Are Robots Taking Our Jobs?

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Abstract

This article assesses the effect of computer-based technologies on employment in Australia. We find that: (i) The total amount of work available has not decreased; and (ii) The pace of structural change and job turnover in the labour market has not accelerated, with the increasing application of computer-based technologies. Furthermore, a review of recent studies that claim computer-based technologies may be about to cause widespread job destruction establishes several major flaws with these predictions. Our suggested explanation for why techno-phobia has such a grip on popular imagination is a human bias to believe that 'we live in special times'.

The consequences of adverse economic events are typically exaggerated by the Armageddonists – a sensation-seeking herd of pundits, seers, and journalists who make a living by predicting the worst. Prognostications of impending doom draw lots of attention, get you on TV, and sometimes even lead to best-selling books … But the Armageddonists are almost always wrong.
[Alan Blinder 2014, p. 119]

1. Introduction

Commentary today on the Australian labour market abounds with claims that the world of work is undergoing radical and unprecedented change. That change is for the most part attributed to the increased application of computer-based technologies in the workplace—most recently, artificial intelligence (AI) and robotics. To support the claims, one of two arguments is generally made: either that the new technologies are causing a reduction in the amount of available work; or that a more rapid pace of substitution of machines for humans is increasing the rate of job destruction and requiring workers to churn between jobs at a faster speed than ever before.

The following quotes—taken from the Australian literature on the future of work—illustrate each of the arguments:

'… work looks, to my eyes, like an idea that has outlived its usefulness. I would go as far to say the era of full-time work is coming to an end and we have to stop holding out the false promise that at some magical moment the jobs are going to reappear'. (Dunlop 2016, p. 4)

'The historic waves of the Industrial Revolution resulted in ever increasing replacement of human with mechanical brawn … The information and telecommunications advances detailed in this report are likely to do exactly that to a range of activities associated with traditional white-collar activity … This is not a new trend, but the pace of change is potentially considerably faster than in the past'. (Taylor 2015, p. 17)[1]

Certainly, there has been rapid growth in the use of information technology (IT) in Australia in recent decades. This can be seen in Figure 1, which shows the net capital stock of computers, software and electronic equipment in Australia from 1966 onwards.[2] The use of computers and IT in Australia began to increase from the early 1980s, and then increased much more rapidly from the mid-1990s onwards. The growth in the role of IT has been driven by a massive reduction in the cost of using computers that has also occurred since the early 1980s (see, for example, Nordhaus 2007).

Evidence for the claimed effects of computer-based technologies on the labour market, however, is remarkably thin. Sometimes it consists simply of descriptions of the new technologies, perhaps with an assertion that these technologies are more transformative than what has come before. Sometimes it consists of forecasts of the proportion of jobs that will be destroyed by the new technologies. Sometimes measures are presented that, it is argued, establish that the new technologies are causing workers to lose their jobs or be forced to shift between jobs more frequently than in the past. Sometimes the evidence is an argument that

categories of workers not previously displaced by technological change are now being affected.

Each of these types of 'evidence' has its own problems. Whether a new technology is having a transformative impact on the labour market can only be judged by analysis of its effect on labour market outcomes. Associating new technologies with the jobs that they may destroy fails to take account of the jobs that will also be created by those new technologies; and ignores that job destruction due to new technology has always been a major feature of modern economic development. Measures that are used to demonstrate higher levels of job turnover are flawed, and often contrived. And it is not uncommon for new technologies to displace workers whose jobs had previously seemed secure, without implying that aggregate job loss is increasing.

In this article we present a wide range of measures of outcomes in the Australian labour market. These measures are chosen to directly address claims regarding the effects of new technologies on employment; and are applied over a sufficient number of years to allow a perspective on whether current labour market outcomes differ from time periods prior to the introduction of new computer-based technologies.

From our analysis of employment outcomes in the Australian labour market we arrive at two main findings. First, there is no evidence that adoption of computer-based technologies has decreased the total amount of work available (adjusting for population size). Second, there is no evidence of an accelerating effect of technological change on the labour market following the introduction of computer-based technologies. Routine and manual jobs are not being replaced at a faster pace by new technologies at present than in decades prior to the adoption of computers; the rate of job churning has decreased in recent years; and the pace of change in the occupation or industry composition of employment has not increased together with the increased application of computers.

Our findings are consistent with what has been found for other countries; for example, in the United States (Autor 2014, 2015) and Europe (Gregory, Salomons and Zierahn 2016).[3] Moreover, we do not think it is difficult to explain the findings. Technological change does not have a long-run effect on aggregate employment because, although it may cause jobs to be destroyed, it has also always meant the creation of extra and new jobs. That the pace of change in the labour market is not accelerating is explained by the constancy of technological change. Major technological change has been on-going since the Industrial Revolution. Developed economies may not have previously experienced an IT revolution, but for 250 years they have been adjusting to many equally dramatic advances in technology.

Getting the facts right is always important. In this case, understanding what effects are and are not being caused by computer-based technologies matters for giving appropriate direction to public policy and thinking about the future of the Australian economy. Clearly, technological change does affect the labour market. Some workers lose their jobs, and this creates the need for policies to assist those workers to regain employment. But our point is

that this policy problem is no different today than in past decades in Australia. Time is scarce, and therefore it is better to spend time worrying about problems that actually exist. As Herbert Simon wrote 50 years ago (1966; and cited in Autor 2015, p. 28): 'The bogeyman of automation consumes worrying capacity that should be saved for real problems …'.

Our focus in this article is to address the aggregate employment consequences of computer-based technologies. It is important to say that technological change can also affect the wages and employment of specific workers, and hence the distribution of earnings and employment. There is some evidence that recent technological change is having this effect in Australia. For example, in our own previous work we have argued that changes in the distribution of and return to employment across occupations, which seem likely to have been driven to a large degree by developments in technology, have been a major cause of increasing earnings inequality in Australia between the mid-1980s and early 2000s (Coelli and Borland 2016). More extreme interpretations of the distributional consequences of technological change have also been made. Sachs and Kotlikoff (2012), for example, suggest the possibility of a world where each new-born generation is worse off than its predecessor.[4]

An outline of the rest of the article is as follows. Section 2 provides an historical perspective, describing previous episodes in Australia where it has been thought that a new technology might adversely affect the aggregate labour market. Section 3 presents a conceptual framework for thinking about how computers, IT and robots affect employment. The next three sections present evidence on outcomes in the Australian labour market, from which we draw inferences on the effects of new technologies. Section 4 describes the evolution of aggregate hours of work in Australia. Section 5 addresses the extent to which job destruction can be attributed to computer-based technologies. Section 6 presents measures of structural change and the extent of job turnover. Section 7 shifts to look at some of the main arguments that have been made to support the hypothesis that new technologies are causing or will cause radical change in the labour market. These arguments are reviewed, and we provide several critiques. Section 8 examines the policy implications of our analysis. In section 9 we consider why—in spite of what we regard as the facts of this matter—there is so much belief that computers, automation and robots are causing unprecedented change in the labour market.

2. An Historical Perspective

There are historical parallels to current concerns about the effects of new technology on the labour market in Australia. Fear of technology appears to peak during periods of high unemployment and phases of structural change; and hence the 'death of work' has been foretold often.[5]

The most recent Australian episode of techno-phobia was in the late 1970s and early 1980s. In their history of Monash University, Graeme Davison and Kate Murphy (2012, pp. 165–6) report that:

In 1978, the historian Ian Turner, organised a symposium on the implications of the new technologies. The world, he predicted, was about to enter a period as significant as the Neolithic or Industrial revolutions. By 1988, at least a quarter of the Australian workforce would be made redundant by technological change … Speaking at another conference, on computers and the law, Professor Chris Weeramantry pondered the dismal prospect that those displaced by the machines might turn to socially damaging activities, even possibly bringing about the end of civilisation.

Some years later, Barry Jones continued the gloomy forecasts in his best-seller *Sleepers Wake!* (1982, Preface):

In the 1980s, new technologies can decimate the labour force in the goods producing sectors of the economy. This will either perpetuate massive unemployment or lead to the creation of large-scale, low-output 'servile' work in the service sector.[6]

Of course, evidence that there have been fears about technology in earlier time periods that have led to nothing, does not imply that the same is happening today. The realisation of the historical parallels does, however, raise the question of why this time will be different.

3. How Computer-Based Technologies Affect Employment

One way to understand the effect of technology on the demand for labour is using a task-based approach (Autor 2013). According to this approach, the role of labour is to perform tasks required for the production of output. The effect of technology on labour demand is interpreted as its potential to substitute for workers in performing some of those tasks.

Computer-based technologies carry out tasks that have been specified by a programmer. Hence, as David Autor has described (2015, p. 10), in order for a computer to substitute for labour in performing a task '… a programmer must first fully understand the sequence of steps required to perform that task, and then must write a program that, in effect, causes the machine to simulate these steps precisely'. It follows that tasks which it is easiest to codify into a program are the tasks that are most likely to be substituted for by a computer or robot. The current convention is to refer to these tasks as 'routine', and to regard computer-based technologies as being substitutable for workers performing tasks that are: (i) cognitive and routine (such as basic clerical jobs); and (ii) non-cognitive and routine (such as operation of basic machinery) (Autor, Levy and Murnane 2003). What tasks can be codified and hence implemented using computer-based technologies is changing over time, although forecasting this process can be difficult. At present, for example, there is disagreement on the range of tasks where workers will be able to be substituted for by advances such as AI in the near future (for contrasting views on this, see Autor 2014, pp. 155–62; Frey and Osborne 2017, pp. 258–62).

