The robotics and automation advantage for Queensland

How the state can harness the benefits and adapt its workforce to the new robot economy

This report was commissioned by Queensland University of Technology

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Adopting robotics and automation will lead to substantial benefits for Queensland

$77.2 billion	1.5% GSP growth	725,810 jobs
$77.2 billion increase over a 10-year period	Benefits include a likely increase of 1.5% pa GSP over a 10-year period	Creation of 725,810 jobs

The faster Queensland adopts robots and automation the greater the benefits in GSP and net job creation

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Executive Summary

The automation process, including robotics and intelligent systems, has begun in earnest across the world. The International Society for Automation (ISA) defines automation as "the creation and application of technology to monitor and control the production and delivery of products and services."

Under this wide-ranging definition anyone involved in the creation and use of technology, including robotics, for the production and/or delivery of goods and services is in the automation profession[1].

The Queensland and Australian economies are increasing their absorption of robotics and other forms of automation significantly but still trail the leading industrial powers. They run the risk of falling further behind unless this situation is addressed. Two issues dominate the current debate over the economic and social aspects of automation

(a) What are the potential benefits of rapid automation in terms of boosts to GSP and employment for Queensland?

(b) How much of these benefits, in terms of potential employment creation, will be displaced by automation?

This report finds, based on a review of international literature and our own research, that substantial net benefits will accrue to the Queensland economy from an acceleration of the automation and robotics process. There will be job dislocation for some jobs, and some job tasks, but this dislocation will be heavily outweighed by employment gains. We concur with a weight of opinion worldwide that suggests machines will not displace occupations on a large scale but will change the existing job mix and create new jobs[2]. In this way, the automation revolution will follow the long-observed economic impact of technological change where the income (job creating) effects of technological change outweigh the substitution (job destroying) effects.

Over the past two decades (1999 to 2018), the Queensland economy has undergone significant structural change in both industrial and occupational employment patterns, some of which resulted from technological developments. However, despite the speed of structural change the Queensland economy managed to produce 790,000 more jobs (50 per cent increase) and an 89.1 per cent increase in real Gross State Product (GSP) showing that the state has the capacity to absorb rapid change.

Yet, the new era of automation will have some differences from past periods of technological change, principally due to the ubiquitous nature of automation, which will be felt across all industries. As a result, there may be greater short-term dislocation; however, this can be managed by combined firm-level and government programs of managed introduction of automation, re-training and re-deployment. It is particularly important that new entrants to the workforce be equipped to cope with rapid technological change.

Industrial processes are subject to continual change because of technological developments. Some of these changes are incremental and result from learning effects over time; others are transformational and result in new industrial paradigms. *The Economist* magazine argues that a revolution is under way. Manufacturing is going digital. A number of remarkable technologies are converging: clever software, novel materials, more advanced robots, new processes and a range of web-based services.

Yet, there is a growing disconnect in the world between technological progress and the apparent outcomes on real and relative income distribution for a significant number of people. The optimism over automation is driven by the promise of changes in the nature of work, the end to boring and repetitive work and the implications for advances in health and well-being, particularly with regard to industrial safety. Fear comes from concern over massive displacement of labour, increasing income inequality and even the dystopian view of a future "AI takeover".

As with most developed economies, the Queensland economy has experienced both slower growth in labour productivity and growing income inequality. Automation will provide many of the solutions to the labour productivity issue but its effects on income inequality is more difficult to judge. In contrast to previous periods of rapid technological change, income inequality in western economies in recent times has grown not reduced.

Economics identifies two major forces in the economics of technological change;

- Income effects (job creating)
- Substitution effects, whereby new processes cause labour market disruption through changes in the nature of an economic return from work

In the medium term (three to five years) and long run (six years and over) it is likely that the income effects will comfortably outweigh the substitution effects and produce economic growth with significant net gains in employment. However, attention may be needed to the distribution of the created wealth to ensure social acceptance of automation. This is particularly true if the automation and robotics programs undertaken are tailored to areas where the Queensland economy has a comparative advantage.

Overall, we find that the potential benefits from automation, particularly from productivity improvements, the emergence of new jobs and the reshoring of former Queensland based companies are substantial. The report uses three scenarios based upon anticipated productivity growth and parameters from international studies to estimate the levels of potential economic benefit to the Queensland economy. Specifically, over a 10-year period the results of these scenarios, which may be described respectively as "conservative", "most likely" and "optimistic", suggest the following results if the automation process in Queensland is embraced;

- Scenario 1 (conservative): a 1 per cent pa growth addition to GSP over a 10-year period through automation which will provide an additional A$37.4 billion in GSP and 492,950 jobs (250,000, above the previous 10 years)
- Scenario 2 (most likely): a 1.5 per cent pa growth to GSP over a 10-year period through automation which will provide an additional A$77.2 billion in GSP and 725,810 jobs (485,000 above the previous 10 years)
- Scenario 3 (optimistic): a 2 per cent pa growth to GSP through automation which will provide an additional A$117.5 billion in GSP and 1,165,830 jobs (925,000 above the previous 10 years)

The extent of likely job dislocation under each scenario is also examined. Significantly, the lower the rate of economic growth, the greater the degree of job dislocation (noting that net job growth occurs under each scenario). For example, the impact at the lower end of automation (one per cent pa growth rate augmentation) coincides with job dislocation of 485,950 jobs, whereas growth augmentation of two per cent pa leads to an approximate job dislocation of 300,000 over the 10-year period. This apparently counter-intuitive result increased because the greater the rate of growth the greater the wealth (income) effects and the greater the capacity for the new technology to alter rather than replace jobs.

The main conclusion from the report is that greater use of robotics and automation within the Queensland economy is inevitable if living standards are to be maintained. The falling cost of robotics and automated systems means that they are now in reach of the small to medium enterprises (SMEs) that make up the bulk of the economy. This enlarges the scope for automation in Queensland well beyond the dominant capital heavy industries of Agriculture, Mining and Manufacturing that are normally associated with automation.

In facilitating the efficient introduction of automation, and for coping with any resultant short-term dislocation, it is important that private enterprise and government work together. Automating firms should look for solutions through good HR practice before relying on governments for remedial action. In general, economic, specifically employment, disruption is caused not so much by the technology per se, as by the timing of its introduction. As a result, technologies should be considered not in isolation, but as part of a broader ecosystem, that supports their introduction.

In the short term, Queensland's comparative advantage in the introduction of automation and robotics seems to lie in Mining, Agriculture (including Food Technology) and Hospitality and Tourism related activities. In the medium to longer term, considerable opportunities exist in SMEs using light robotics in manufacturing and tapping into the Asian value chain. With this in mind, and noting the state's limited capacity to ameliorate adverse income distribution outcomes, the main policy options are:

- Appropriate technical advice - especially to SMEs concerning the optimum time for the introduction and management of the automation process and creating the required ecosystems
- The development of adequate funding sources (including seed funding) for technical development
- Developing a skilled workforce capable of making best use of available technologies
- Developing industry specific readjustment packages to cope with any short-term dislocation
- Providing adequate educational and information services to demonstrate the value of automation and robotics, and its wealth generating potential

1 Introduction

Industrial processes are subject to continual change because of technological developments. Some of these changes are incremental and result from learning effects over time; others are transformational and result in new industrial paradigms. Historically, it is possible to identify several periods of transformation. The first industrial revolution (1760-1840) laid the basis of mass production. In the period of the second industrial revolution (1870-1940), residents of the developed world (in particular the US) saw large-scale improvements in material living through the applied use of technology.

That period of the second industrial revolution saw the widespread use of electric lighting, telephones, electric appliances, refrigeration, clean water, sewerage systems and antibiotics. McCauley (2016) describes this time as the period "when cars and trucks displaced horses, land previously devoted to growing horse fodder that could be turned to food production, and that clean streets suddenly became a reality"[3].

Economists differ over whether we are currently in a third industrial revolution or even fourth industrial revolution[4]. The prevailing view is that the pace of change and the rate of innovation has never been higher. *The Economist* magazine argues, "a third revolution is under way. Manufacturing is going digital. A number of remarkable technologies are converging: clever software, novel materials, more dexterous robots, new processes (notably three-dimensional printing) and a whole range of web-based services"[5]. These changes are blurring the lines between manufacturing and services.

Others like the economist Robert Gordon, in his influential book *The Rise and Fall of American Productivity*, argue that since the 1940's most technological developments have been incremental rather than revolutionary. He cites basic metrics on US productivity in support of his arguments pointing to an inverted "U" shape in official measures of productivity (as measured by output per hour). From 1870 to 1920 US productivity rose 1.8 per cent a year, from 1920 to 1970 2.8 per cent a year (in spite of the depression and war), and since then has been 1.6 per cent a year[6].

The first two industrial revolutions made people richer and more urban. Gordon does not dismiss the idea of a "third industrial revolution" associated with Information and Communications Technology (ICT), but he points out that compared with earlier periods of technological progress its benefits have been far less profound in improving our quality of life. This is observed in the role of labour in production, as exemplified with the iPad. A first generation iPad included only about 6.5 per cent of manufacturing labour, of which the final assembly in China accounted for just 1.3 per cent. It is evident, in Australia (and Queensland), as elsewhere, labour productivity has not kept pace with the productivity of capital. For example, between 1961 and 2014, in the US, labour productivity rose by 220 per cent while real wages rose by less than 100 per cent. The result is that labour's share of GDP has fallen. Moreover, the share that goes to labour has predominately been going to the people that earn high salaries, exacerbating the inequality problem.

It is this growing disconnect between technological progress and outcomes on real and relative income distribution for significant numbers of people. This produces a mixture of fear and delight over the forces of automation, robotics and digitalisation.

The optimism comes from the promise of changes in the nature of work, a reduction in boring and repetitive work and improvements in health and well-being, particularly in industrial safety. The fear comes from concern over massive displacement of labour, increasing income inequality and even an "AI takeover". The "AI takeover" is the hypothetical scenario in which artificial intelligence (AI) becomes the dominant form of intelligence in the world, with computers or robots effectively taking control of the planet away from the human species. In addition, *The Economist* magazine speaks of "automation angst" whereby workers, including professionals who believed their jobs were individualised and highly stable, are now fearful of replacement by machines[7]. These fears are investigated further in a special edition of the *Journal of Economic Perspectives* (2015)[8].

To fully understand both the opportunities and potential dangers of rapidly increasing automation through robotics requires a multi—disciplinary approach across a range of physical science and social science disciplines. However, examining the issues through a conventional economics viewpoint can provide a strong basis for realistic analysis.

This report traces the suitability and preparedness of the Queensland economy to absorb and benefit from automation. It does this by providing a comprehensive survey of international developments and experiences of automation. It identifies the lessons for Queensland in managing transition and in harnessing the potential growth opportunities offered up by the automation process. Consequently, the report identifies those Queensland industries and occupations that have greater capacity to harness the benefits of automation through leveraging their comparative advantage.

It is this growing disconnect between technological progress and outcomes on real and relative income distribution for significant numbers of people. This produces a mixture of fear and delight over the forces of automation, robotics and digitalisation

The report also recognises that there may be short-term dislocation in some industries and occupations through the automation process. It identifies those Queensland industries and occupations most likely to be impacted and draws on international experience and local knowledge to map out policy and training options to minimise any disruption.

Effective policy in this area recognises that changes in the industrial structure of Queensland, in the wake of new technology, are inevitable. In doing so, the report outlines a Queensland specific program of automation and robotic dispersion, which complements existing comparative advantage, provides economic growth and minimises short-term dislocation.

