing in place of the traditional labour market.

The two most similar of the 'mixed' scenarios are the UKCES (2014) 'Forced Flexibility' and Shift (2017) 'Jump Rope Economy'. Both describe a future labour market characterised by insecure employment relations and fragmented tasks for those at the bottom of the skills distribution. Both of these scenarios anticipate continued economic growth and sustained labour demand, but with employment opportunities and earnings becoming even further polarised between those with and without high-level skills.

Also similar are the UKCES (2014) 'Innovation Adaptation' and Méda (2016) 'Technological Revolution' scenarios. Each of these foresees technology having a dramatic impact on the labour market, triggering profound changes in work organisation. Both describe a future in which a stagnant economy is revived through the ongoing uptake of new information and communication technologies. For employees, the outcomes are mixed (and again divided), with reduced job security for many, but improving opportunities for the highly skilled. The Méda (2016) report points out that, although this sort of scenario is frequently discussed, too little consideration is generally given to the likely resistance that it would trigger from the many current workers whose jobs (and livelihoods) are displaced.

Pessimistic scenarios

Between the three international reports, there is perhaps the strongest convergence in their respective pessimistic scenarios. Each considers the emergence of a fundamentally weak future labour market, with fewer worker protections, endemic unemployment, and gaping social inequality. In the UKCES (2014) report, this scenario is called 'The Great Divide'. This scenario describes a world in which rapid technological change has driven strong growth in a few sectors but has widened the gap between 'haves' and 'have-nots'. It closely resembles the Shift's (2017) 'King of the Castle Economy', in which the economy is dominated by large corporations employing a small 'core' of workers on secure terms, to the exclusion of broad sections of the population.
In this scenario:

'...society splits into three classes: those who work in high-tech jobs at large, profitable companies... those who have full-time jobs protecting the people and assets in the corporate class... and those who perform on demand work, when it is available.' (Shift, 2017: 13)

These scenarios are justifiably seen by both reports as paths to political and social unrest. Méda (2016) predicts similarly undesirable outcomes in a scenario called 'The Deregulated Economy', in which governments have actively dismantled labour market protections in response to technological disruptions. The importance of this scenario is its focus on the role of government policy choices in leading human societies away from (or toward) the less-attractive alternative visions of our future. Even when technological changes tend to draw societies in the direction of greater inequality and division, these tendencies are not inevitable or beyond control. Effectively targeted policy making can work to slow or resist some of these tendencies. Equally, however, as Méda's (2016) pessimistic scenario makes clear, poorly-judged policies can magnify problems and lead even more quickly to unrest.

4.3.2 - Scenarios for Australia's Future

The CSIRO's (2016) scenarios on the future of the Australian economy and labour market can also be viewed broadly in terms of their optimism and pessimism. On the positive side, 'Digital DNA' is a sketch of a future Australian labour market in which there has been a drastic shift toward digital services and a knowledge-driven economy. This positive scenario emerges through continuing exponential growth in computer processing power and the increasing capacities of information and communication technologies. In this scenario, Australia is 'stable, wealthy, and heavily connected into global supply chains and trade networks' (CSIRO, 2016: 14).

'Digital DNA' differs from both the 'Innovation Adaptation' (UKCES, 2014) and 'Technological Revolution' (Méda, 2016) international scenarios, in that it envisions relatively few negative social impacts and externalities from pervasive technological advancements. For this reason, it is closest to the Shift report's (2017) 'Go Economy' scenario.

CSIRO's (2016) other optimistic scenario, 'Clean and Lean', portrays a possible future in which the imperative for economic growth has been subordinated to environmental sustainability. Coordinated global action on climate change, combined with consumer preferences for more sustainable lifestyles, gives rise to a new economy built on triple bottom line accounting—taking into account the economic, environmental and social impacts of decisions. In this scenario, a new labour market also emerges in which work-life balance and wellbeing are prioritised. The 'Clean and Lean' scenario for Australia closely mirrors the international 'Ecological Conversion' scenario (Méda, 2016): both envision an economy in which environmental and social considerations have much greater importance.