Establishing that computer-based technologies can cause job losses, however, is only part of the story. What must also be taken into account is the variety of ways in which new technologies increase the amount of work available, and how the workforce adapts to take advantage of the opportunities created by the new technologies.

First, new technologies may reduce the total amount of labour time needed to produce today's consumption bundle, but the higher real incomes that result, together with non-satiation in consumption, cause an increase in demand for existing products, as well as demand for new products (some of which are created by new technologies). The increase in employment that results will be intensified where the extra spending is directed towards income-elastic services which are labour intensive (Baumol 1967).

Second, new technologies may substitute for some types of labour, but are generally complementary to, and hence will increase demand for, other types of labour. Specifically, computer-based technologies appear to be complementary to workers who perform non-routine cognitive-intensive work.

Hajkowicz et al. (2016, pp. 72–3) suggest a range of examples for Australia—such as an increase in demand for photographers at the same time as demand for photographic developers and printers has decreased; an increase in demand for graphic designers versus a decrease in demand for printers and graphic press workers; and a decrease in demand for bank tellers that has been accompanied by an increase in demand for finance professionals.

More generally, the increased use of IT and computers in the United States, Europe and Australia has been found to coincide with the phenomenon of job polarisation (see, for example, Acemoglu and Autor 2011; Goos and Manning 2007; Coelli and Borland 2016). Job polarisation is a pattern of changes in the composition of employment where there is an increase in the share (proportion) of employment in high-skill jobs, a decrease in the share in middle-skill jobs, and an increase in the share in low-skill jobs. Jobs involving non-routine cognitive and non-routine manual tasks tend to be concentrated respectively at the top and bottom of the skill distribution, and jobs intensive in routine tasks in the middle of the skill distribution. Hence job polarisation is interpreted to be consistent with computer-based technologies having increased the relative demand for workers doing non-routine cognitive tasks and decreased the relative demand for workers able to perform routine tasks.

Other evidence is also consistent with computer-based technologies substituting for labour doing routine tasks and complementing labour doing non-routine cognitive tasks. From a study of 17 developed countries Michaels, Natraj and Van Reenen (2014) conclude that increased use of IT from 1993 to 2007 raised the hours of work of high-skill workers at the expense of middle-skill workers. Applying a similar cross-country method to examine the effect of increased use of robots, Gratez and Michaels (2015) find that hours of low-skill workers were reduced, but there was no effect on hours of high-skill workers. Acemoglu and Restrepo (2017) use geographic variation in usage of robots in the United States to estimate that the direct effect of an extra robot per 1,000 workers is to reduce the employment/population rate by 0.2 to 0.3 percentage points, with the largest effect being for routine manual blue collar occupations. Acemoglu and Restrepo (2016) describe how computer-based technologies, as well as causing the loss of some existing labour-intensive jobs, create new complex jobs. Gaggl and Wright (2017) present evidence from the United

Kingdom of complementarity between computer-based technologies and workers who perform non-routine cognitive-intensive work.

Third, adaption by the potential workforce to the requirements of new technologies is likely to be important in explaining how aggregate labour market outcomes are affected by these technologies. It has been described how computer-based technologies are regarded as complementary to, and hence have increased demand for, workers who can perform non-routine cognitive tasks. An essential aspect of adjustment to these technologies is therefore to have an increased proportion of the workforce able to perform cognitive non-routine tasks. The ability to perform such tasks requires workers with high levels of education attainment (see, for example, Goldin and Katz 2008, p. 90). Hence, an increase in the proportion of the workforce with high levels of education is critical for taking advantage of job creation opportunities from computer-based technologies. It follows that a large part of the explanation for whether and how computer-based technologies have affected the Australian labour market is the rapid rise in education attainment since the early 1980s. Figure 2 shows the proportion of the working-age population in Australia with a Bachelor degree or higher. From 1982 to 2016 that proportion rose from 6 to 30 per cent.

4.   The Aggregate Quantity of Work

Since the mid-1960s the aggregate amount of work available to the Australian population on a per capita basis has remained stable. This can be seen in Figure 3, which shows indices of hours per capita from 1965–66 to 2015–16. The total annual hours worked are expressed as a proportion of total population and the working age population (15 to 64 years) in Australia. Neither index exhibits a long-run decline in the aggregate amount of work that matches the timing of the progressive introduction of computers to the workplace since the early 1980s. Instead, the main variation over time in hours per capita appears to have been due to the business cycle. A decline in hours per capita coincided with the recessions from the mid-1970s to early 1980s, a general upward trend occurred from the early 1980s to late 2000s, and there has been a small reduction since the late 2000s due to the recent slower growth in economic activity.[7]

Of course, there are jobs where many fewer workers are employed today than in previous decades. Figure 4a shows the 10 four-digit (ANZSCO) occupations with the largest absolute decreases in employment between 1986 and 2016. The list does seem to correspond to tasks where computer-based technologies would be expected to have substituted for workers—for example, secretaries, sewing machine operators, bank workers and farming-related occupations. What explains stability in the total hours of work is that there are also jobs that have experienced large increases in employment. Figure 4b shows the 10 four-digit occupations with the largest absolute increases in employment from 1986 to 2016. Some of the occupations on the list seem consistent with the predicted effects of computer-based technologies. For example, jobs such as child care, aged care and nursing are, at present, difficult to substitute for with computer-based technology; and the increased employment of

office managers may reflect that IT systems have allowed an increased size of organisations and hence scope of management. Several of the occupations that have seen large increases in employment, however, seem to contradict the predicted effects of computers—for example, accountants and checkout operators and cashiers.

Our analysis is intended to respond primarily to claims that the effect of computer-based technologies has been so overwhelming as to cause a decrease in aggregate hours of work. However, it might be argued that the absence of any decrease in total hours worked is explained by the effect of computer-based technologies being offset by other factors. This seems unlikely, and would imply that there have been other factors, the timing of which has exactly coincided with and undone the effect of increasing adoption of computer-based technologies, over a period of 30 years since the mid-1980s.

Another problem might seem to be the apparent inconsistency between our claim that the total amount of work in Australia has remained steady and the increase in unemployment and under-employment since the 1970s. But once it is recognised that unemployment and under-employment depend on both labour demand and labour supply, these outcomes are easily reconciled. As one way to make this point, we undertake a hypothetical exercise. Using the data on annual hours worked, for each year we calculate the proportion of the workforce age population who could have been employed if each employed person worked 40 hours per week for 48 weeks. This 'hypothetical employment/population rate' is shown in Figure 5, where it is compared with the actual labour force participation rate for the workforce age population. It can be seen that, based on the actual annual hours of work in Australia, the proportion of the workforce age population who could have been employed full-time has increased from the early 1980s (after a large decline from the mid-1970s). At the same time, however, there has been steady growth in labour force participation, from 68.9 per cent in 1982 to 76.5 per cent in 2016. The answer to how an increase in the total amount of work can occur together with increasing unemployment and under-employment is, therefore, growth in labour supply. Since the early 1980s an increasing amount of work has been spread amongst a growing labour force.[8]

5. Computer-Based Technologies and the Demand for Labour

The standard methodology to assess the effect of new computer-based technologies on labour demand is to examine changes in the demand for labour with the capacity to undertake routine tasks. The motivation for this methodology was explained in section 3. In previous research (Coelli and Borland 2016), we have undertaken this analysis for Australia.

The analysis involves several steps. First, we follow the template from international research to assign measures of the intensity of abstract, manual and routine tasks to each four-digit occupation in Australia. Second, these measures are used to create employment-weighted aggregate indices of the demand for labour to perform each type of task in each Census year from 1966 to 2016. Third, we track these measures over time in order to reveal changes in the demand for workers who are able to perform abstract, manual and routine tasks.

Figure 6 shows the indices for the demand for labour to perform abstract, routine and manual tasks from 1966 to 2016. A summary index of routine task intensity of occupations is also presented.[9] At present, a measure of employment by four-digit occupation is not available from the 2016 Census. Hence Figure 6 uses Census data for 1966 to 2011 and Labour Force Survey data for 2016.[10]

Each of the indices in Figure 6 is based at 50 in 1966.[11] Where an index for a task increases over time, this shows that changes to the occupational composition of employment are tending to increase the relative demand for labour to perform that task; that is, a relatively larger share of total employment is in occupations that require performance of that task to a greater degree. By contrast, a decrease in an index reflects a decrease in relative demand for labour to perform that task.

The indices in Figure 6 show that there has been a strong decline in demand for labour to perform routine tasks, and an increase in demand for labour to complete abstract tasks. Notably, the rate of change in demand for labour to perform routine and abstract tasks appears to be fairly consistent over time. A decline in demand for labour to complete manual tasks is also observed up to 2001.

To investigate further the timing of changes in the demand for labour to perform routine tasks, Figure 7 shows decadal changes in the shares of employment according to the routine task intensity of occupations, using Labour Force Survey data from 1986 to 2016. Changes in the employment shares of jobs in each decade have been negatively related to their intensity in routine tasks. The extent of reallocation of employment between jobs according to their intensity in routine tasks did increase slightly from 1986–96 to 1996–2006. However, the extent of reallocation then slowed in the final decade from 2006–16. An even longer-run historical perspective can be obtained by using Census data to track decadal changes in employment shares from 1966 to 2006. This is done in Appendix Figure A3. The Census data suggest that the extent of reallocation of employment increased between the decades from 1966–76 to 1986–96, but then slowed in the decade from 1996–2006.