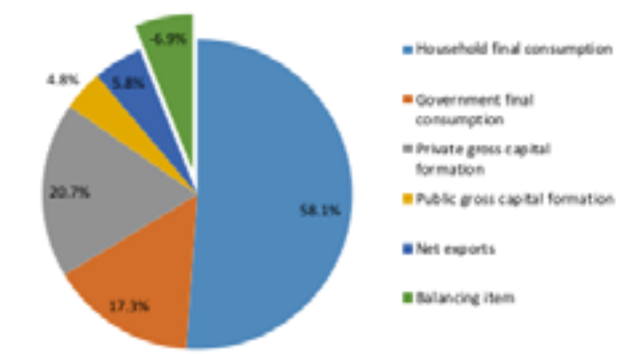
2 The Queensland economy contemporary and projected future developments with particular reference to the labour market[9]

2.1 Sources of wealth in Queensland

The Gross State Product (GSP) for Queensland in 2016/17 was approximately A$298 billion, which represents a 1.8 per cent real increase over the previous year. The main components of that appear below in Figure 1. The largest component is household final consumption, which takes up 58.1 per cent of GSP, followed by private gross capital formation (20.7 per cent) and government final consumption (17.3 per cent). Household consumption as a proportion of GSP in Queensland is below the Australian average of 60.1per cent, reflecting both a lower wage threshold in Queensland and differences in industrial structure. Public gross capital formation (4.8 per cent) in Queensland is also below the Australian average.

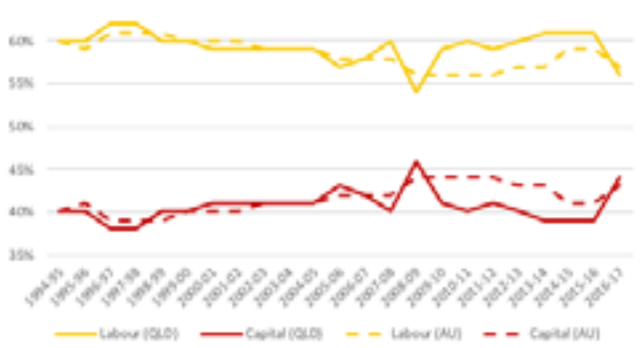
Table 1 draws on other recent GSP data to examine the recent behaviour in the Queensland economy.

Figure 1 Components of Gross State Product (Queensland, 2016/17) - ABS: 5220.0



Source: Gross State Product (Queensland, 2016) – ABS: 5220.0

Figure 2 Queensland and Australia income shares



Source: Estimates of Industry Multifactor Productivity, ABS Cat 5260.

Table 1 Recent Economic Activity in Queensland

Recent Economic Activity	2015/16	2016/17
GSP (Current Prices, Billion)	275.0	298.0
Annual Growth Rate in Real GSP%	2.6	1.8
Real GSP Growth per Capita	1.3	0.3
Proportion of Australian GSP%	18.3	18.6
Percentage of Australian Population	19.7	19.8
Change in Final Real Demand	-1.1	2.4
Labour Share	0.61	0.581
Capital Share	0.39	0.419

Source: Gross State Product (GSP) (Queensland, 2015-2017) – ABS: 5220.0

The data in Table 1, while only covering a two-year period, indicates two potential issues in the Queensland economy, which both can be positively impacted by automation and robotics. First, the Queensland economy is underperforming by failing to gain a share of GSP proportionate to its population (that is, a lower than average per capita share). Second, the share of state income going to labour (wages) is falling (see Figure 2). Queensland has approximately 20 per cent of the Australian population but has less than 19 per cent of National GDP. Real demand fell in 2015/16 (-1.1 per cent) and real GSP Growth per capita grew only slowly in 2016/17 (0.3 per cent). More significantly, for the welfare of the workforce the share of labour (wages and other income) fell to 58.1 per cent of GSP from a high of 61 per cent in 2015[10].

In a domestic economy, the distribution of wealth is eventually determined by the interaction of capital and labour. Figure 2 traces the movements in income share between the broad dimensions of labour and capital.

Issues in the Queensland economy can be positively impacted by automation and robotics

It can be seen from Figure 2 that the labour share of production is at its second lowest level since 1994-15 (56 per cent). The 2008-09 financial year saw the lowest share of labour in Queensland production, however this occurred during a spike in unemployment (from 3.7 per cent to 5.5 per cent) accompanied by low economic growth.

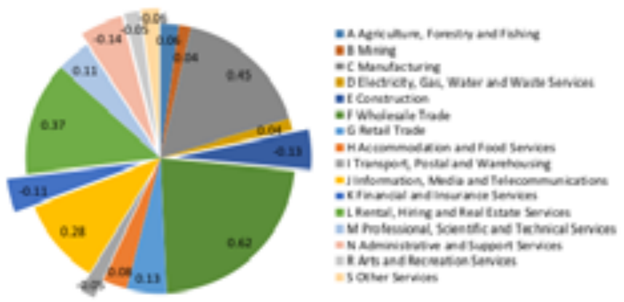
Figure 3 Labour productivity 1995-2017- Australia and Queensland

Source: Estimates of Industry Multifactor Productivity, ABS Cat 5260.

Therefore, the production in this financial year was attributed to a smaller workforce. However, the 2016-17 spike in capital share has not been accompanied by a notable rise in unemployment, indicating an increased role of capital and a decline in labour productivity. Labour productivity in Queensland has fluctuated over the last two decades. On brief occasions it has moved above the Australian average, largely due to boosts in mining activity. In aggregate, these one-off mining boosts have made average labour productivity over the period 1995-2017 of Queensland (2.3 per cent) slightly higher than the 2.2 per cent for whole of Australia but normally, on a year-by-year basis, the state's productivity has been below the Australian average. This low level of productivity growth has not permitted much in the way of wages growth in Queensland particularly since 2008[11].

While Queensland specific data is not available for a disaggregated break down in the contribution of each industry to total productivity in the state, Figure 4 shows that in 2015-16 the Australian total labour productivity growth consisted of productivity gains (and losses) in the following industries (see figure 4), which, collectively, in aggregate led to Australian labour productivity growth of 1.64 per cent.

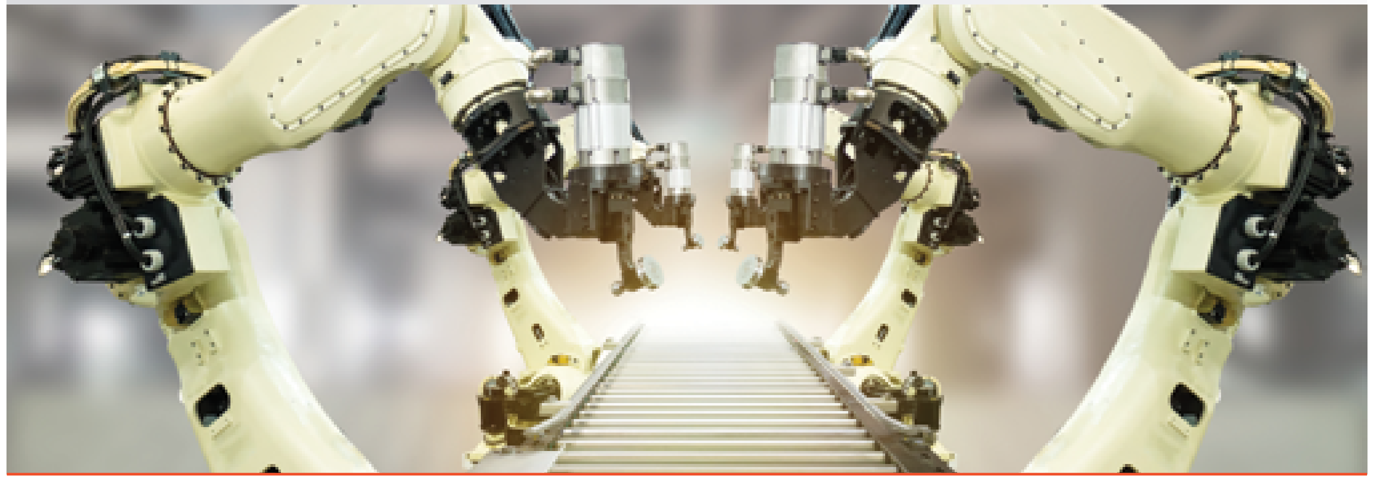
Figure 4 Industry breakdown of contribution to labour productivity growth in 2015-16-Australia



Source: Australian Bureau of statistics Catalogue: 5260.0

Key points

- The rate of wealth generation in Queensland has been slowing and moving away from returns to labour
- The reduction in wealth creation and the share of labour has been fuelled by low productivity growth
- This trend of a shift in income distribution, away from labour and towards capital and non-wage income is occurring in a number of countries
- In part, it is due to technological change, which in its more recent growth spurt, and in contrast to earlier periods, has increased rather than reduced income inequality. This has the effect of diverting labour income towards higher skilled jobs as well as reducing the overall share of labour
- In economic speak however, the income effect (job producing) of technological change has still outweighed the substitution effect
- However, internationally the distribution of the economic gains is not spread evenly. The issue has been one of the distribution of the gains from technology not its overall benefits in wealth creation
- A new wave of automation and robotics is needed to arrest the productivity slow-down in Queensland and increase job opportunities
- The public policy issue then becomes ensuring a more equitable and socially acceptable distribution of the gains



2.2 Current industrial structure

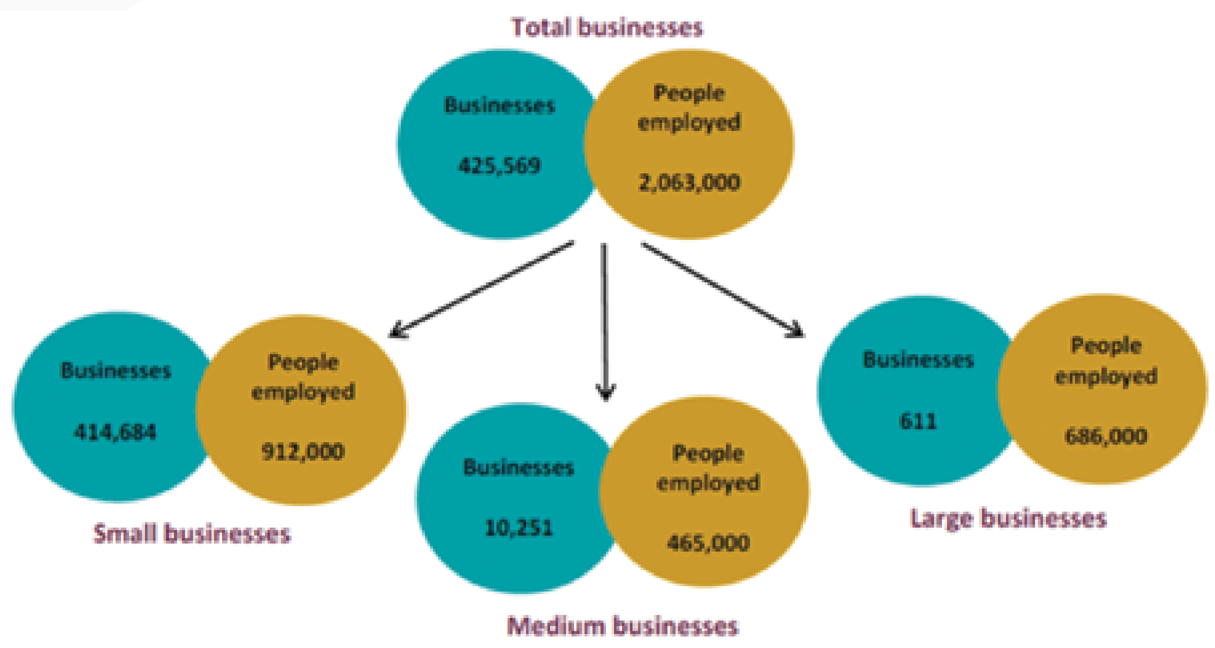
Table 2 shows the contribution to gross value-added and the change in relative share of GSP by industry in Queensland between 1999 and 2017. GSP estimates are in current prices and at factor cost including aggregate measures of compensation of employees and gross operating surplus as well as mixed income. The salient points are the significant declines in relative contribution by some industries to state GSP including Agriculture Forestry and Fishing (-20 per cent), Manufacturing (-46 per cent), Information Media and Telecommunications (-45 per cent), Wholesale Trade (-30 per cent) and Accommodation and Food Services (-32 per cent). These relative declines were offset by large gains in the relative contribution to GSP by Administrative and Support Services (+83 per cent) Professional, Scientific and Technical Services (+78 per cent), Mining (+75 per cent) Rental, Hiring and Real Estate Services (+58 per cent) and Health Care and Social Assistance (+39 per cent).