'Mining and Dining' presents a more mixed outlook. In this scenario, the Australian economy benefits from resurgent resource prices, driven by continuing rapid growth in developing countries. The mining and agricultural sectors benefit greatly at the expense of other sectors, such as manufacturing. Some high-quality jobs are created in growth sectors but other middle-class jobs disappear. Overall, the economy remains reasonably strong, but there are negative social impacts from growth, and further detriment to the environment.

The most pessimistic of the CSIRO's (2016) scenarios is called 'Weathering the Storm.' This describes a world in which global geopolitical tensions, climate change and disrupted trade cause prolonged economic stagnation. In response, Australia expends substantial public and private resources building domestic production capacity to meet its own needs in areas such as manufacturing and electronics. Economic growth is slow, social cohesion is eroded and the environment suffers. The labour market in this scenario would be likely to resemble the more pessimistic international outlooks discussed above, with high unemployment, reduced worker protections, and deepening inequality.

4.3.3 - Key themes from the scenarios

One of the recurring themes from these various reports and scenarios is the importance of agency. To some extent, each report emphasises that the design of technology, and the responses to new technologies from labour market actors and social policy makers, are ultimately human decisions. Government policies, along with the decisions of businesses, workers and their representatives, guide the direction and impacts of technological change.

In this context, there is a broad consensus about the enduring importance of public and private investments in human capital. Education and skills remain essential, as partial insurance against technological unemployment, as a basis for innovation and competition, as a contributor to individual resilience and adaptability to change, and as a bulwark against further deepening of inequalities in opportunity. A policy suite intended to capture the best of new technology, while cushioning against its negative consequences, would thus have education, skills and human capital development at its core.

5. Conclusion

In this report, we have sought to evaluate the available evidence relating to the impact of technological innovation on labour markets, occupations, jobs and skill needs.

The starting point for our evaluation was an assessment of how technological innovations have intersected with work organisation and the production of goods and services. Here, the evidence highlights an array of complementary technological innovations that appear to have increasingly disruptive effects on the world of work: the growing ubiquity of ICT, CBT and AI technologies, which together have generated a number of discontinuities in the way technologies have been developed and applied in industry, as well as technical advances in genomics, bioengineering and other areas, creating new sources of growth and value. These innovations are not simply technical ones, but have also reshaped business models across a range of sectors, creating new sources of value, undermining established models, and altering the basis of competition between firms within traditional sectors as well as creating new industries and sources of jobs for the future. A key concern within this literature is the extent to which these technologies have begun to displace humans in the workplace. While there is clear evidence that this trend has grown more prevalent in the context of routine jobs and production, automation has increasingly extended into more complex tasks and processes.

This concern has, in turn, spurred a strong interest in identifying the effects of such technological innovations on employment – both in terms of the amount of work available, and the potential 'distributive' effects of these technologies on the types and locations of work demanded. Notwithstanding early estimates suggesting that automation would have an overwhelming destructive effect in coming decades, more careful consideration of both existing trends, and more robust approaches to projecting these trends into the future, reveals a less dramatic impact of automation, with the most recent estimates suggesting that around 1 in 10 jobs are at high risk of full automation. By contrast, estimates indicate a significantly stronger effect on job and occupational transformation, as tasks that make up jobs and the skills required to do them are reconfigured to accommodate technological change. In assessing the pattern of job destruction, this more careful analysis reveals that other factors are also likely to play a significant role in shaping patterns of net employment growth – including the impacts of trade and investment in new productive capacity, which entails shifting employment opportunities from one location to another within global value chains. These developments are only shaped in part by technological forces and choices.

Our assessment suggests that the more profound consequences of technological innovations are likely to be manifest in the *patterns* of job creation and destruction. This is widely known as the polarisation or 'hollowing-out' hypothesis, with net job creation most concentrated in highly-skilled (and higher-paying) and low-skilled occupational categories.