As a check on these findings, we also apply an alternative method for deriving measures of the demand for labour to perform routine and non-routine tasks. Each four-digit (ANZSCO) occupation is assigned to one of five categories: routine cognitive, routine manual, non-routine cognitive, non-routine manual, and sales, and the share of employment in each category is tracked from 1986 onwards. This method follows the approach used in Heath (2016); except that we use four-digit rather than one-digit occupations to classify occupations into the categories,[12] and we have a separate category for sales. Sales is included as a separate category as we believe it requires being able to perform routine and non-routine tasks, and has cognitive and non-cognitive elements; and hence including it in the other categories would bias measurement of trends in the demand for labour to perform routine tasks.

Figure 8 presents the findings using the alternative method. Since the mid-1980s there have been downward trends in the demand for labour to perform cognitive and manual routine tasks; and upward trends in the demand for both types of non-routine tasks. What is also apparent (and confirmed by simple regression analysis) is the absence of any acceleration in these trends. The shifts away from employment in routine tasks and towards employment in non-routine tasks has been steady since the mid-1980s.

Our overall conclusion is that a decrease in demand for workers to perform routine tasks commenced at least as far back as the mid-1960s, and has been happening at a fairly steady rate since that time. Any acceleration in the extent of reallocation of employment between jobs according to their intensity in routine tasks appears to have been concentrated in the 1980s and 1990s; and there is no evidence that computer-based technologies have caused an increased pace of destruction of routine-intensive jobs through the 2000s.

6. The Pace of Change in the Composition of Employment and Job Turnover

A variety of other measures can be applied to evaluate the pace of structural change and job turnover in the labour market in Australia. These measures provide a consistent story. There is no evidence that increasing use of computer-based technologies has been associated with a higher rate of job destruction or a faster pace of structural change in the Australian labour market.

Information on job destruction within detailed occupation and industry categories is reported respectively in Tables 1 and 2. Each table presents two measures. One measure is the total decrease in the share of employment in occupations/industries in which the share of employment decreased in the specified time period.[13] For example, the first entry in the top row in Table 1 shows that (using Census data) the total decrease in the share of employment of four-digit occupations in which the share of employment decreased between 1971 and 1981 was 8.2 per cent. The second measure is the total decrease in employment in occupations/industries where the level of employment decreased expressed as a proportion of total employment in the base year. For example, the first entry in the third row in Table 1 shows that (using Census data) the decrease in total employment in occupations in which employment declined between 1971 and 1981 was 2.4 per cent of total employment.

The measures of job destruction by occupation do show some increase from the 1970s to the 1980s and 1990s, but thereafter they return to lower levels in the 2000s. While the pattern of job destruction from the 1970s to 1990s might be seen as consistent with an effect of the introduction of computer-based technologies, given the increasing rate of adoption of those new technologies in the 2000s, the decrease in job destruction in the 2000s onwards is not consistent with such an effect. The measures of job destruction by industry begin from the mid-1980s. These measures also suggest a decrease in the rate of job destruction in the 2000s.

Job tenure reveals the extent to which workers are moving between jobs. Figure 9 shows the proportions of currently employed workers in their jobs for less than one year and for more

than 10 years. Not only is there no evidence that more workers are being forced to work in short duration jobs, but what is apparent is that the opposite has happened. The proportion of workers in very long duration jobs has increased from 19.3 per cent in 1982 to 26.7 per cent in 2016, and there has been a corresponding decrease in the proportion of workers in their jobs for less than a year. The increase in the proportion of workers in their jobs for more than 10 years has mainly occurred for females, as part of their increasing engagement with the workforce over the past 35 years.

A final measure of churning in the labour market is the rate at which workers flow out of employment. Figure 10 shows the monthly rate of outflow from employment (to unemployment or to out of the labour force) from early 1980 onwards. The message is again that there is no pattern evident that would indicate that computer-based technologies have caused an increase in the pace of structural change. For males there is no long-run trend in the rate of outflow from employment. There was some increase from the early 1980s to mid-1990s, but after that time the rate decreased. For females there was a steady and large decrease in the rate of outflow from employment until the mid-2000s, after which time it has been relatively steady.

7. What is Wrong with the Prophecies of Doom?

Recent well-publicised forecasts of the numbers of jobs that will be lost due to computer-based technologies are a major part of the case for thinking that these technologies are causing a substantial decrease in the amount of work. The seminal study is by Frey and Osborne (2017) who predicted that in the United States 47 per cent of employment was at high risk (probability greater than 7/10ths) of being computerised or automated over the next one to two decades.

As has already been noted, forecasts of job destruction in future years provide only a partial perspective on the effects of new technologies. First, to understand the effect on aggregate labour demand it is also necessary to know how the new technologies affect job creation. Second, knowing that a certain percentage of jobs may be lost in the future due to computer-based technologies tells us nothing about the pace of change in the labour market. That can only be learned from a comparison with earlier time periods.

Furthermore, we believe that there are several important limitations with the specific method used by Frey and Osborne (2017, pp. 263–5). Their method involves several stages. In the first stage, drawing on consultations with colleagues, who were provided with job descriptions and information on O*NET tasks for 70 six-digit US occupations, they subjectively hand-labelled those occupations to be automatable or not automatable. In the second stage, the coding for whether an occupation is automatable is regressed on a set of characteristics for the occupation relating to its requirements for workers to apply social intelligence, creativity and perception and manipulation taken from O*NET data. In the third stage, the estimates from the regression model, together with O*NET data on the characteristics of all 702 six-digit occupations in the United States, are used to predict the

automatability of each of those occupations. In this stage, a non-linear 'classifier' model is applied which has the effect of pushing the predicted likelihood of automation for most occupations towards the boundaries of zero and 100 per cent. In the fourth stage, any occupation with a predicted probability of automation of above 70 per cent is classified as 'high risk' of automation, and it is assumed that all workers in that occupation will be replaced by automation.

A first specific criticism of Frey and Osborne's method is that everything depends on the validity of the predictions on the likelihood of future automation. Their method identifies 37 of the 70 occupations as being at risk of automation. To the extent that they have over-estimated this risk for the sample of jobs they considered, it follows that estimates of the overall proportion of jobs at risk will be inflated. Indeed, some examples of occupations that Frey and Osborne's colleagues deem automatable seem rather far-fetched—such as surveyors, accountants, tax and revenue agents, and marketing specialists; all of which are occupations where employment has grown strongly in Australia in the past five years. It also seems that Frey and Osborne's procedure has led to predictions that are in direct contrast to their own argument about the requirements of a job that will make it difficult to automate. For example, the authors identify finger dexterity as an impediment to automation (a 'bottleneck'), yet the automation of watch repairers is predicted with a probability of 98 per cent.

Second, Frey and Osborne argue that an occupation being computerised or automated implies that all jobs in that occupation would be destroyed. For example, driverless vehicle technology is predicted to lead to the loss of all driving jobs: taxi drivers and chauffeurs, truck drivers, couriers, et cetera. These jobs currently comprise nearly 4 per cent of the Australian workforce. Obviously this is a major simplification. In most cases where new technologies do substitute for labour, it seems unlikely that all jobs would be lost.[14] Using an alternative methodology that applies direct worker reports of the tasks undertaken in their jobs to predict the overall share of employment within occupations that would be destroyed by new technology, Arntz, Gregory and Zierahn (2016) conclude that only 9 per cent of jobs in the United States are at risk due to computerisation and automation. This methodology is based on the more reasonable concept that automation can be employed to undertake certain tasks within jobs, but not all tasks within those jobs.

Third, even for those jobs which are technically feasible to automate, it still needs to be profit-maximising for firms to substitute technology for labour (Acemoglu and Restrepo 2016). That is, just because an organisation has the option to replace a worker with a machine is not sufficient for substitution to happen; what is also required is that the organisation's costs of production are lowered by making that substitution.

There are other limitations of Frey and Osborne's predictions of job loss due to automation. The availability of workers skilled in the setting up and use of new technologies is likely to be quite limited initially, restricting substitution possibilities for firms. Preferences for human interaction in certain spheres may preclude certain occupations being automated, such as care

for the elderly and children (Finkel 2017). It has also been argued that there may be legal and ethical constraints on the replacement of workers by new technologies.

Some Australian research—Durrant-Whyte et al. (2015) and Edmonds and Bradley (2015)—has sought to replicate the Frey and Osborne study. The method used in the Australian studies is to concord Frey and Osborne's estimates of the likelihood of jobs in the United States being computerised or automated to the Australian occupational classification, and to then calculate the proportion of jobs in Australia at high risk of automation. Not surprisingly, the Australian studies arrive at similar forecasts to Frey and Osborne. Durrant-Whyte et al. (2015) forecast that 40 per cent of jobs in Australia are highly susceptible to computerisation and automation in the next 10 to 15 years; and Edmonds and Bradley (2015) forecast 44 per cent.

In our own related research (Coelli and Borland 2017), we construct an estimate of the risk of automation of Australian jobs using the Arntz, Gregory and Zierahn (2017) task-based procedure.[15] That procedure estimates the risk of automation for US workers in two stages. First, using data for individual workers, the Frey and Osborne prediction of the automation risk of a worker's occupation is regressed[16] on worker-level job task measures (and other worker attributes) as reported in the Programme for the International Assessment of Adult Competencies (PIAAC) worker survey data. Up to 39 separate job tasks are measured in the PIAAC, including the frequency of 'advising others', 'solving complex problems' and 'using hands and fingers'. Second, the predicted values from this regression model are constructed for all workers, and those workers with predicted probabilities above 0.7 (the same cut-off used in Frey and Osborne) are classified to be at high risk of automation.