Table 2 Queensland, Gross State Product (GSP) by industry

Industry	1999 ($m)	2017 ($m)	% change	Change in Relative Share
Agriculture, Forestry and Fishing	4,232	10,851	156%	-20%
Mining	5,567	31,255	461%	75%
Manufacturing	11,576	20,075	73%	-46%
Electricity, Gas, Water and Waste Services	2,420	8,999	272%	16%
Construction	6,886	24,579	257%	11%
Wholesale Trade	5,923	13,364	126%	-30%
Retail Trade	5,507	14,715	167%	-17%
Accommodation and Food Services	2,974	6,457	117%	-32%
Transport, Postal and Warehousing	6,400	16,332	155%	-20%
Information Media and Telecommunications	3,344	5,907	77%	-45%
Financial and Insurance Services	5,715	18,874	230%	3%
Rental, Hiring and Real Estate Services	1,994	10,091	406%	58%
Professional, Scientific and Technical Services	3,143	17,880	469%	78%
Administrative and Support Services	1,810	10,621	487%	83%
Public Administration and Safety	5,586	18,168	225%	2%
Education and Training	4,501	15,455	243%	7%
Health Care and Social Assistance	5,415	24,029	344%	39%
Arts and Recreation Services	803	2,029	153%	-21%
Other Services	1,986	4,966	150%	-22%
Ownership of dwellings	7,362	23,607	221%	0%
Total	93,144	298,254	220%	0%

Note: GSP estimates are in current prices. Source: Synergies calculation.

Figure 5 The Structure of Business Enterprise in Queensland



Source: ABS 8165.0 and ABS 8155.0, unpublished data.

These shifts in relative share are, on the surface, indicative of the shift to services and away from Manufacturing in the Queensland economy (with Mining being of major importance). There are some anomalies, particularly the decline in relative importance of Arts and Recreation Services and Other Services, which, being essentially non-routine activities, might be expected to be making greater contributions to the economy. The other noticeable feature of the Queensland economy is the significance of small business to the industrial structure.

> 19.6 per cent of all businesses in Australia are operating in Queensland

The Australian Bureau of Statistics defines a small business as "a non-employing business or a business employing less than 20 people". This includes sole proprietorships and partnerships without employees. By way of comparison, a medium business employs between 20 and 199 employees and a large business employs 200 employees or more[12]. Latest data, taken at June 2016 shows that there were 2,171,544 businesses actively trading in Australia. Distributed spatially and by size, Queensland has 414,684 small businesses, 10,251 medium businesses and 611 large businesses. This is shown above in Figure 5.

The key points from this data are:

- 425,569 businesses (19.6 per cent of all businesses in Australia) were operating in Queensland
- Small business is the predominant type of business actively trading in Queensland (97.4 per cent), compared with their share nationally (95.7 per cent)
- There were 414,684 small businesses actively trading in Queensland
- In the same period, there were 10,251 medium businesses and 611 large businesses actively trading in Queensland
- Construction had the largest share of small business (17.3 per cent), followed by Rental, Hiring and Real Estate services industry (11.8 per cent)
- Queensland, in Construction, Rental Hiring and Real Estate, Agriculture, Forestry and Fishing and Administrative and Support Services had a higher share than that recorded at the national level and appeared to have a comparative advantage
- Together, the top 10 industries accounted for more than four-out-of-five small businesses in Queensland (83.1 per cent)

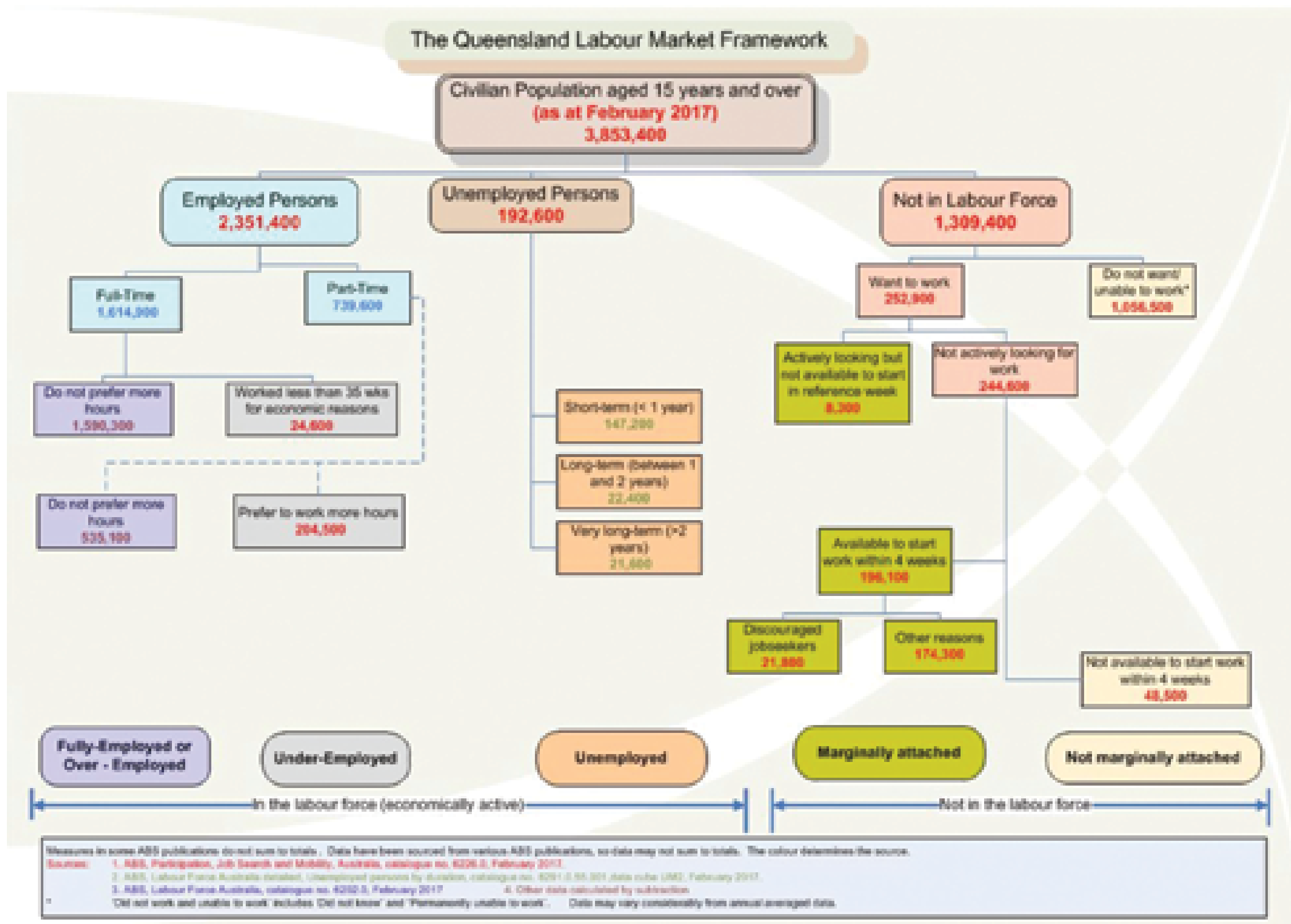
2.3 The structure of the Queensland labour market

Figure 6 is a stock based figure, showing the approximate numbers of persons in each normally defined state of the labour market (job status) according to the latest ABS data. In a dynamic labour market, there are significant flows between these stocks as people move in and out of employment and the labour market in general.

The skill profile of people helps determine their job status, the probability of them staying in that status (status duration) and their ability to transit out of the undesired job category. However, an examination of Figure 6 quickly establishes that most people in the Queensland labour market are employed (60 per cent) and that an even higher proportion participate (either employed or defined as unemployed) (67 per cent).

Thirty-three per cent do not currently participate for a variety of reasons from age, infirmity care responsibilities, lifestyle and inability. As well, there is considerable diversity among these groups. Currently, training initiatives concentrate on the long and very long-term unemployed, who, though an important problem, make up a small fraction of the labour market (approximately one per cent). Whereas, those who are classified as under-employed make up a much larger proportion of the workforce. Often, low skills are the basis for their underemployment issue. Consequently, in this analysis, we concentrate on those participating in the labour market.

Figure 6 Queensland Labour Market Framework



Note: Constructed from data provided by the Labour Market Research Unit, Department of Education and Training

2.3.1 General labour market supply and demand in Queensland

Figure 7 shows labour demand (employment + vacancies) and labour supply (employment + unemployment) for the Queensland labour market over the period 2008-2017.

Over the last decade, labour supply has exceeded labour demand in Queensland, widening from 2008-2014 and remaining relatively constant since then at around six per cent excess supply. Moreover, since 1999 there have been significant shifts in the relative importance of particular industries and occupations in terms of their share of total employment. Table 3 shows the large absolute and relative increases in the employment significance of Health Care and Social Assistance, Electricity, Gas, Water and Waste Services, Mining, Professional Scientific and Technical Services, Public Administration and Safety and Administrative and Support Services (see, Table 3).

This shift towards services (Mining excepted) is mirrored in the changes over the period 1999- 2017 in occupational classification (Table 4).

Figure 7 Aggregate Labour Demand and Supply in Queensland 2002-2017

Note: Labour supply and labour demand data were derived using quarterly employment, unemployment and trend-adjusted vacancy data for the Queensland Labour Market.

Table 3 Queensland, total employment by industry

Industry	1999 ('000)	2017 ('000)	% change	Change in Relative Share
Agriculture, Forestry and Fishing	104.6	54.9	-47.5%	-65%
Mining	18.6	59.5	219.9%	114%
Manufacturing	166.7	169.1	1.4%	-32%
Electricity, Gas, Water and Waste Services	14.0	26.8	91.4%	28%
Construction	135.8	234.1	72.4%	15%
Wholesale Trade	73.5	63.1	-14.1%	-43%
Retail Trade	193.4	249.7	29.1%	-14%
Accommodation and Food Services	118.3	186.9	58.0%	6%
Transport, Postal and Warehousing	86.8	133.6	53.9%	3%
Information Media and Telecommunications	29.8	33.5	12.4%	-25%
Financial and Insurance Services	40.0	62.0	55.0%	4%
Rental, Hiring and Real Estate Services	29.6	48.7	64.5%	10%
Professional, Scientific and Technical Services	84.3	169.6	101.2%	34%
Administrative and Support Services	45.2	79.2	75.2%	17%
Public Administration and Safety	86.5	170.4	97.0%	32%
Education and Training	116.0	187.4	61.6%	8%
Health Care and Social Assistance	148.0	311.9	110.7%**	41%
Arts and Recreation Services	30.3	44.1	45.5%	-3%
Other Services	74.8	104.4	39.6%	-7%
Total	**1,596.0**	**2,389.1**	**49.7%**	**0%**

Source: Synergies calculation.