In understanding these patterns, it is important to be cautious in assuming that the trends are the same across countries. Although there are some remarkably common trends across different economic and institutional settings, the international data reveal the confluence of technological changes and its consequences varies considerably from country to country. This begs the question: what does Australian evidence reveal? In this context, it is perhaps important to keep in mind the particular trajectory of economic growth in Australian over the last decade or so, compared with other countries where the global financial crisis was associated with a significantly stronger adverse consequence for employment and growth.

Our assessment of the evidence concluded that over the last three decades the Australian labour market has generally outperformed the US (and other national economies), reflected in both higher labour force participation, especially among women and older cohorts, and more muted evidence of occupational hollowing out through the net destruction of mid-level jobs. Moreover, the evidence does not generally reveal marked shifts in employment patterns in areas we might expect to have observed, if technological changes were having dramatic effects – in terms of the growth of 'atypical' work arrangements, self-employment, or the prevalence of teleworking.

Nonetheless, the evidence points clearly to a marked shift in the patterns of job creation and destruction – as well as in the transformation of work. Across a number of Australian studies, there is a high degree of consensus that recent decades have seen a growing tendency for job destruction to be concentrated in both low- and mid-skilled occupations. More speculative analyses about the likely future of work using scenario planning have added store to the general belief that this trend will intensify in coming decades. We stress the need to be cautious in interpreting these scenarios as 'facts'. As we have shown, the scenarios vary widely across the spectrum of positive and negative sentiment, and there is no strong basis on which to presume that any one of these scenarios necessarily represents the future. As any reflection on prior attempts to envision the future in this more open and speculative way suggest, scenario planning has its uses, but cannot be taken as a substitute for an evidence-based assessment of what is actually happening.

The developments that we describe have implications for skills, as a small but hopefully growing number of studies also demonstrate. This work addresses two separate but related issues: first, the attendant effects of automation on jobs that require different levels of skill; and, second, the extent to which new technologies are likely to reshape the bundles of skills required in different occupations and jobs. Insofar as patterns of job change are associated with hollowing out across the skills hierarchy, trend analysis leads us to anticipate further growth in employment at the extremities of the skills distribution. As for how technology is altering bundles of skills, two salient pieces of evidence cast light on what is happening: the first is the growing prevalence of STEM skill requirements across a broader array of jobs and occupations, and the second is the mixing of both STEM and HASS skills in many jobs that had previously required mainly one or the other type. Finally, the evidence shows that skills mixing may be associated with a reconfiguration of job clusters, with workers gaining new capacities to move between what were previously viewed as unrelated jobs.

What likely trends do we anticipate for the decades ahead? As noted, projecting scenarios into the future is hazardous for all sorts of reasons. Nonetheless, scenario-based planning does provide for some consideration of different possible futures. As our assessment of the most systematic attempts at scenario planning revealed, this approach also highlights that as individuals, members of organisations, and societies, we have considerable capacity to influence the trajectory and impact of technology on work and jobs.

Overall, our analysis shows the importance of trying to weigh both the negative and positive consequences of change and innovation on work and skills. This requires effort in a number of policy areas, including: labour market regulation, skills and education policies, and social welfare arrangements. The aim is to find a balance between minimising the adverse effects of technology on the quantity and quality of work, while promoting ongoing innovation and maximising the potential 'upsides' of the wave of technological innovations now underway.

ABS (Australian Bureau of Statistics) (1996) *Transition from Education to Work, Australia, May 1996*, Catalogue no. 6227.0, Canberra.

ABS (Australian Bureau of Statistics) (2014) *Australian Labour Market Statistics, July 2014*, Data cubes, 'Employment type'. Table 1. Employed persons by Sex, Full-time/part-time and Age. Catalogue no. 6105.0, Canberra.

ABS (Australian Bureau of Statistics) (2015) *Information Paper: Construction of Experimental Statistics on Employee Earnings and Jobs from Administrative Data, Australia, 2011-12*. Catalogue no. 6311.0, Canberra.

ABS (Australian Bureau of Statistics) (2017a) *Education and Work, Australia, May 2016*, customised data produced using ABS TableBuilder, Catalogue no. 6227.0, Canberra.