Our approach (following Arntz, Gregory and Zierahn 2016) is to take the coefficient estimates from the regression model estimated for US workers, and to use these estimates to predict automation risks for Australian workers using the Australian version of the PIAAC worker survey data. Our estimate is that around 9 per cent of Australian workers are at high risk of their jobs being automated. This is almost identical to the risk Arntz, Gregory and Zierahn (2017) estimate for the United States, and in the middle of the 6 to 12 per cent range of estimates across OECD countries reported in Arntz, Gregory and Zierahn (2016). This risk of 9 per cent of jobs being automated is significantly below the estimates of 40 to 44 per cent from the Australian studies. Note also that this 9 per cent estimate only adjusts for one of the criticisms made of the Frey and Osborne method—that is, the assumption that all jobs in an occupation identified as being at high risk of automation will be destroyed.

8. The Policy Question

The implication of our conclusions on the effects of computers and IT on the Australian labour market is not that there is no policy problem to be solved. Rather, we argue that it is the same policy problem that needs to be solved now as needed to be solved in the past.

Technological change does increase the rate at which jobs are destroyed and hence raises the number of workers who must shift to new jobs. Technological change also creates winners and losers. At present, for example, job losses due to computer-based technologies appear to be concentrated among workers with lower levels of education attainment (for evidence of declining employment outcomes for the male population without post-school qualifications in Australia, see Coelli 2015).[17] Arntz, Gregory and Zierahn (2016) also predict that future job losses are likely to be concentrated among the less educated.

The policy problem therefore is twofold. First, policy is needed to facilitate the adjustment and re-employment of workers who are displaced due to technological change. Second, there should be a safety net for those who are temporarily or permanently disadvantaged by job loss due to new technologies. But there is nothing special about these problems today.[18] They have always been the problems that policy makers have faced in dealing with technological change, and other sources of job loss and structural change such as international trade.

9. Why Is This So Misunderstood?

Our conclusion is that there is no radical transformation underway in the Australian labour market. The total amount of work does not appear to be decreasing; and the pace of change in the labour market is not accelerating. Yet there are many commentaries that argue otherwise; and it is likely that their opinion would be shared by a majority of the Australian public. How can this be explained?

One possibility is that mistaken views about the effects of technological change derive from a human bias to feel that 'we live in special times'.[19] An absence of knowledge of history, the greater intensity of feeling about events that we experience first-hand, and perhaps a desire to attribute significance to the times in which we live, all contribute to this bias. The bias makes us predisposed to believe that phenomena such as technological change are having a more substantial and different effect today than they did at earlier times.

And of course there are many who are all too happy to take advantage of this bias, and in the process intensify public perceptions of the transformation being wrought by new technologies. You are likely to sell a lot more books writing about the future of work if your title is 'The end of work' rather than 'Everything is the same'. If you are a not-for-profit organisation wanting to attract funds to support programs for the unemployed, it helps to be able to argue that the problems you are facing are on a different scale to what has been experienced before. Or if you are a consulting firm, suggesting that there are new problems that businesses need to address, might be seen as a way to attract extra clients. For politicians as well, it makes good sense to inflate the difficulty of the task faced in policy making; or to be able to say that there are new problems that only you have identified and can solve.

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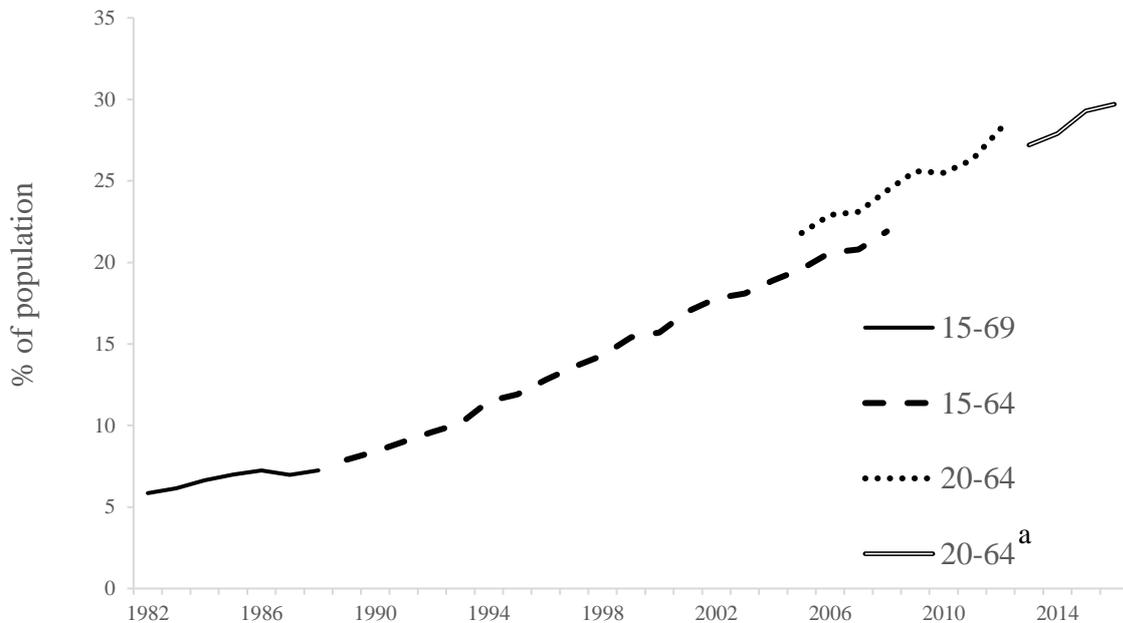
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Figure 1 Net Capital Stock of Computers, Software, and Electronic and Electrical Equipment, All Industries, Constant Value Measure, 1966–2016 (June)
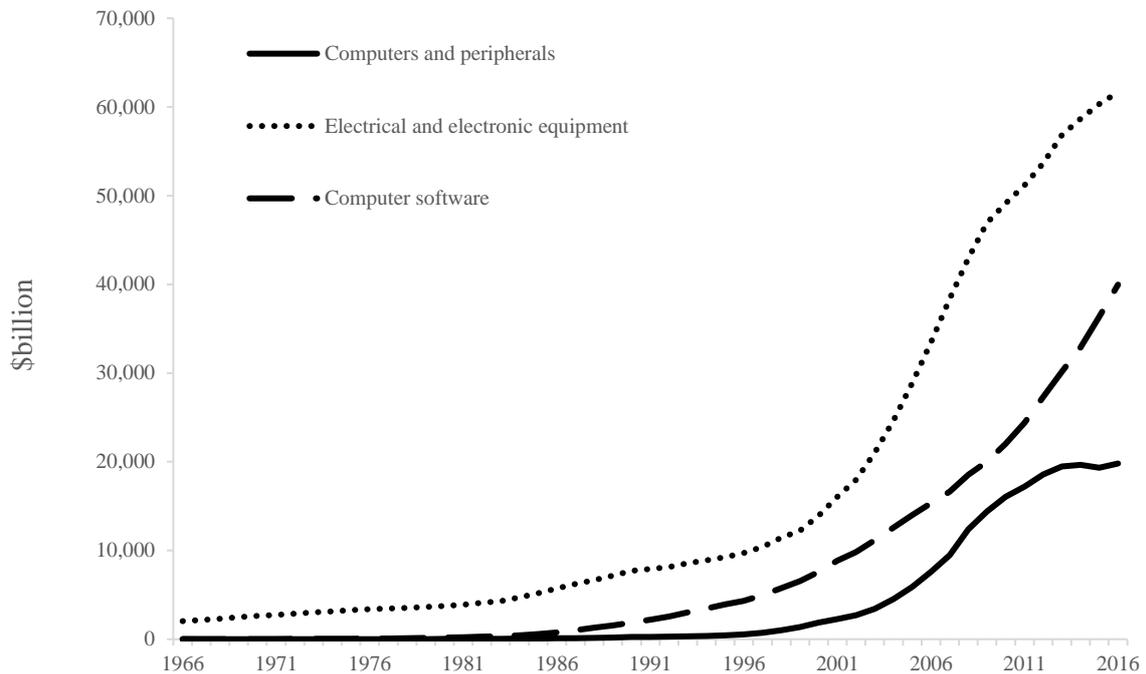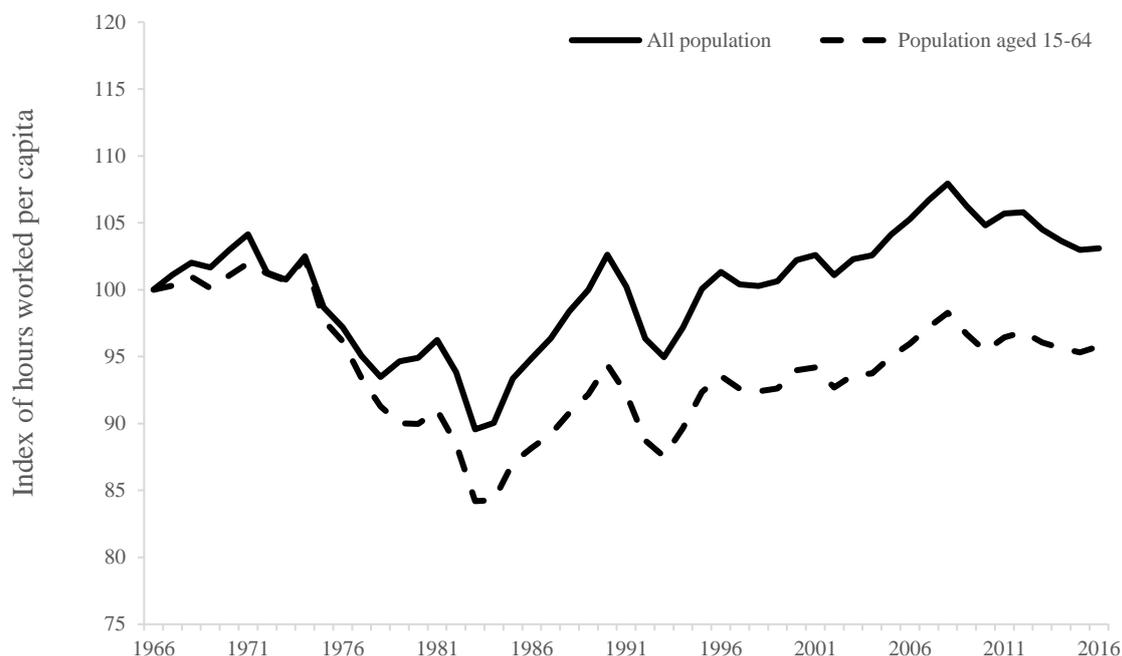

Source: ABS (2017a), Table 69.