Table 4 Queensland, total employment by occupation

Industry	1999 ('000)	2017 ('000)	% change	Change in Relative Share
Managers	181.20	274.60	51.5%	1%
Professionals	244.20	501.40	105.3%	37%
Technicians and Trades Workers	261.20	359.70	37.7%	-8%
Community and Personal Service Workers	136.50	271.50	98.9%	33%
Clerical and Administrative Workers	250.10	326.30	30.5%	-13%
Sales Workers	180.10	235.70	30.9%	-13%
Machinery Operators and Drivers	124.70	165.30	32.6%	-11%
Labourers	217.90	254.50	16.8%	-22%
Total	**1,596.00**	**2,389.10**	**49.7%**	**0%**

Source: Synergies calculation.

Table 4 shows significant increases in the relative importance of Professionals (+37 per cent) and Community and Personal Service workers (+33 per cent) as well as large absolute changes in Managers (+51.5 per cent), Professionals (105 per cent) and Clerical and Administrative Workers (+33 per cent). However, Clerical and Administrative Workers fell in relative importance (-13 per cent) as did Sales Workers, (-13 per cent) Machinery Operators and Drivers (-11 per cent) and Labourers (-22 per cent).

This shift in employment seems to be following a pattern.

Overall, while demand and supply for these higher skilled occupations appear to be roughly in balance, it is important to understand why this might be the case and what is leading it. If demand is the causal factor, then clearly educational institutions (or migration) are providing the required training. If supply is leading, this may indicate some form of qualification creep whereby tertiary-trained workers are moving into areas, such as farm management, where their formal skills were previously not required.

*Specifically, the occupational classification "Managers" appears to be in equilibrium with aggregate demand matching aggregate supply. However, diagrams such as these are descriptive only, they do not show causation nor adjustment mechanisms between demand and supply that characterise the occupation. Nor are they able to predict future movements in either demand or supply. To obtain a better picture of what is actually occurring, a greater disaggregation of the job categories classified as managerial would need to be undertaken. One interpretation of the current situation would be that the nature of managerial positions is changing with more people and tasks being classified as managerial than in the past.

Similarly, within the category known as "Professionals" there appears an approximate equilibrium between supply and demand at the aggregate level. However, this aggregate behaviour does not pick up mismatch in certain types of professions and does not highlight issues of classification or qualification creep. It is an open question as to whether labour markets into the future can continue to absorb the numbers of new graduates, particularly in compliance related professions faced with the short-term job substituting aspects of automation, block chain technology and artificial intelligence.

> While the occupational categories of managers and professionals seem to be performing strongly, there is a danger that both markets will become demand constrained

In short, while the occupational categories of managers and professionals seem to be performing strongly, there is a danger that both markets will become demand constrained. If this is the case, the issues of qualification creep and job reclassification are likely to intensify. Fortunately, at this level of the labour market (one of upper and higher formal qualifications), there are some short-term supply responses such as more and better-defined educational programs and greater task specification.

Community and Personal Service workers` are another category that seems to be roughly in equilibrium in aggregate terms. There are a number of drivers of demand for this occupational group; in particular, shifts in public sector expenditure and community expectations. Supply is unlikely to be an issue, given the large numbers in the economy that seek part-time work in this sector, the consistent supply of new graduates and the relatively fluid entry conditions, particularly in the non-government sector. In this sense, the dangers to employment growth in this sector are likely to be from the demand side if employment in the Public Service contracts.

Within the occupational group "Technicians and Tradesmen", the data suggests a mild oversupply of between two and three per cent over most of the period covered with a movement towards equilibrium in 2017. The dynamics of this occupational market are closely tied to activity in the Construction and Mining industries. As well, the qualification requirements also tend to be fluid, with workers moving between tasks as the economic cycle dictates or region-specific shortages necessitate.

There is a consistent over supply of Clerical and Administrative Workers in a pattern that suggests consistent, but mild disequilibrium. The reasons for this, historically, relate to the relative ease of entry on the supply side and the pro-cyclical activity of demand for these services. Employment in this industry has been identified as being particularly vulnerable to technological change.

The same can be said for the remaining occupations such as Sales Workers, Machine Operators and Drivers, and Labourers. In all cases, excess supply exists and is likely to become a continuing issue. Currently, over supply among labourers is the more acute problem but sales workers face significant challenges from technological change and changes to the structure of sales models. Moreover, there are limited supply responses to these challenges through education and training.

It is an open question as to whether labour markets into the future can continue to absorb the numbers of new graduates entering the labour market

Key points

- The Queensland labour market has been shown to be diverse although taking on many characteristics of other advanced economies; declining full-time employment, increased casualisation and part-time employment and a significant group of "marginally attached to the workforce"
- In aggregate, labour supply slightly exceeds labour demand, which indicates a potential fragility to employment in the event of any economic downturn
- Employment by industry has changed substantially over the period 1999-2017, with service industries, particularly Health Care and Social Assistance, Public Administration and Safety and Administration and Support Services becoming increasingly important as well as higher skilled jobs in the Professional, Scientific and Technical Services
- These industrial changes have been mirrored in by changes in occupation with large absolute increases in employment of Managers, Professionals, Technicians and Trades workers[13] and Community and Personal Service industries
- The quasi-permanent nature of mild excess supply indicates the Queensland economy is in need of a productivity-induced demand boost, possibly concentrated in those industries that have shown slow or negative growth over the last decade

2.4 Labour force skill mapping, current labour force shortages and projected bottlenecks to 2030

Economic modelling tends to rely heavily on past results and is not particularly good at factoring in large-scale changes in technology such as promised by automation and robotics. Below, economic modelling looks at the predicted structural change facing each industrial and occupational group[14]. The degree of structural change is estimated by the ratio of baseline predictions for each industry and occupation in Queensland, against a business as usual case where each industry and occupation grows or declines at the same rate as in past periods. By contrast, the baseline predictions take into account estimates of technical substitution as well as predicted increases in productivity and value added.

Table 5 Structural change adjustment in Queensland by industry, 2017 to 2030

Industry	Baseline ('000)	Business as usual ('000)	Structural change adjustment ('000)
Agriculture, Forestry and Fishing	56.90	57.47	-0.57
Mining	76.79	62.29	14.51
Manufacturing	177.92	177.02	0.90
Electricity, Gas, Water and Waste Services	36.75	28.06	8.70
Construction	260.96	245.06	15.90
Wholesale Trade	69.35	66.06	3.30
Retail Trade	275.09	261.39	13.69
Accommodation and Food Services	173.38	195.65	-22.27
Transport, Postal and Warehousing	142.36	139.86	2.50
Information Media and Telecommunications	33.35	35.07	-1.72
Financial and Insurance Services	66.68	64.90	1.77
Rental, Hiring and Real Estate Services	59.59	50.98	8.61
Professional, Scientific and Technical Services	186.07	177.54	8.53
Administrative and Support Services	89.23	82.91	6.32
Public Administration and Safety	169.16	178.38	-9.22
Education and Training	196.13	196.18	-0.05
Health Care and Social Assistance	308.63	326.51	-17.87
Arts and Recreation Services	43.19	46.17	-2.97
Other Services	102.43	109.29	-6.86
Total	2,501.00	2,501.00	0.00

Source: Synergies calculation.

The results in Table 5 show mixed results, with some industries in Queensland predicted to grow at a greater rate than previously, and therefore requiring greater resources of labour and capital, and others expected to require less resources than previously. Noticeable industries facing negative structural change are Health Care and Social Assistance (indicating that the days of very rapid expansion are temporarily over) and Accommodation and Food Services. The greatest non-mining positive structural adjustment will occur in Retail Trade, Construction, Professional Scientific and Technical Services and Administrative and Support Services.

Similarly, in terms of structural change adjustment for occupations, Managers (after a lull in recent years), Technicians and Trades Workers and Clerical and Administrative Workers are expected to grow at a greater rate than in previous times in the short run but face pressure from automation in the medium term.

The difficulty in interpreting these predictions are that they relate to broad categories of occupation and industry and are not task specific. Therefore, it is not immediately apparent how a spurt in automation and robotics will impact on these predictions. To do this requires some analysis of the tasks involved in these jobs.

Table 6 Structural change adjustment in Queensland by occupation, 2017 to 2030

Industry	Baseline ('000)	Business as usual ('000)	Structural change adjustment ('000)
Managers	311.81	287.46	24.35
Professionals	514.90	524.88	-9.98
Technicians and Trades Workers	386.48	376.55	9.93
Community and Personal Service Workers	257.12	284.22	-27.10
Clerical and Administrative Workers	359.33	341.58	17.75
Sales Workers	238.06	246.74	-8.68
Machinery Operators and Drivers	176.15	173.04	3.11
Labourers	262.69	266.42	-3.73
Total	**2,501.00**	**2,501.00**	**0.00**

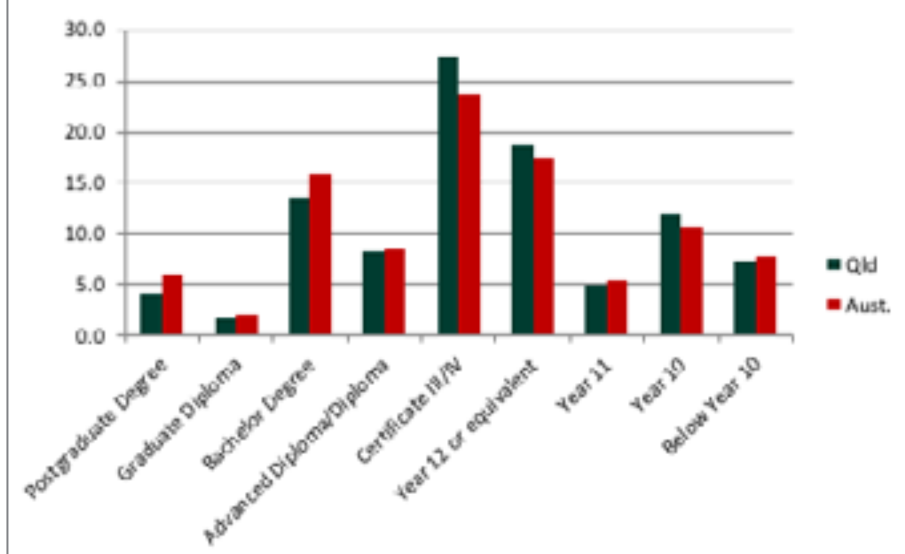
Source: Synergies (2018).