ABS (Australian Bureau of Statistics) (2017b) *Labour Force, Australia, Detailed - Electronic Delivery, Jun 2017*, Time series spreadsheets, 'Table 8: Employed persons by status in employment of main job and sex', Catalogue no. 6291.0.55.001, Canberra.

ABS (Australian Bureau of Statistics) (2017c) *Labour Force, Australia, Detailed, Quarterly, May 2017*, Time series spreadsheets, 'Table 7: Employed persons by occupation major group of main job (ANZSCO) and sex', Catalogue no. 6291.0.55.003, Canberra.

Acemoglu, D. and Restrepo, P. (2017) 'Robots and jobs: Evidence from US labor markets', Working paper no. 23285, National Bureau of Economic Research, Cambridge, MA.

Agrawal, A., Horton, J., Lacetera, N. and Lyons, E. (2015). *Digitization and the Contract Labor Market: A Research Agenda*: University of Chicago Press.

Arntz, M., Gregory, T. and Zierahn, U. (2016) 'The risk of automation for jobs in OECD countries', OECD Social, Employment and Migration Working Papers no. 189, Paris: Organisation for Economic Cooperation and Development.

Aronowitz, S. and DiFazio, W. (1994) *The Jobless Future: Sci-Tech and the Dogma of Work*, Minneapolis: University of Minnesota Press

Atkinson, R. and Wu, J. (2017) 'False alarmism: Technological disruption and the US labor market, 1850-2015', Report, Information Technology and Innovation Foundation, Washington, DC.

Autor, D. (2015) 'Why are there still so many jobs? The history and future of workplace automation', *Journal of Economic Perspectives*, 29(3): 3-30.

Autor, D. and Dorn, D. (2013) 'The growth of low-skill service jobs and the polarization of the US labor market', *American Economic Review*, 103(5): 1553-1597.

Autor, D., Levy, F. and Murnane, R. (2003) 'The skill content of recent technological change: An empirical exploration', *Quarterly Journal of Economics*, 118(4), 1279-1333.

Autor, D. and Wasserman, M. (2013) *Wayward sons: The emerging gap in labor markets and education*. Report, Third Way: Washington, DC.

Baldwin, R. (2016) *The Great Convergence: Information Technology and the New Globalization*, Cambridge, MA: Harvard University Press.

Beerepoot, N. and Lambregts, B. (2015). Competition in online job marketplaces: towards a global labour market for outsourcing services? *Global Networks*(2), 236. doi: 10.1111/glob.12051

Bernhardt, A. (2016). It's Not All About Uber. *Perspectives on work, 20*, 14.

Bersin, J., Mariani, J. and Monahan, K. (2016) 'Will IoT technology bring us the quantified employee?' *Deloitte University Press.* Available at: bit.ly/2rcLmXK (accessed 7 June 2017).

Borland, J. (2016a) 'Are our jobs being taken by robots?' Labour market snapshot #31, September 2016. Available at: bit.ly/2bvwCfs (accessed 27 July 2017).

Borland, J. (2016b) 'How has the volume of work affected GDP per capita in Australia?' Labour market snapshot #26, April 2016. Available at: bit.ly/2bvwCfs (accessed 27 July 2017).

Borland, J. and Coelli, M. (2015) 'Labour market inequality in Australia', *Economic Record*, 92(299): 517-47.

Bradlow, H. (2015). *The impact of emerging technologies in the workforce of the future*. Melbourne: Committee for the Economic Development of Australia. Report.

Brynjolfsson, E. and McAfee, A. (2014). *The second machine age : work, progress, and prosperity in a time of brilliant technologies*: New York : W. W. Norton & Company, [2014] First Edition.

Castells, M. (2010). *The rise of the network society*: Chichester, West Sussex ; Malden, MA : Wiley-Blackwell, 2010. 2nd ed.