Figure 2 Per Cent of Population with Bachelor's Degree or Higher, Australia, 1982–2016

Note: (a) Also includes for the first-time people permanently unable to work.

Source: ABS (2016), Tables 27 and 29.

Figure 3 Hours of Work Per Capita, Australia, 1965–66 to 2015–16, Actual Hours Worked Series (equals 100 in 1965–66)

Sources: (1) (a) All population: 1965–2010 (December): Butlin et al. (2014), Table A2; 2011–2015 (December): ABS (2017b), Table 4; (b) Population aged 15–64 years: 1965–68: Commonwealth Bureau of Census and Statistics (1970), Table 4; 1969–77: ABS, *Labour Force Australia*, Cat. no. 6203.0; 1978 onwards: ABS (2017c), Table 18; (2) Annual hours worked: (a) Total employment: 1978 onwards: ABS (2017c), Table 1; 1966–77: ABS (1987), Table 1; 1965–66: Commonwealth Bureau of Census and Statistics (1970), Table 2; (b) Average hours worked by persons employed: 1991 onwards: ABS (2017d), Table 09; 1984–90: ABS (1996); 1969–83: ABS, *Labour Force Australia*, Cat. no. 6203.0, Assorted tables; 1965–68: Commonwealth Bureau of Census and Statistics (1970), Table 21.

Figure 4a 10 Four-Digit Occupations with the Largest Decreases in Employment, Persons, Australia, 1986–2016 (August)
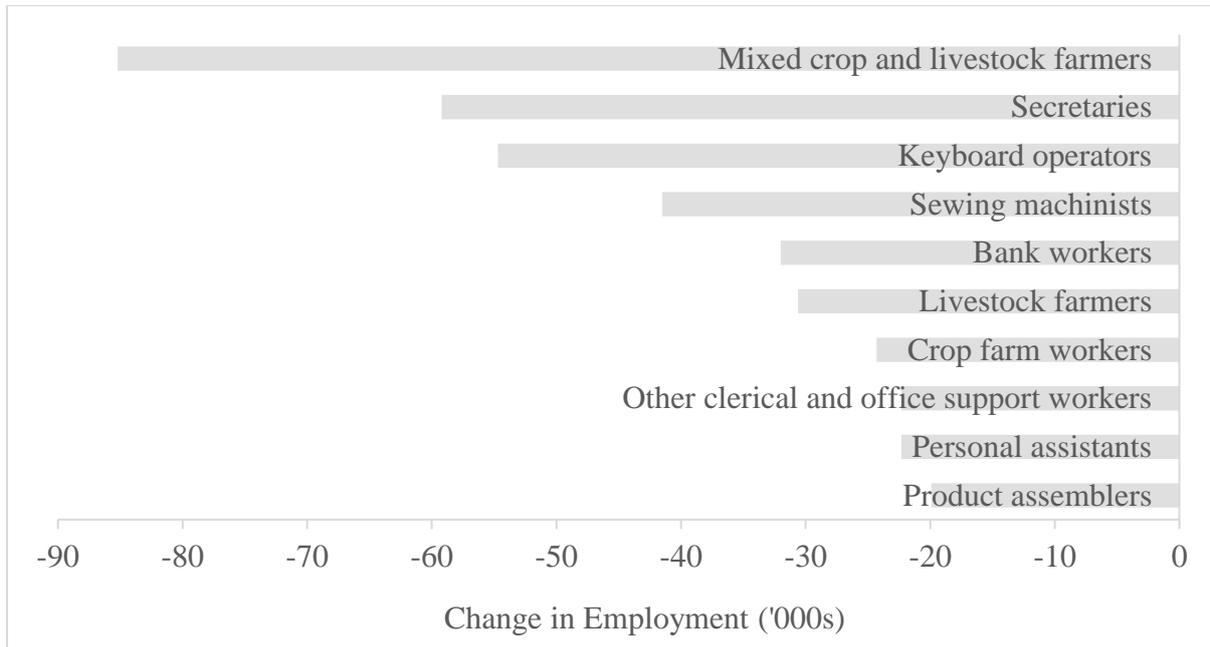
Source: ABS (2017e), EQ08.

Figure 4b 10 Four-Digit Occupations with the Largest Increases in Employment, Persons, Australia, 1986–2016 (August)
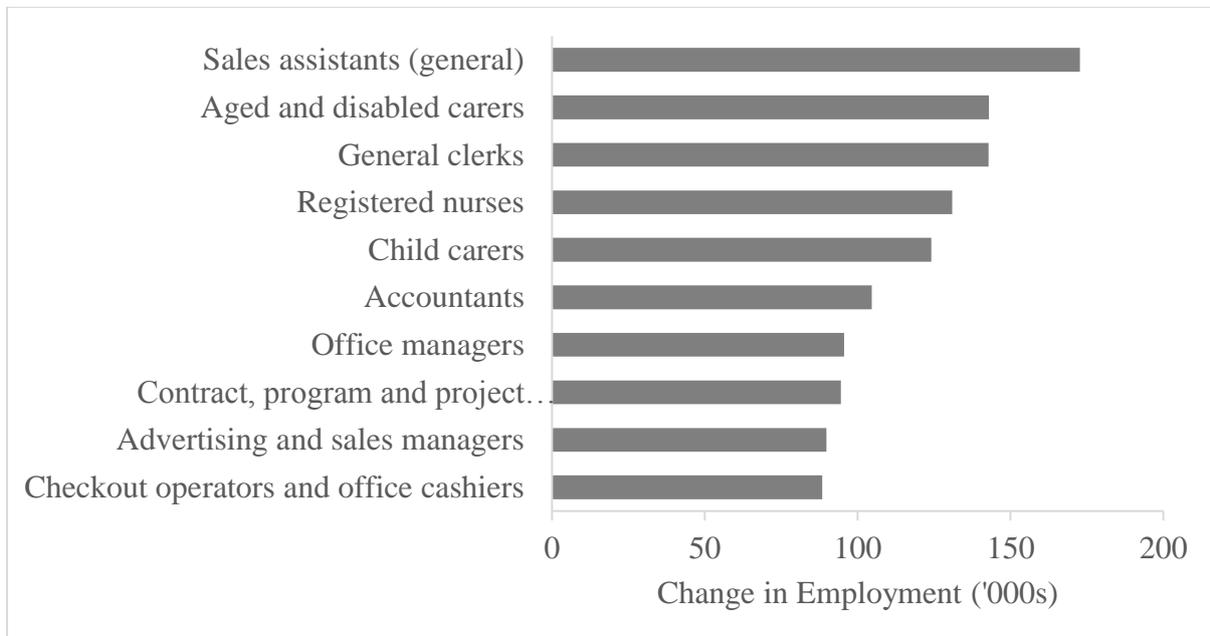

Source: See Figure 4a.