Key points

- For over a decade, the Queensland labour market has been in steady market disequilibrium with labour supply slightly exceeding labour demand by approximately six per cent on average
- The last two decades have seen considerable structural change in employment both in the relative importance of industries and occupations
- The observed shifts have been skewed towards service industries and towards managerial, professional and technical occupations which have a higher formal skill requirement
- Projections to the year 2020 show a continuation of these trends, with some notable exceptions such as Health and Social Assistance which is predicted to display a slow-down in growth from the high levels of the last decade
- One issue in considering employment in terms of broad occupational and industrial groupings is that they cover a range of tasks, some automatable and other less automatable
- As a result, it is important to consider the employment profile in Queensland in terms of skill level and the degree of routineness in tasks
- The difficulty in interpreting these predictions is that they relate to broad categories of occupation and industry and are not task specific. Therefore, it is not immediately apparent how a spurt in automation and robotics will impact on these predictions. To do this requires some analysis of the tasks involved in these jobs

2.5 Labour force skills, qualifications and routine and non-routine jobs in Queensland

Figure 8 The Labour Force by Qualifications- Australia and Queensland

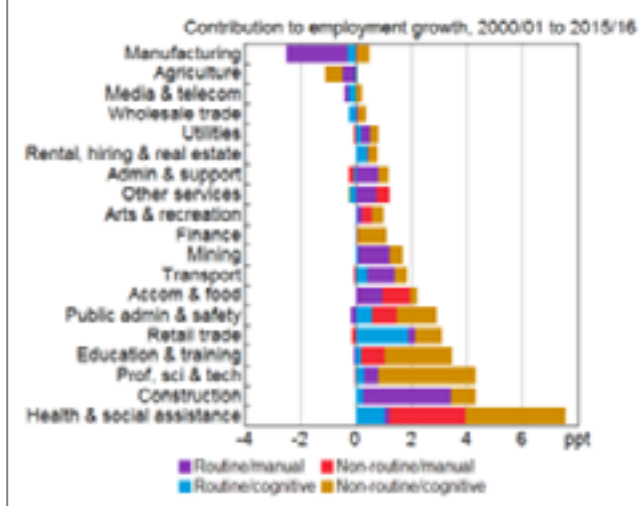


Source: ABS 8165.0 and ABS 8155.0, unpublished data.

Figure 8 confirms that the Queensland workforce has less formal educational qualifications than the Australian average. This is true in terms of percentages with Postgraduate Degrees, Graduate Diplomas, and Certificate 111 & IV[15]. Gorloch and Wessel (2008) redefined workforce skills by subdividing the workforce into four quadrants; routine manual, non-routine manual, routine cognitive and non-routine cognitive[16]. This classification was specifically designed to examine the potential for jobs to be replaced by automation and robotics.

There is a reasonable overlap between formal education and the Gorloch and Wessel (2008)[17] categories into which your job would be placed, but the mapping is not exact. For example, accountants and auditors who have relatively high formal education are seen as among the most likely to be automated[18]. Using the Gorloch and Wessel classifications, it is possible to trace employment growth patterns in Australia (see Figure 9).

Figure 9 Employment by Skill Type (Queensland) using the Gorloch and Wessel Classification

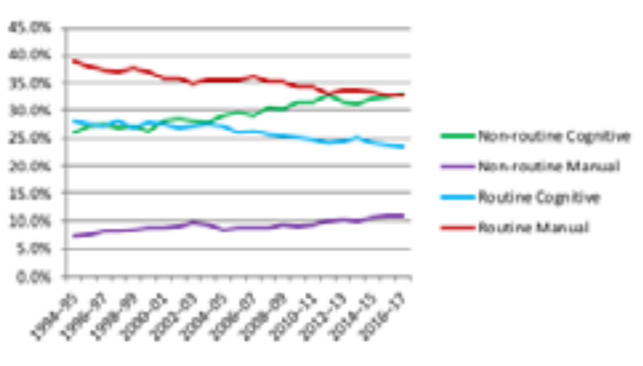


Source: Reserve Bank of Australia (2017).

Figure 10 shows that the majority of growth in employment has come in the non-routine cognitive category (that is skilled jobs displaying some discretion) with the exception of Construction and Agriculture Forestry and Fishing. Within the manual categories, non-routine manual has performed well in Health and Social Assistance, Education and Training and Public Administration and Safety; whereas, routine manual performed well in Construction and Other Services but badly in Manufacturing. Figure 10 confirms that most trend growth in employment came in non-routine areas both manual and cognitive.

Finally, as can be seen in Table 7 below, the majority of non-routine cognitive work requires a Bachelor Degree. This might be an issue as Queensland slightly underperforms in terms of the Australian average on formal education.

Figure 10 Employment by Skill Type (Queensland)[19]



Source: Constructed from ABS data.

Table 7 Education attainment by skill type

Occupation	Postgraduate Degree	Graduate Diploma	Bachelor Degree	Advanced Diploma	Certificate III/IV	Certificate I/II	Certificate n.f.d.
Routine manual	2.49%	1.30%	12.62%	11.70%	*45.97%	6.35%	2.00%
Non-routine manual	1.38%	1.00%	7.37%	9.30%	50.49%	2.06%	0.89%
Routine cognitive	9.83%	6.10%	42.16%	40.55%	56.83%	8.66%	2.66%
Non-routine cognitive	29.97%	11.29%	73.65%	23.60%	21.15%	1.50%	0.70%

Source: Calculated from ABS. Catalogue. 6227.0 Education and Work 2017.

Key points

- Queensland has a lower formal educational profile in formal education qualifications than the Australian average
- The job market has consistently moved in favour of higher education and skill profiles
- Gorloch and Wessels (2008) redefined job skills by using classifications of routine and non-routine as a means of tracing vulnerability to automation
- These classifications are task rather than education based but have a relatively strong overlap with formal education and skill
- Applying these classifications to employment trends in Australia and Queensland confirms that most job growth has come in the non-routine categories both cognitive and manual
- The majority of non-routine cognitive work requires a Bachelor Degree; this can be an issue as Queensland has a slightly lower output in this area than the average for the rest of Australia

Traffic lights

Red things that will end as a result of automation

- An end to boring, repetitive and often dangerous work

Amber what needs to be done to ensure best results

- Need for Government and Industry to work together
- Managed introduction of automation, re-training and re-deployment
- Focus on distribution of created wealth to ensure social acceptance of automation

Green positive results of automation

- Big productivity gains, job creation, emergence of new and more satisfying jobs, reshoring of former Queensland-based companies
- Advances in health and well-being
- Greater automation = cheaper robots/systems + access to SMEs (97.4% of Queensland's economy), helping them become or remain competitive

2.6 Capacity of industrial structure to absorb and grow from technological change including automation and robotics, with concentration on areas of comparative advantage

The key value of automation is that it gets products to customers fast!

To this stage, the report has established a number of important points regarding the economic structure of Queensland including sources of wealth, returns to labour, the industrial and occupational distribution of employment and the skill distribution of the labour force. Traditionally Queensland has had a comparative advantage in what was formerly known as the "four pillars":

- Agriculture Forestry and Fishing
- Mining
- Construction
- Tourism

Taken together, these industries make up about 25 per cent of the Queensland economy but these have seen mixed economic performance over the last decade. In terms of relative share of GSP, Agriculture has declined by 22 per cent, and Accommodation and Food Services by 32 per cent, which is a major indicator of both activity in tourism and processing of agricultural products. Construction has seen a modest increase in relative importance by 11 per cent. These of course are not absolute declines just a shift in relative significance. Moreover, if the future lies in creating non-routine work for humans to work alongside robots, Agriculture has performed badly (see Figure 9) with virtually no increase in non-routine work. The other three: Construction, Tourism and Mining combined have shown that a significant part of their job growth has been in non-routine employment. The contribution of these industries to aggregate productivity growth is also low. Using Australian data as a proxy (see Figure 4) Agriculture, Forestry and Fishing contributed 0.06 per cent, Construction (-0.13 per cent), Mining (0.04 per cent) and Accommodation and Food Services (0.08 per cent) towards the Australian 1.64 per cent.

If these cornerstone industries are to continue to have the same degree of significance to the Queensland economy as previously, they need a significant boost in productivity. Expansion of their automation and robotics programs can provide a major boost in this area if aided by supporting labour supply and finance infrastructure. Agriculture, Forestry and Fishing would seem a prime example where Queensland can build on its competitive advantage and natural resources to raise productivity through automation[20]. Agricultural robots may be used to increase production yields in a number of different ways. Capital equipment ranging from drones to autonomous tractors to robotic arms allow creative and innovative use of these technologies. Robotic applications in agriculture that are now in increasingly common use include;

- Harvesting and picking
- Weed control
- Autonomous mowing, pruning, seeding, spraying and thinning
- Phenotyping
- Sorting and packing
- Utility platforms[21]

Recent examples of increased automation in Agriculture include[22]:

- Platform for agricultural technology; the SwarmBot platform utilises robotic technology and an ecosystem of independent developers that create modular technology for application to the platform. It is a platform for carrying smart tools and implements around paddocks in a much more precise and repeatable manner than is achievable on board a tractor. Ultimately, this technology will make it easy for farmers to put new AgTech in their paddocks, undertake new field practices, and deploy technology into their farming systems by using 'swarms' of smart, mobile, and automated robots. SwarmBots are already being successfully used in commercial broadacre cropping operations, with scope to expand the technology to other agricultural industries. The innovative Queensland start-up is working with a leading global supplier of technology and services, Bosch, to redesign its unique SwarmBot robotic platform for commercial production. In this partnership, SwarmFarm Robotics will develop the final production model of the SwarmBot ahead of commercial sales to farmers in mid-2018.
- Capsicum-picking robot; the horticulture industry in Australia has a gross value of more than A$8 billion per annum. Australia produces more than 36,000 tonnes of capsicum per year, worth approximately A$92 million, mostly grown in North Queensland [DAF14]. The Queensland Government supported QUT to develop a new agricultural robot prototype designed to harvest capsicums – nicknamed 'Harvey'. Harvey was developed as part of the Queensland Department of Agriculture and Fisheries (DAF) three-year strategic investment in farm robotics [SIF17]. The process relies on an algorithm to detect approximately 70 per cent of in-field capsicum that improves on state-of-the-art vision systems and is comparable with detection by humans. Harvey's robotic arm has a camera and a unique cutting tool attached to it. Using data from the camera, the robot detects the fruit and cutting location and plans and controls the robotic arm and harvesting tool to detach the fruit from the plant. The combination of state-of-the-art robotic vision software and novel crop-manipulation tools enable successful harvesting of the crop. This advancement promises significant benefits for horticulture growers, who export more than A$2 billion in products every year.
- Agrobot SW6010, a tractor like robot that uses sensors and robotic arms to detect ripe berries and pick these up from the ground
- The Festo Fin Ray-Fingers is a modular and intelligent robot platform that uses cameras and other sensor technology to detect the ripeness and the position of the fruit. The robot also detects and avoids obstacles and other objects

Robots will be used alongside human workers to augment their work

All of these devices raise productivity significantly and may, as with most technologies, have short-term job implications in such areas as fruit picking and processing. However, Agriculture is now not a major employer. For example, Retail Trade now employs 250,000 (4.6 times as many). The workforce in Queensland in Agriculture has reduced from 104,000 in 1999 to 54,000 in 2017. At the same time, value of production has risen significantly as has the export of agriculture products. In short, the future value of the Agricultural sector in Queensland lies not in being a large employer of labour but rather as a technologically efficient producer of wealth and GSP growth.