Chesbrough, H. (2010). 'Business model innovation: Opportunities and barriers', *Long Range Planning, 43*, 354-363. doi: 10.1016/j.lrp.2009.07.010

Coelli, M. and Borland, J. (2016) 'Job polarisation and earnings inequality in Australia', *Economic Record*, 92(296): 1-27.

Cohen, B., and Kietzmann, J. (2014). 'Ride on! Mobility business models for the sharing economy', *Organization and Environment*, 27(3), 279-296.

Crawford, M. (2009) *Shop Class as Soulcraft: An Inquiry Into the Value of Work*. The Penguin Press.

CSIRO (2016) *Australia 2030: Navigating Our Uncertain Future*. Commonwealth Scientific and Industrial Research Organisation, Futures Series Report.

Cunningham, S., Theilacker, M., Gahan, P., Callan, V. and Rainnie, A. (2016) *Skills and Capabilities for Australian Enterprise Innovation*, Report: Australian Council of Learned Academies, Canberra.

Dobbs, R., Woetzel, J. R. and Manyika, J. (2015). *No Ordinary Disruption : The Four Global Forces Breaking All the Trends*. New York: PublicAffairs.

Dosi, G. and Kogut, B. (1993). National Specificities and the Context of Change: The Co-evolution of Organization and Technology. In B. Kogut (Ed.), *Country competitiveness: Technology and the organizing of work* (pp. 249-262): Melbourne: Oxford University Press.

Dunlop, T. (2016) *Why the Future is Workless*, Sydney: New South Publishing.

Dunn, M. (2015). Going, Going, Gone: The Online Labor Market and the Global Reverse Auction For Jobs. *Conference Papers: American Sociological Association*, i-67.

Durrant-Whyte, H., McCalman, L., O'Callaghan, S., Reid, A. and Steinberg, D. (2015). *The impact of computerisation and automation on future employment*. Melbourne: Committee for the Economic Development of Australia.

Dvorkin, M. (2016) 'Jobs involving routine tasks aren't growing', Federal Reserve Bank of St Louis, *On the Economy* Blog, 4 January 2016. Available at: bit.ly/1n7P7w1 (accessed 18 June 2017).

Finkel, A. (2015). Reflecting on the future of work in Australia: Pessimism, optimism and opportunities. *Journal and Proceedings of the Royal Society of New South Wales* (457/458), 125.

Ford, M. (2015) *Rise of the Robots: Technology and the Threat of a Jobless Future*, New York: Basic Books.

Frey, C. and Osborne, M. (2013) 'The future of employment: How susceptible are jobs to computerisation?' Working paper, Oxford Martin School, University of Oxford.

Furman, J. (2016) 'Is this time different? The opportunities and challenges of artificial intelligence', Speech at New York University, New York, 7 July 2016. Available at: bit.ly/2mxLdQg (accessed 7 June 2017).

FYA (Foundation for Young Australians) (2016) *The New Work Mindset: 7 New Job Clusters to Help Young People Navigate the New Work Order*. Available at: bit.ly/2oAurBB (accessed 31 July 2017).

Gahan, P., Harbridge, R., Healy, J. and Williams, R. (2016) 'The ageing workforce: Policy dilemmas and choices', *Australian Journal of Public Administration*, Published online 9 December 2016.

Gahan, P., Healy, J. and Nicholson, D. (2017) Technology, the Digital Economy and the challenge for Labour Market Regulation. In: Eds: Howe, J., Chapman, A. & Landau, I.: *The Evolving Project of Labour Law: Foundations, Development and Future Research Directions*. Melbourne: The Federation Press.

Girotara, K. and Netessine, S. (2014) 'Four Paths to Business Model innovation.' *Harvard Business Review.* Available at: hbr.org/2014/07/four-paths-to-business-model-innovation (accessed 05 June 2017).

Godet, M. (2000) 'The art of scenarios and strategic planning: Tools and pitfalls,' *Technological Forecasting and Social Change,* 65: 3-22.

Goos, M. and Manning, A. (2007) 'Lousy and lovely jobs: The rising polarization of work in Britain', *Review of Economics and Statistics*, 89(1): 118-133.