Figure 5 Labour Force Participation Rate (LFPR) and Hypothetical Employment/Population Rate (E/POP), Australia, 1965–66 to 2015–16
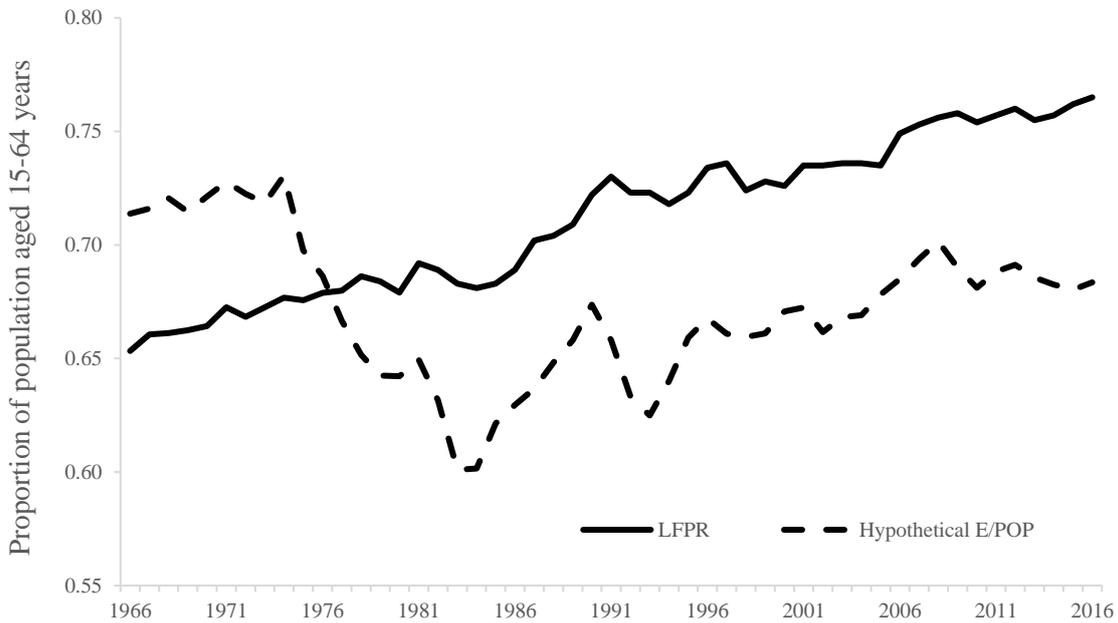

Sources: (1) LFPR: 1965–68: Commonwealth Bureau of Census and Statistics (1970), Table 4; 1969–77: ABS, *Labour Force Australia*, Cat. no. 6203.0; 1978 onwards: ABS (2017c), Table 18; (2) Hypothetical E/POP rate: see Figure 3.

**Figure 6 Indices of the Demand for Labour to Perform Selected Tasks, 1966–2016**
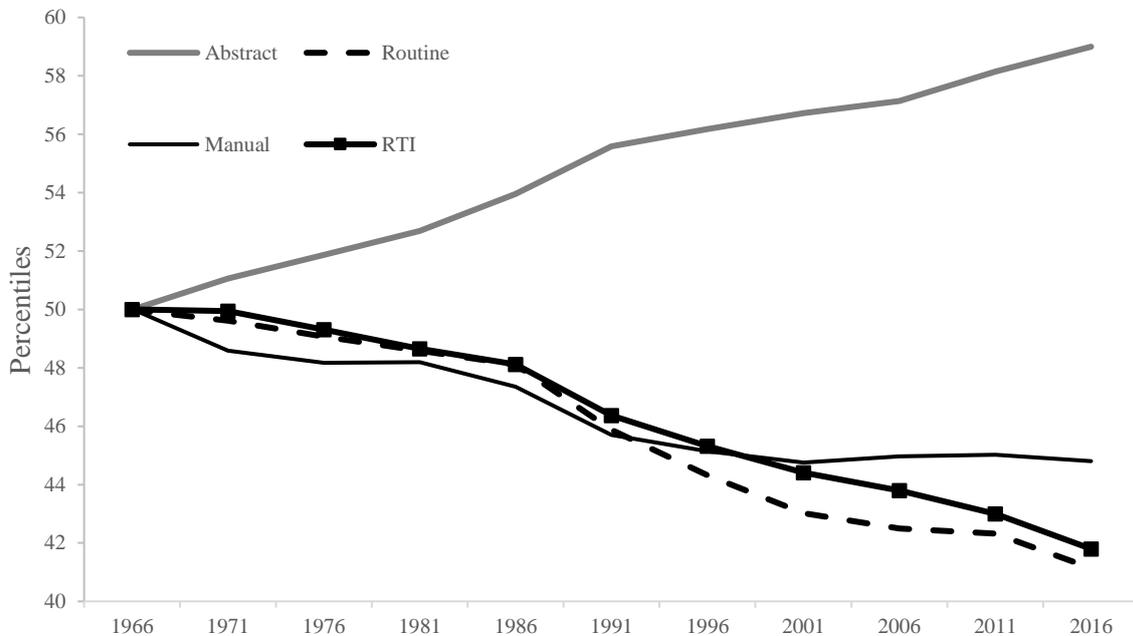
Sources: Updated version of Coelli and Borland (2016, Figure 7). 1966 to 2011 derived from Census data; 2016 derived from ABS (2017e), EQ08.

Figure 7 Changes in Employment Shares by Routine Task Intensity of Occupation, by Decade, 1986–2016
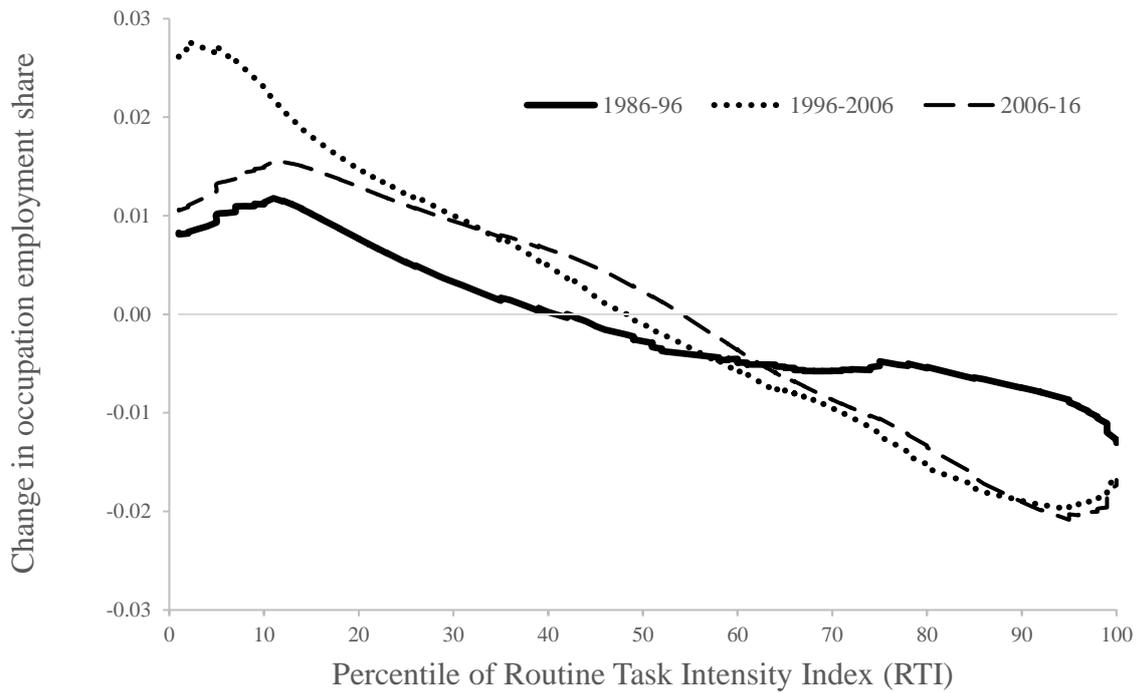
Sources: Authors' calculations based on: (1) ABS (2017e), EQ08, February 2017; and (2) Coelli and Borland (2016) measures of routinisation by occupation. Lines were smoothed.

Figure 8 Share of Employment by Skill Type, Australia, 1986–2016
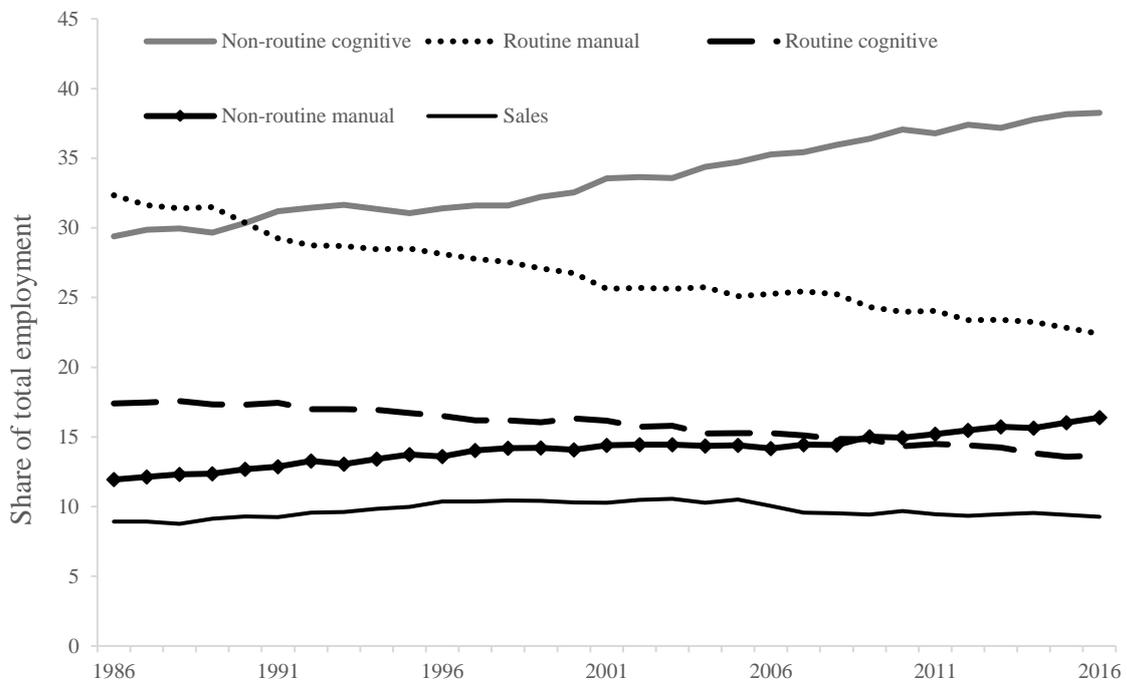
Sources: ABS (2017e), EQ08, February 2017. Details of the mapping of four-digit ANZSCO occupations into the five groups are provided in Appendix Table A1.