In contrast, Construction is a large employer of labour. However, robots are coming to the construction site[23]. Fortunately, for future employment in the Industry, Kendall (2018) argues:

> *"While there may be some attrition in the future, the most likely scenario is that robots will be used alongside human workers to augment their work, keep them safer and boost productivity. The current capabilities of existing robots combined with a growing labour shortage will probably lead to robots handling some of the more menial repetitive tasks, leaving the human worker to focus on other aspects of their job". (Kendall, 2018, p2.)*

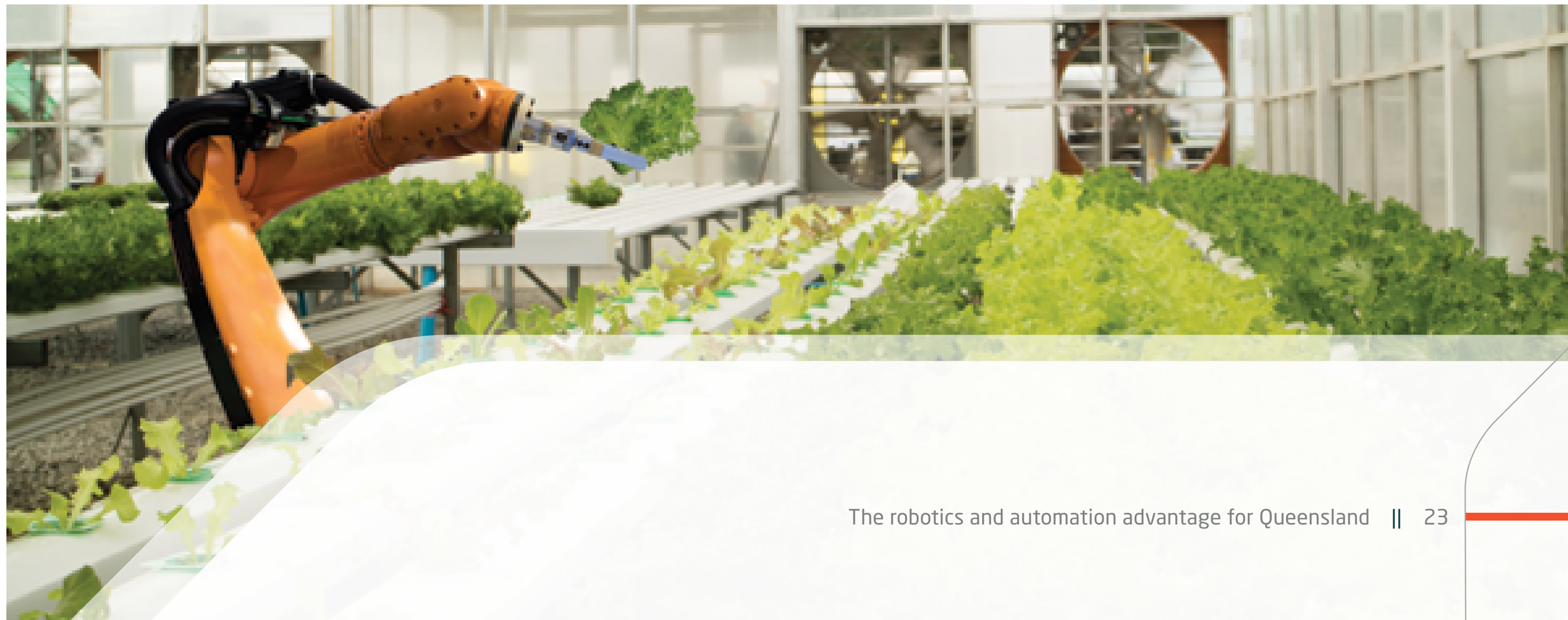
Further examples of the increasing application of artificial intelligence (AI) and robotics to construction include:

- Using robots and AI to monitor jobsite progress with real-time, actionable data
- Using autonomous drones and rovers equipped with high-definition cameras and LiDAR to photograph and scan the construction site each day with pinpoint accuracy.
- Using AI to process scans and compare against BIM models, 3D drawing
- Schedule and estimate and inspect the quality of the work performed and determine the extent of daily work progress

Accommodation and Food Services (including restaurants and representing tourism)

This sector has already seen disruption in the Accommodation sector through Airbnb and it is expected that future impacts of automation will come through the Food Services sector[24]. Technical innovations currently making an impact in the Food Services industry include:

- Chatbots and Apps whereby food outlets and restaurants are using virtual assistants to respond to customer inquiries and to process and customise customer orders
- Robots where restaurants utilise AI-controlled robots to increase capacity and speed of food preparation and delivery
- Recommendation engines – under this innovation programmers design applications that use AI
- AI to facilitate customer choice based on past eating preferences
- The use of AI-controlled queue systems in the restaurant and kiosk queuing integrating AI-driven kiosks to reduce customer waiting time and enhance the customer ordering experience[25]



2.7 Mining

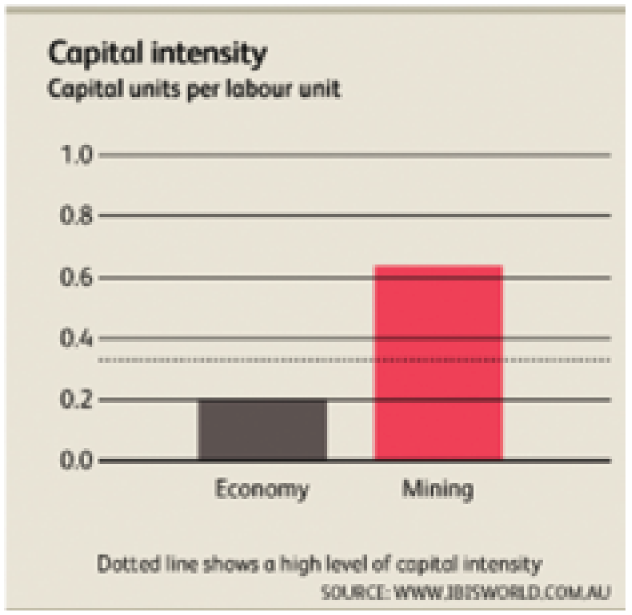
The fully automated mine has long since passed the days of concept and evolved into a reality… total automation of many of the processes is the way forward (Latimer, 2015, p2)[26].

Currently emphasis is being placed on autonomous vehicle operations that can help increase productivity by between 15 to 20 per cent, and truck usage by up to a fifth. For example, Rio Tinto automated fleets have recently recorded a 12 per cent production increase compared to operated vehicles (Latimer, 2015 p.1). Rio Tinto, along with BHP, Roy Hill and Fortescue are well advanced in implementing autonomous haulage systems in the Pilbara.

Rio Tinto is also integrating the automation process with automated locomotives that drive themselves and might have the capacity to load and unload automatically. The *MIT Review of Technology* uses the Australian Mining example to talk of "using robots for 24-hour a day mining"[27]. The Mining industry in Australia currently already has higher capital intensity than the Australian industrial average. For every dollar required for Mining in Australia in labour costs in 2017-18, approximately A$0.64 invested in capital plant, equipment and vehicles[28]. The Mining Industry in high labour costs countries, such as Australia[29], need to maintain high productivity growth to remain competitive in a world economy which has seen increased competition in recent years.

It is for this reason that further automation is required within Australian mining. The industry has never been a major direct employment producing industry and further automation may cost jobs but the flow-on employment effects and its contribution to total GSP have been substantial. In 2016-17, Mining contributed A$31.3 billion to the Queensland economy and made up 37 per cent of the value of total exports[30]. An increase of 15 per cent to 20 per cent as a productivity dividend through increased automation would provide, all things being equal, approximately A$5 billion support and upwards of 50,000 jobs outside of the Industry[31]. However, automation will impact all industries in Queensland. Table 8 provides a brief summary of views on the propensity of each industry sector in Australia to become automated.

Figure 11 Capital Intensity in Australia - Mining compared to the Economy Average



Source: IBIS World Industry Report (2018) "Mining", p3.

Table 8 Queensland Industries Potential for Automation

Industry	Potential for automation	Explanation	Policy response
Agriculture, Forestry and Fishing	Medium to high	Widespread incidence of AI and Robotics for agricultural use; need to remain competitive	Encourage innovation, increase farm size, Agricultural bridging loans, staff retraining and relocation
Mining	High	High labour wage costs for routine work will encourage substitution through need to remain competitive	Socio-economic policy responses to impacted communities, development of more value adding and processing of output

Table 8 Queensland Industries Potential for Automation (Continued)

Industry	Potential for automation	Explanation	Policy response
Manufacturing	High	Declining industry in need of productivity increase and promise of more use of light and cheaper robotics in SMEs	Active policies to encourage re-shoring by use of robotics to bring previously offshored manufacturing industry back to Queensland
Electricity, Gas, Water and Waste Services	Moderate	Many functions in the industry are open to automation including metering, billing and settlements, consumption management, customer records management, complaints resolution and customer transfer[32]	Phased introduction of robotics and expansion of client services for human employees
Construction	High	Accelerating rate of construction related automated processes will force builders to use robotics to maintain competitiveness in domestic market. Presence of routine and repetitive tasks	Important to foster the use of labour augmenting automation to shift job mix rather than replace jobs. Significant changes needed to vocational training, including appropriate infrastructure
Wholesale Trade	Moderate to high	Automation mainly in warehousing and distribution. Increased use of self-delivery robots for shipping, staffing and cargo tracking intelligent systems. Cost incentive to reduce	Foster introduction of connected robotics with manufacturing and processing outlets and robotics integrated to workforce such as human pickers around the warehouse picking products. The robots follow the worker around, stopping when the worker stops to load the bins on the robot[33]
Retail Trade	Moderate to high	Apart from the now standard self-serve checkouts, retailers are also testing robotics for both inventory management and customer service and airborne drones for faster delivery Other retailers concentrate on using robotics in / In-store customer service / Using robots to manage stores like warehouses / Bringing the store to the customer	Policy to assist market forces in encouraging human augmenting functions in robotics and training staff for advisory and consumer support roles. Customer service robots will need a significant amount of training working alongside human experts in order to serve customer needs[34]
Accommodation and Food Services	Moderate to high	Accommodation services are already impacted by "helper robots" that carry bags, give directions, clean rooms, and perform other low-level tasks. Robots are also a data gathering source on customer preferences[35]	Training requirements that freed up hotel staff to spend more time assisting guests[36]
Transport, Postal and Warehousing	High/very high	Rated by Frey and Osbourne (2017) as 99% automatable, the transport aspect of this sector faces significant challenges due to emerging technology and the routineness of tasks	Significant policy challenges around insurance and legal issues concerned with autonomous vehicles and short-term labour market dislocation

Table 8 Queensland Industries Potential for Automation (Continued)

Industry	Potential for automation	Explanation	Policy response
Information, Media and Telecommunications	Moderate	Significant amount of non-routine cognitive work plus increased demand for services from other areas of automation[37]	Close liaison with educational institutions to provide relevant training opportunities
Financial and Insurance Services	High	Combined with blockchain technology and its impact on compliance processing. Technology will have large scale impact on insurance through Robotics and Cognitive Automation (R&CA)	Recognition of changes in employment mix. For example, Deloitte report (2016) found that employment mix in insurance will change from 40% lower process workers, 35% middle management and 25% senior management to 28-30%, 28-30% and 32-37% respectively[38]
Rental, Hiring and Real Estate Services	Moderate	Automation and robotics will be used in maintenance, security, appraisals/inspections and customer research, but to augment humans not replace them[39]	Training programs for staff on how to work with and best utilise robotics
Professional, Scientific and Technical Services	Moderate	Professionals cover a wide variety of tasks. The automation of their work depends on the routineness of the tasks. Some tasks of most professionals can be automated including healthcare and insurance workers, architect's, journalists, teachers and legal workers and para-legal professionals[40]	Professional bodies and training institutions need to devise means of integrating the new technology into professional work practices and examine greater discretionary roles for professionals
Administrative and Support Services	High	Most studies identify Transportation and Storage, Retail, Manufacturing, and Administrative and Support services as the industries most likely to be heavily automated. This is because of the routine nature of the tasks and because of the relatively high wage bill as a proportion of total costs[41]	Close liaison with educational institutions to provide relevant training opportunities
Public Administration and Safety	Moderate to high	Similar to Administrative and Support services with the exception that the work tasks are more discretionary and therefore less likely to be automated to the same degree	Acceptance that the administrative and process aspects of this industry will be disrupted and that careful thought must be given to retraining and making changes to the existing job mix
Education and Training	Moderate	Automation, including big data systems have the potential to replace some areas of teaching and training depending upon the routines of the instruction. As well, labour is the largest single cost to universities and schools. However much of education rests on the discretion of the teacher and it is believed that the impact of automation here will be to change the job mix not lead to replacement of teachers[42]	Policy here should be about adapting the teaching and instruction job mix. Increased opportunities to provide more courses and programs should create a net increase in jobs

Table 8 Queensland Industries Potential for Automation (Continued)

Industry	Potential for automation	Explanation	Policy response
Health Care and Social Assistance	Moderate	Routine tasks will be replaced but this represents less than 30% of Health Care. Process work in the social assistance element is likely to be replaced by automation; High wage costs in parts of the industry are also a factor increasing the likelihood of automation	The large degree of non-routine and empathy related work would limit job displacement. The policy issues relate to equipping health staff including doctors to work with automation to extend their range of services
Arts and Recreation Services	Low to moderate	The Recreation component will be impacted in terms of processing bookings etc. The Arts sector involves high discretion and is unlikely to be greatly impacted	Policy options include integrating the Arts and automation
Other Services	NA	NA	General labour market deregulation

Source: Synergies analysis from published data.