Goos, M., Manning, A. and Salomons, A. (2014) 'Explaining job polarization: Routine-biased technological change and offshoring', *American Economic Review*, 104(8): 2509-2526.

Healy, J. (2015) 'Graduating into a weak job market: why so many grads can't find work', *The Conversation*, 29 July 2015. Available at: bit.ly/1MTUV3g (accessed 28 June 2017).

Healy, J. (2016) 'The Australian labour market in 2015.' *Journal of Industrial Relations*, 58(3): 308-323.

Heath, A. (2016) 'The changing nature of the Australian workforce', Speech to *CEDA – Future Skills: The Education and Training Pipeline* conference, Brisbane, 21 September 2016. Available at: bit.ly/2uLGACd (accessed 11 August 2017).

Ho, J.C. and Lee, C.-S. (2015). A typology of technological change: Technological paradigm theory with validation and generalization from case studies. *Technological Forecasting & Social Change, 97*, 128-139.

Holtgrewe, U. (2014). 'New new technologies: the future and the present of work in information and communication technology.' *New Technology, Work & Employment,* 29(1): 9-24.

Howcroft, D. and Taylor, P. (2014). 'Plus ça change, plus la meme chose?' Researching and theorising the 'new' new technologies. Editorial, *New Technology, Work & Employment,* 29:1, p. 1-8.

Hunter, L. W. (2001). It's not Just the ATMs: Technology, Firm Strategies, Jobs, and Earnings in Retail Banking. *Industrial & Labor Relations Review*, 54(2): 402-424.

Kane, C. (2015). 'Why some employers are ditching the office — literally.' *Fortune.* Available at: fortune.com/2015/05/15/office-less-virtual-companies/ (accessed 15 June 2017).

Kaplan, J. (2015) 'The age of the robot worker will be worse for men', *The Atlantic*, 4 August 2015. Available at: theatln.tc/2uh1dGL (accessed 28 June 2017).

Knight, W. (2016) AI Winter Isn't Coming. *MIT Technology Review.* Available at: www.technologyreview.com/s/603062/ai-winter-isnt-coming/ (accessed 31 May 2017).

Lee, T. (2017). Artificial intelligence is getting more powerful, and it's about to be everywhere. *Vox*. Available at: www.vox.com/new-money/2017/5/18/15655274/google-io-ai-everywhere (accessed 29 May 2017).

Leslie, I. (2014) 'Kodak vs Instagram: This is why it's only going to get harder to make a good living.' *NewStatesman.* Available at: www.newstatesman.com/politics/2014/01/kodak-vs-instagram-why-its-only-going-get-harder-make-good-living (accessed 9 June 2017).

Levy, F. and Murnane, R. (2013) *Dancing with Robots: Human Skills for Computerized Work*. Report, Third Way: Washington, DC.

Levy, F. and Murnane, R. J. (2004). *The new division of labor: how computers are creating the next job market.* Princeton, NJ : Princeton University Press.

Marx, L. and Smith, M.R. (1994). *Does technology drive history? The dilemma of technological determinism.* Cambridge, Mass.: MIT Press.

McAfee, A. and Brynjolfsson, E. (2012). 'Big Data: The Management Revolution.' *Harvard Business Review.* Available at: hbr.org/2012/10/big-data-the-management-revolution (accessed 1 June 2017).

Méda, D. (2016) 'The future of work: The meaning and value of work in Europe.' ILO research paper no. 18, Geneva: International Labour Office.

Michaels, G., Natraj, A. and Van Reenen, J. (2014) 'Has ICT polarized skill demand? Evidence from eleven countries over twenty-five years', *Review of Economics and Statistics*, 96(1): 60-77.

Mietzner, D. and Reger, G. (2005) 'Advantages and disadvantages of scenario approaches for strategic foresight', *International Journal of Technology Intelligence and Planning*, 1(2): 220-239.