Table 1 Measures of Job Turnover by Four-Digit Occupation, Australia, 1971–2011

	Data	1971–81	1981–91	1991–2001	2001–11
Total decrease in share of employment from occupations where share of employment decreases[a]	Census	0.0824	0.1115	0.1116	0.0860
	LFS			0.1214	0.1131
Decrease in employment in occupations where level of employment decreases, as a share of total employment[b]	Census	0.0243	0.0672	0.0439	0.0359
	LFS			0.0625	0.0485

Sources: (a) Authors' calculations from ABS Census; (b) Author's calculations from ABS (2017e), EQ08.

Table 2 Measures of Job Turnover by Two-Digit Industry, Australia, 1986–2016

|	1986–91	1991–96	1996–2001	2001–06	2006–11	2011–16
Total decrease in share of employment from industries where employment share decreases	0.0573	0.0581	0.0581	0.0630	0.0523	0.0482
Decrease in employment in industries where level of employment level decreases, as a share of total employment	0.0301	0.0270	0.0326	0.0287	0.0258	0.0254

Source: Authors' calculations from ABS (2017e), Table 06.

Figure 9 Current Job Tenure for Employed Persons, Australia, 1982–2016 (February)
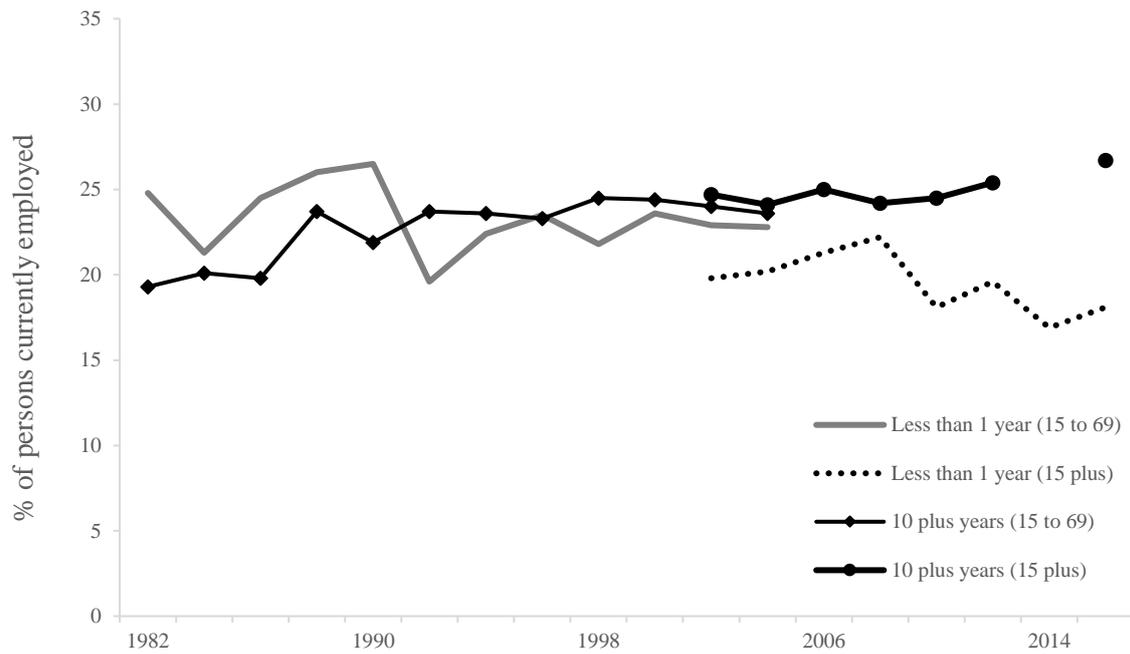
Source: Author's calculations from: (1) 1982–2013: ABS, *Labour Mobility, Australia*, Cat. no. 6209.0; (2) 2015–2017: ABS (2017e), EQ2.

**Figure 10 Rate of Outflow from Employment,
13-Month Average, Australia, February 1980–November 2016**
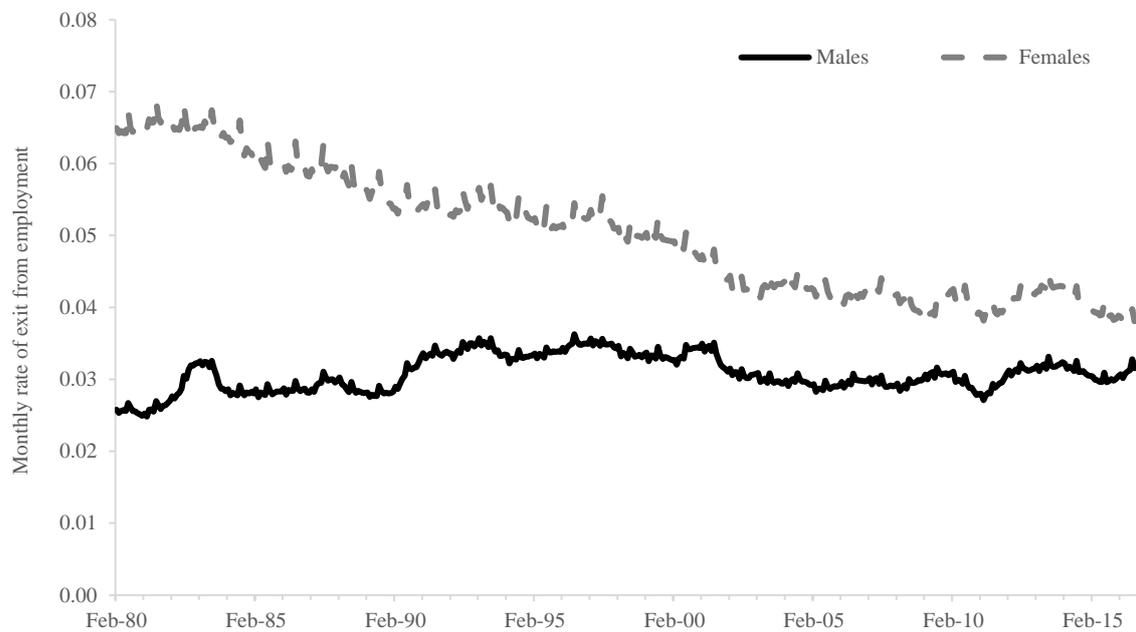
Sources: Authors' calculations from: (1) 1979–90: ABS, *Labour Force, Australia*, Cat. no. 6203.0; (2) 1991 onwards: ABS (2017c), GM1.

Appendix 1: Extra Figures and Table

Figures A1 to A3 present alternative versions of figures in the main body of the article that use different data sources or over different time periods. Table A1 shows the method used for classifying occupations into the categories used in Figure 8.

Figure A1 Hours of Work Per Capita, Australia, 1989–2016, Monthly Hours Worked Series (equals 100 in 1979)
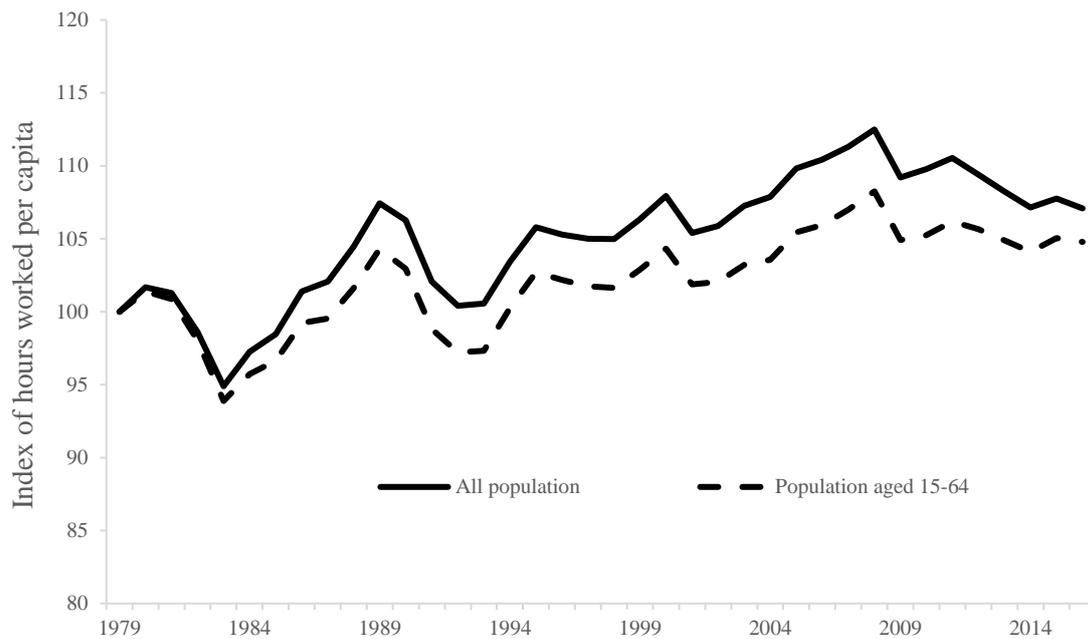

*Source*s: (1) Population: see Figure 2; (2) Annual hours of work: ABS (2017c), Table 19.