3 Overview of the changing nature of work and review of major studies of job change[43]

"Accelerating artificial intelligence (AI) capabilities will enable automation of certain tasks which have long required human labour. These transformations will open up new opportunities for individuals, the economy and society, but they have the potential to disrupt the lives of millions of Americans" *Executive Office of the President (2016) "Artificial Intelligence, Automation, and the Economy, Washington 2016, p.2.*

3.1 Introduction

Even casual observation of the labour market over the last three decades reveals the significant changes that have taken place in workforce composition, the regulatory framework surrounding the labour market and the wage outcomes for the participants. Chief among these changes have been in:

- Job status, with significant increases in the relative importance of casual and part-time work
- Industrial and occupational distribution of the workforce
- Widening gap in wage differentials
- Significant shift in gender composition
- Technological change

The drivers of change in the labour market are difficult to identify. For firms it has been the desire to cut costs, particularly those associated with the fixed costs of labour and this has seen significant changes in job status as well as increased application of technology. Externally, the forces of globalisation have created a more standardised and less regulated labour market.

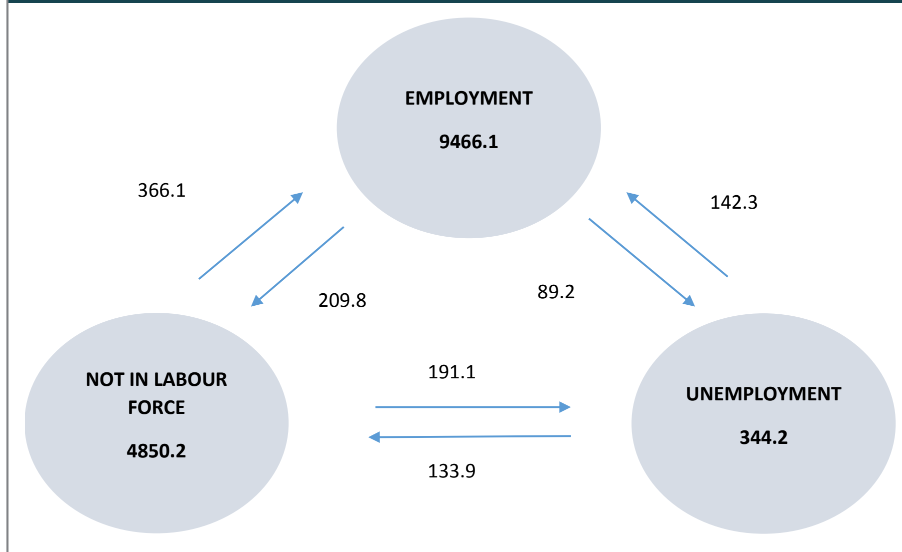
3.2 Job loss and creation

The labour market has always been a more dynamic place than stock data (unemployment rates, annual employment numbers) indicate. While aggregate data such as annual unemployment rates appears to remain relatively static, the inflows and outflows that make up the aggregate numbers is large.

Utilising newly (at the time) available gross flow data Davis, Haltiwanger and Schuh (1998) published the influential book *Job Creation and Destruction*[44]. Their work provided detailed analysis of the extent of the dynamics of the modern labour market. The authors used the Longitudinal Research Data constructed by the US Census Bureau for the US manufacturing sector from 1972 to 1988 and developed a statistical portrait of the microeconomic adjustments to the many economic events that affect businesses and workers.

The picture that emerges is one of large, persistent, and highly concentrated gross job flows, with job destruction dominating the cyclical features and job creation occurring on the upswings of net job flows. The authors describe in detail characteristics that both create and destroy jobs over time (including industry of origin, wage payments, international trade exposure, factor intensity, technological change, size, age, and productivity performance), while also providing a broader measure of the process of job churn that will be directly relevant to macroeconomists and policymakers.

Figure 12 Labour Market Gross Flows Australia August 2017



Source: Estimated from ABS Data.

The book was important because it demonstrated the dynamic and multi-faceted nature of the labour market when viewed in terms of gross flows in contrast to the static view of labour market stocks. The results reinforced the conclusion that, over time, job creation has consistently outweighed job destruction, notwithstanding that in the process there have been impacts on income distribution, job mix and the industrial and occupational distribution of employment. Moreover, within the United States these large-scale countervailing flows occurred largely outside of the influence of public policy. The implication being, that some of the observed disruption may have been avoided if more active government policy, which understood the dynamics of the modern labour market, had been in place.

Clearly, over the last two decades a number of factors have impacted on the job market that have changed both the distribution of employment and the reward structure associated with that employment. These factors include changes in job status (the shift to casualisation), technological change, increased feminisation of the workforce, the reduction in the influence of labour organisations such as unions and the mobility factors associated with globalisation.

It is difficult to decompose these forces from one another but collectively they still conform to the basic laws of economics including the economics of labour demand.

Key points

- Labour markets are more dynamic than they appear from stock data
- Job creation and destruction is an ongoing process
- Technological change plays a role in job churn
- Although changing the nature of jobs and the distribution of income, technological change has always been a net producer of jobs

3.3 Basic relationships in production and the demand for labour

Labour demand is a derived demand from the production of goods and services at any point in time in which labour is one component of a production function that includes physical capital and financial capital at any point in time.

Over the course of time the parameters of the production function change through technological innovation (expanding what is technically feasible), shifting the relative price of labour and capital (determining what is economically viable). This is summed up in equation 1.1

$$Q = AK^{\alpha}L^{\beta}$$
(1.1)

Where Q is the measure of output, A represents a shift parameter measuring technology or institutional factors. Thus, differences in A reflect differences in the technological base between industries or countries in their production process. K relates to the stock of physical capital including stadiums, training facilities. L relates to the characteristics of the labour force. α and β are the marginal productivities of each of the main category of factors of production for industrial process studied.

Ultimately the impact of the technological change on factors of production, will be determined by wealth generation, output expansion properties and the degree to which the process substitutes some factor of production.

The strength of the production function is that it identifies the combination of physical and financial that combine in the modern production process. Because the function is differentiable, it allows rates of change in each factor to be identified and determine the impact this will have on factor input demand. For example, a number of key relationships can be identified.

3.3.1 Marginal productivities and relative costs

The marginal productivity of labour is defined by the first derivative of Q with respect to {$\delta Q/\delta L = A.\alpha L^{\alpha-1} K^{\beta}$ and the productivity of capital is defined by {$\delta Q/\delta L \backslash K = A\beta L^{\alpha} K^{\beta-1}$

These are largely technical possibilities, they determine the productive gain of adding more of one factor of production but they do not necessarily determine usage. This will depend on the relative costs of shifting between factors. The total payment to each factor is the rate of pay per unit times the number of units employed. The real income of labour is given by [$Y_L = \delta Q/\delta L.\ L = A\ \alpha L^{\alpha-1} K^{\beta} L$]

Under a Cobb-Douglas production function (where α + β= 1), the value of the function is exactly equal to the sum of the partial derivatives with respect to each variable) which implies that value of the total product is exactly exhausted by the income payments to the factors of production. This also allows the establishment of the well-known economics relationship where the wage rate of each unit of labour is equal to the marginal revenue product of that unit. Problems arise when α+β > 1 (or increasing returns to scale occur).

The net combination of factors that will be used by the efficient firm is determined by the rates of change in factor (usually technical) capability and by shifts in relative factor price. This is represented by the coefficient of elasticity (ε) = d(L/k) r/w/d(r/w) L/k the ratio of the proportionate change in factor proportions to the proportionate change in relative factor proportions. In short, the impacts of technological change at the firm level, including automation and the use of AI will be determined by the same factors that have always determined the applications of new technology: (1) Technical feasibility and (2) Economic or cost feasibility. At a national level other factors can be added such as (3) absorption rate and (4) social acceptance.

Ultimately the impact of the technological change on factors of production, including labour, will be determined by the wealth generating and output expansion properties of the new developments (the income effect) and the degree to which the process substitutes some factor of production for others (the substitution effect).

3.4 Automation in the contemporary and emerging industrial process

Automation is simply another form of capital deepening but one that has profound potential to change the production function of many tasks and activities[45]. It refers to a process of automatically producing goods and services through the use of robots, control systems and other appliances with minimal human contact[46].

Within manufacturing industries, automation has led to increased labour productivity with fewer workers being required per unit of output. A perceived downside of automation is that it leads to jobs being displaced in traditional areas of work such as blue collar jobs but recent research indicates that many white collar jobs (or tasks within those jobs) are equally susceptible[47]. Less visible is how the process of automation leads to the creation of large numbers of new jobs in areas such as robot manufacture, research, marketing and software development.

> AI is not a single technology but rather a collection of technologies that are applied to specific tasks

As discussed above, economists describe two opposing effects in terms of employment: the substitution effect with capital replacing jobs and the income effects, which are the job creating effects. The basic concept of the (generally) opposing forces of income and substitution effects is, conceptually, easy to grasp. Measuring these impacts is far more difficult. Job loss in traditional areas is obvious and easy to measure, it is much more difficult to observe income effects as their impact tends to be widely spread and delayed.

Normally this quantification is done in aggregate and at appropriate times because job losses in particular industries tend to occur quickly, whereas job gains from technological change occur over a longer time period and are spread across a variety of industries and occupations. Moreover, to fully achieve job growth through the automation process may require a combination of factors such as appropriate policy settings or a more deregulated labour market that would need to accompany the changes in technology. Nevertheless, historically a positive transfer must have been occurring because total employment continues to grow, albeit that the distribution of the employment by job status, gender make-up, relative occupational, industrial mix and wage distribution have all changed markedly. In this sense, the real impact of technological change of labour markets is not on total employment but on the characteristics of that employment[48].