Miller, C.C. (2017) 'Man versus machine: Evidence that robots are winning the race for jobs.' *The Age* (March 29, 2017). Available at: www.smh.com.au/business/workplace-relations/man-versus-machine-evidence-that-robots-are-winning-the-race-for-jobs-20170328-gv8mub.html (accessed 5 June 2017)

Minifie, J. and Wiltshire, T. (2016) Peer-to-peer pressure: Policy for the sharing economy, Grattan Institute Report no. 2016-7, Melbourne.

Mishel, L. and Bivens, J. (2017) 'The zombie robot argument lurches on', Report, Economic Policy Institute, Washington, DC. Available at: epi.org/126750 (accessed 7 June 2017).

Mitchell, T. & Brynjolfsson, E. (2017) 'Track how technology is transfoming work.' *Nature:* vol. 544; p.290-92.

Mokyr, J., Vickers, C. and Ziebarth, N. L. (2015). 'The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different?' *Journal of Economic Perspectives,* 29:3.

Moon, Y. (2015). Uber: Changing the Way the World Moves. *Harvard Business School Cases:* Nov. 01, 2015, p. 1, 20p.

National Academies of Sciences, Engineering, and Medicine (2017) *Information Technology and the US Workforce: Where Are We and Where Do We Go from Here*? Report of the Committee on Information Technology, Automation, and the US Workforce. Washington, DC: The National Academies Press. Available at: www.nap.edu/read/24649 (accessed 15 June 2017).

OECD (2017) *OECD Employment Outlook 2017*, Paris: Organisation for Economic Cooperation and Development. Available at: dx.doi.org/10.1787/empl_outlook-2017-en (accessed 26 July 2017).

OECD.Stat (2017a) *Dataset: Decile ratios of gross earnings*. Online resource. Available at: stats.oecd.org/Index.aspx?DataSetCode=DEC_I (accessed 31 July 2017).

OECD.Stat (2017b) *Dataset: Labour force statistics by sex and age*. Online resource. Available at: stats.oecd.org/Index.aspx?DataSetCode=LFS_D (accessed 31 July 2017).

Peck, D. (2013) 'They're Watching you at Work.' *The Atlantic*. Available at: dupress.deloitte.com/dup-us-en/focus/internet-of-things/people-analytics-iot-human-resources.html (accessed 7 June 2017).

Porter, M.E. and Heppelmann, J.E. (2015). 'How smart, connected products are transforming companies.' *Harvard Business Review*(10), 96.

Rayner, J. (2016) *Generation Less: How Australia is Cheating the Young*. Carlton, Victoria: Redback Quarterly.

Redrup, Y. (2015) 'Deliveroo to launch in Australia after $140 million capital raising.' *Australian Financial Review* (November 24 2015). Available at: bit.ly/2rtYbxJ (accessed 7 June 2017).

Regional Australia Institute (2015). 'The Future of Regional Australia: Change on Our Terms.' Regional Australia Institute Discussion Paper, Novemeber 2015.

Regional Australia Institute (2016). 'The Future of Work: Setting Our Kids Up for Success.' Regional Australia Institute: Report, November 2016.

Rifkin, J. (1995) *The End of Work: The Decline of the Global Workforce and the Dawn of the Post-Market Era*, London: Penguin Books.

Schwab, K. (2016). *The fourth industrial revolution*. Geneva, Switzerland: World Economic Forum.

Schwartz, P. (1991) *The Art of the Long View: Planning for the Future in an Uncertain World*, New York, Doubleday.

Seek (2015) *Seek Annual Report: Employment, Education, Volunteer, Commercial*.

Sherk, J. (2010). Technology Explains Drop in Manufacturing Job. *The Heritage Foundation:* Report.

Shift (2017) *Report of Findings: The Commission on Work, Workers, and Technology*. New York, Bloomberg.

Simonite, T. (2016) 'Moore's Law is dead. Now what?' *MIT Technology Review*, 13 May. Available at: bit.ly/1VVn5CK (accessed 25 July 2017).

Smidt, M., Becker, K., & Bradley, L. (2015). Forces shaping the future of work in a changing regional economy. *Australasian Journal of Regional Studies*, (3), 349.