**Figure A2 Indices of the Demand for Labour to Perform
Selected Tasks, 1986–2016, Labour Force Survey Data**
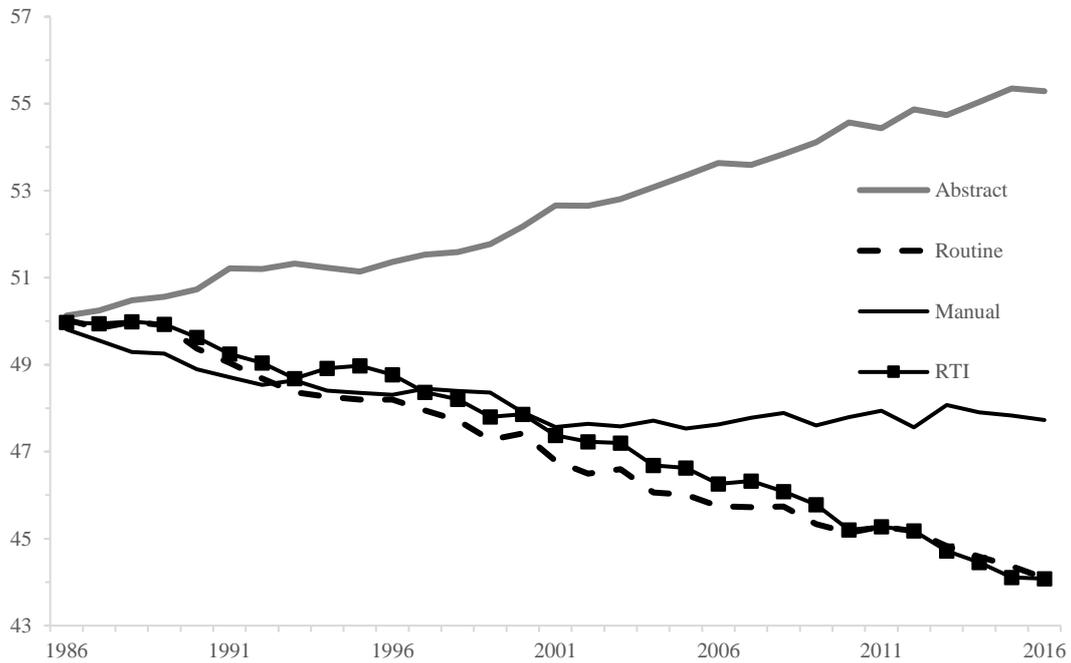
Sources: Authors' calculations based on: (1) ABS (2017e), EQ08; and (2) Coelli and Borland
(2016) measures of routinisation by occupation.

**Figure A3 Changes in Employment Shares by Routine
Task Intensity of Occupation, 1966–2006, Census Data**
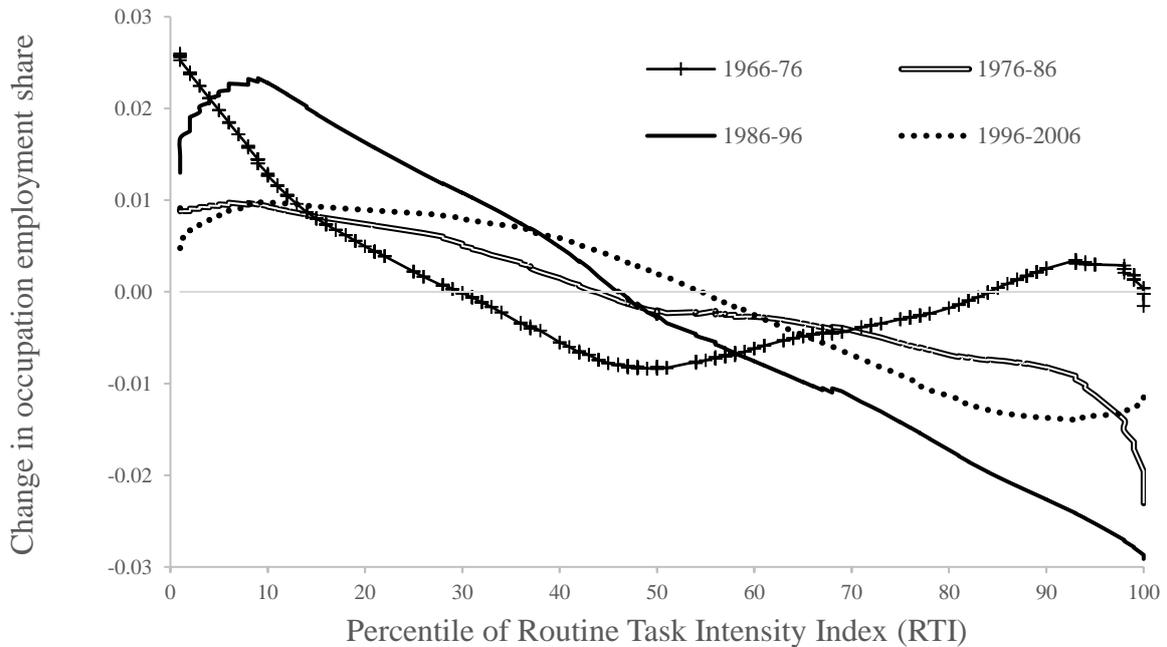
Source: Based on Figure 10 of Coelli and Borland (2016), using an alternative specification
of decades.

Table A1 Classifying Four-Digit ANZSCO Occupations into Figure 8 Categories

Figure 8 category	Coelli and Borland (2016) group	ANZSCO codes
Non-routine cognitive	Managers	1000–1499
	Professionals	2000–2726
	Technicians	3000–3132, 3993, 3995
Routine manual	Production	3200–3424, 3600–3900, 3920–3992, 3994, 3996, 3999
	Operators/labourers	5612, 7000–8000, 8210–8419, 8900–8990, 8992–8995, 8999
Routine cognitive	Office/admin	5000–5611, 5613–5999
Non-routine manual	Protective service	4400–4422, 8991
	Food/cleaning	3510–3514, 4310–4319, 8110–8116, 8510–8513, 8996
	Personal care	4000–4234, 4500–4524
Sales	Sales	6000–6399, 8997

Note: The Coelli and Borland (2016) groups were based on the 10 groupings of Acemoglu and Autor (2011).

Endnotes

[1] A sample of other recent examples is: 'The nature, scope and pace of change at this time is unprecedented in human history' (Bishop 2017); 'An unprecedented reinvention of work is coming. The coming reinvention of work is unlike anything we have witnessed before, even in this era of disruption' (EY 2016, p. 29); and '… traditional, linear career trajectories are rapidly becoming an antiquated notion. It's more likely that a 15-year-old today will experience a portfolio career, potentially having 17 different jobs over 5 careers in their lifetime' (Foundation for Young Australians 2017, p. 3).

[2] See Bureau of Communications Research (2016) for an overview of IT use in Australia.

[3] See also the review of international evidence in Raghnaill and Williamson (2014).

[4] Suppose that smart machines substitute for young, unskilled labour and complement old, skilled labour. The wages of young workers will therefore be depressed and they will be less able to invest in skills acquisition. This will lower their productivity when they become old, thereby making them worse off than the previous generation.

[5] For international reviews of episodes when it was feared that new technologies were about to bring about the end of work, see Akst (2013) and Moky, Vickers and Diebarth (2015).

[6] Not all commentators saw the future this way—see, for example, the Boyer lectures delivered by Bruce Williams (1982).

[7] Appendix Figure A1 shows a similar pattern from 1979 onwards using a measure of annual hours worked derived from an alternative ABS data series for hours worked.

[8] That the available work in Australia is being spread over a larger workforce has an interesting consequence. Despite the rise in unemployment and under-employment, it seems that the distribution of work amongst the Australian population is becoming increasingly equal (see Borland 2017).

[9] Formally, the index for routine task intensity is constructed from the other indices as: RTI Index = ln(Routine) − ln(Manual) − ln(Abstract) (Autor and Dorn 2013).

[10] To check that merging the data series has not affected our conclusions, in Appendix Figure A2 we also present the same measures of task intensity for each year from 1986 to 2016 derived exclusively using data from the Labour Force Survey. Consistent data on employment by occupation from the Labour Force Survey are only available from 1986 onwards.

[11] For each task measure a percentile score is assigned to each four-digit occupation according to its rank-level on that measure. This is done using 1966 employment by occupation and gender. By construction, therefore, for each task measure the average percentile score in 1966 is 50 (Coelli and Borland 2016, pp. 12–13).

[12] Details of the occupation classification we used are provided in Appendix Table A1.

[13] This measure is equivalent to the coefficient of compositional change.

[14] Technological change also affects the types of tasks workers undertake within their jobs. Learning new skills to use these new technologies has also been a feature of employment since the advent of the personal computer in the early 1980s. Changes in work tasks are likely to continue in the future as new technologies are adopted in workplaces.

[15] Arntz, Gregory and Zierahn (2016) constructed estimates for a number of OECD countries using their technique, but not for Australia.

[16] The authors use a generalised linear model during estimation to account for the bounding of automation probabilities from zero to one.

[17] It is not our purpose in this article to provide a detailed analysis of the types of workers who are experiencing job loss due to computer-based technologies or of their experiences post-displacement. This is, however, an important research topic in order for policy makers to know how to design appropriate policy responses to current technological change.

[18] It is also worth adding that changes over time in the types of workers whose jobs are being destroyed by new technologies is also a recurring theme of the 'policy problem'.

[19] Tetlock and Gardner (2015, pp. 232–3) discuss the phenomenon of 'WYSIATI – What You See Is All There Is – the mother of all cognitive illusions, the egocentric worldview that prevents us from seeing any world beyond the one visible from the tips of our noses'.

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