Solow, R. (1987) 'We'd better watch out' (Review of *Manufacturing Matters: The Myth of the Post-Industrial Society*), *The New York Times Book Review*, 12 July 1987, page 36.

Srnicek, N. and Williams, A. (2015) *Inventing the Future: Postcapitalism and a World Without Work*, London: Verso Books.

Staples, M., Chen, S., Falamaki, S., Ponomarev, A., Rimba, P., Tran, A. B., Weber, I., Xu, X., Zhu, J., (2017) Risks and opportunities for systems using blockchain and smart contracts. *Data61* (CSIRO), Sydney.

Stewart, I., De, D. and Cole, A. (2015) 'Technology and people: The great job-creating machine', London: Deloitte. Available at: bit.ly/2qVLbjA (accessed 5 June 2017).

Stewart, J. and Williams, R. (1998) 'The coevolution of society and multimedia technology: Issues in predicting the future innovation and use of a ubiquitous technology,' *Social Science Computer Review*, 16(3): 268-282.

Susskind, R. E. and Susskind, D. (2015). *The future of the professions: how technology will transform the work of human experts*: Oxford, United Kingdom : Oxford University Press, 2015. First edition.

The Economist (2016). After Moore's Law. Technology Quarterly: The Economist. Available at: www.economist.com/technology-quarterly/2016-03-12/after-moores-law (accessed 30 May 2017).

The White House (2016) *Artificial Intelligence, Automation, and the Economy*, Report, Executive Office of the President of the United States, Washington, DC. Available at: bit.ly/2jsebMI (accessed 14 June 2017).

Thompson, D. (2015) 'A world without work' *The Atlantic*, July/August 2015 issue. Available at: theatln.tc/2kCryhc (accessed 7 June 2017).

Thompson, D. (2017) 'So, where are all those robots?' *The Atlantic*, 31 May 2017. Available at: theatln.tc/2qJPTk9 (accessed 7 June 2017).

UKCES (2014) *The Future of Work: Jobs and Skills in 2030*. London: UK Commission for Employment and Skills.

Vidot, A. (2016) 'Almost half of regional Australians report internet is 'very poor', 'inadequate': University of Canberra survey.' *ABC News*, 21 June. Available at: ab.co/2fxivNL (accessed 11 August 2017)

Walport, M. (2015) 'Distributed Ledger Technology: Beyond Block Chain.' *United Kingdom Government Chief Scientific Advisor:* Report, London.

Walsh, T. (2017) *It's Alive! Artificial Intelligence from the Logic Piano to Killer Robots*. La Trobe University Press: Melbourne.

Weldon, D. (2017) 'Robots and software may not be taking your job after all', *Australian Financial Review*, 20 April 2017. Available at: bit.ly/2riQZEU (accessed 15 June 2017).

Whiteford, P. (2017) 'Here's why it's so hard to say whether inequality is going up or down', The Conversation, 2 August. Available at: bit.ly/2u1xzFQ (accessed 10 August 2017).

Wilkins, R. (2017) *The Household, Income and Labour Dynamics in Australia Survey: Selected Findings from Waves 1 to 15 – The 12th Annual Statistical Report of the HILDA Survey*, Melbourne Institute of Applied Economic and Social Research, The University of Melbourne.

Wilkins, R. and Wooden, M. (2014) 'Two decades of change: The Australian labour market, 1993-2013', *Australian Economic Review*, 47(4): 417-431.

Wingfield, N. and Scott, M. (2016) 'In Major Step for Drone Delivery, Amazon Flies Package to Customer in England.' *The New York Times* (December 14, 2017). Available at: nyti.ms/2rFW5iA (accessed 7 June 2017).

Wooden, M. 2001. 'Industrial Relations Reform in Australia: Causes, Consequences and Prospects.' *Australian Economic Review*, vol. 34, no. 3, pp. 243–262

Yglesias, M. (2015) 'The automation myth', *Vox*, 27 July 2015. Available at: bit.ly/2ror2UR (accessed 15 June 2017).