The recent report from the Executive Office of the President (2016) supports the view that the labour force outcomes from technological change are difficult to predict because of the time lags involved and because AI is not a single technology but rather a collection of technologies that are applied to specific tasks[49]. For example, various forms of automation and robotics have varying attributes, which impact differently on labour demand. These attributes include;

- Artificial intelligence – intelligence of machines and the branch of computer science that aims to create it
- Computer vision enhanced robotics[50]
- Degrees of freedom – extent to which a robot can move itself; expressed in terms of Cartesian coordinates (x, y, and z) and angular movements (yaw, pitch, and roll)
- Emergent behaviour – complicated resultant behaviour that emerges from the repeated operation of simple underlying behaviours
- Humanoid – resembling a human being in form, function, or both

Combinations of these abilities have led to a number of potential robotic forms including:

- Cyborg – also known as a cybernetic organism, a being with both biological and artificial (e.g. electronic, mechanical or robotic) parts
- Industrial robot – reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialised devices through variable programmed motions for the performance of a variety of tasks [5]
- 3D Printing.
- Mobile robot – self-propelled and self-contained robot that is capable of moving over a mechanically unconstrained course [5]
- Service robot – machines that extend human capabilities [5]
- Microbots - microscopic robots designed to go into the human body and cure diseases

In essence, these various forms interact differently with the human workforce, but in essence, they all lie within the standard economist definition of capital or at least the aspect of physical capital that is embodied in technological change.

Key points

- Within economic theory the automation process is simply another form of capital deepening
- As such, the rate of automation will depend upon basic economics; technical facility and relative costs between labour and capital
- These are normally defined by the elasticity of substitution
- While technological change, of which automation and robotics are the latest incantation, will invariably be a net job producer it does not control the distribution of benefits - this is a social and policy question

3.5 What factors drive the automation process (the economics of automation and robotics)

Technological change is initiated at the micro (firm) level but quickly diffuses into the macro economy if the right policy settings are in place. The incidence or spread of technological change is measured by the rate of absorption, or take-up rate. Individual firms must weigh up the distribution of benefits over time as well as the costs.

As shown in Figure 13 there are three main stages of technological change; invention, innovation and diffusion.

Figure 13 The Innovation Process

Source: IBIS World Industry Report (2018) "Mining", p3.

Invention involves the creation of something new but it generally does not take place in isolation but as the result of economies of scale built up elsewhere and is driven by the need to solve production problems. Rates of invention are usually measured by patent levels[51]. Innovation relates to the adaption of the technology to fit specific purposes.

Diffusion or acceptance of new technology has a number of casual factors. Rogers outlines five main attributes of innovative technologies which influence acceptance, which he calls the ACCTO criteria[52].

These are:

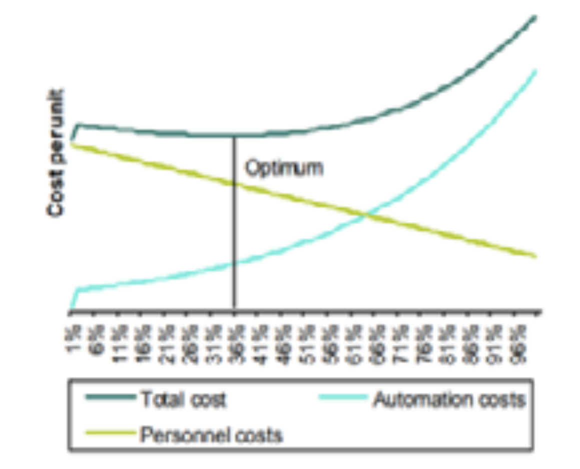
- Relative advantage (economic or non-economic) - the degree to which an innovation is seen as superior to prior innovations fulfilling the same needs. It is positively related to acceptance
- Compatibility - the degree to which an innovation appears consistent with existing values, past experiences, habits and needs to the potential adopter; a low level of compatibility will slow acceptance
- Complexity - the degree to which an innovation appears difficult to understand and use; the more complex an innovation, the slower its acceptance
- Trial-ability - the observed extent to which an innovation is able to trial on a limited basis to increase acceptance. Trial-ability can accelerate acceptance if trials indicate safety and reliability
- Observability - the perceived degree to which results of innovating are apparent to others and positively related to acceptance

Diffusion of technology generally follows an S-shaped curve, whereby the early or prototype versions are less successful, followed by a period of successful innovation and high levels of adoption before reaching a mature market stage which itself may be overtaken by other innovations.

The shift towards automation and widespread use of robotics is well advanced in terms of relative advantage internationally with 25 per cent and 20 per cent of publicly-listed companies in Switzerland and the United States respectively engaging in automation of industry[53].

Using the same measurement scale, Australia now ranks 18th in world usage, up from 30th in the previous report. Encouraging as this trend is, a constraint on further improvement is Australia's industrial structure, which is relatively devoid of large-scale manufacturing such as car manufacturing, where automation has been widespread. *However, it is clear that the Australian and the Queensland economies suffer from both a compatibility and a complexity problem, which reduces the opportunity for trial-ability and observability.*

Figure 14 Behaviour of Total average costs on Tesla Project



Source: Gorlach I., Wessel O., (2008) Optimal Level of Automation in the Automotive Industry. *Engineering Letters*, 16 (1) and Bernstein analysis

Finally, as with all factors of production, even automated processes run into diminishing returns. Gorloch and Wessel (2008) applied standard neoclassical economics to map the emergence of diseconomies in the Tesla production process[54].

As shown in Figure 14 the authors found that there is likely to be an optimum level of automation beyond which automation costs rise. Using the attempts by Tesla to fully automate, Gorloch and Wessel (2008) examined automation costs in the automobile industry and concluded that the need for skilled labour was the major constraint faced when increasing the level of automation. In their example, the benefits of automation over the older method of production ran out about 66 per cent into the output levels.

3.6 Identifying the impacts of automation and robotics

As stated earlier the chief issue facing labour market analysts, regarding the net job impact of automation, is that the substitution effects are rapid, industry based and easy to observe. The income, job-producing effects are economy wide, slower in materialising and involve new job types that still may be evolving.

The positive job attributes of automation and robotics derive from their impact on productivity that, in turn, drives higher wages, profits and boosts consumption. While there are debates over the income producing aspects of automation, particularly in terms of equitable distribution, few disagree that automation will boost productivity. The International Federation of Robotics (2017)[55] saw this productivity increase emanating from a number of sources:

- Enabling companies to become or remain competitive, which they saw as particularly important for small-to medium sized enterprises (SMEs)
- Supporting large companies to increase their competitiveness through faster product development and delivery
- Reshoring - enabling companies in high cost countries to reshore, or bring back to their domestic base parts of the supply chain that they have previously outsourced to sources of cheaper labour. This increased productivity can lead to increased demand, creating new job opportunities
- Industrial spillovers within an individual organisation, along an industry sector's value chain, and in other sectors, particularly services

A large number of recent empirical studies point to the productivity increasing attributes of increased automation and robotics. In their study of the impact of robots on productivity, Graetz and Michaels (2015) found that robot densification increased annual growth of GDP and labour productivity between 1993 and 2007 by about 0.37 and 0.36 percentage points respectively across 17 countries studied, representing 10 per cent of total GDP growth in the countries studied. They contrasted this result to the estimated 0.35 percentage point aggregate contribution of steam technology to British annual labour productivity growth between 1850 and 1910[56].

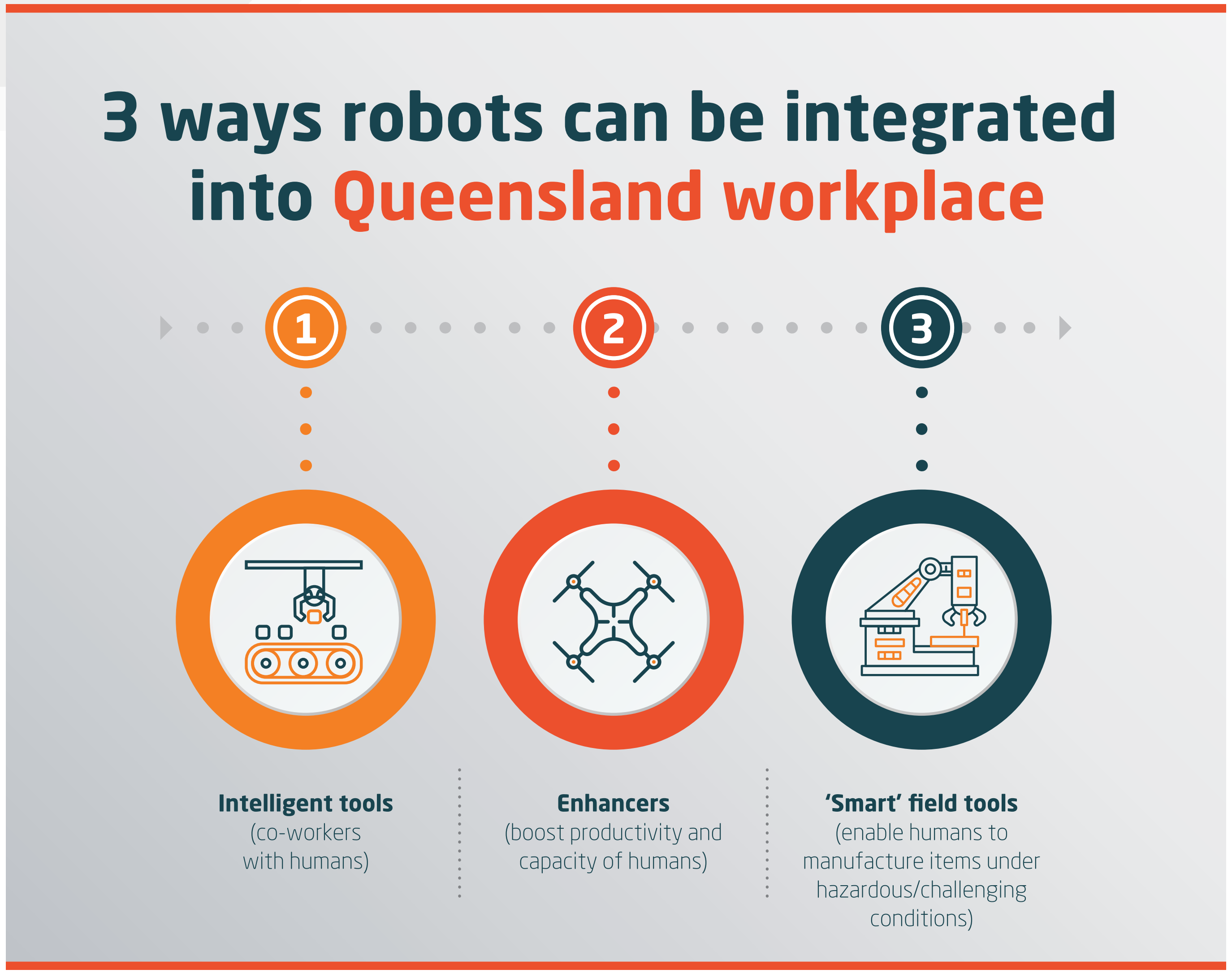
The Centre for Economics and Business Research (2017) found that the increased density of industrial robots contributed 10 per cent to growth in GDP per capita in OECD countries between 1993 and 2016. Quantitatively, they found that the increase in labour productivity from a one-unit increase in robot density (defined as the number of robots per million hours worked) was 0.04 per cent[57]. Muro and Andes (2015), supported the productivity story by observing that those advanced countries that invested most in robotics in manufacturing were far more likely to hold market share and avoid losing jobs than those that did not[58]. Their analysis took place within a scenario of the need for each nation to improve their global competitiveness.

Future predictions of productivity growth and job gains have come from Frontier Economics (2016) who forecast that automation has the potential to double Gross Value Added (GVA) across 12 developed economies by 2035, with labour productivity improvements of up to 40 per cent[59]. The McKinsey Global Institute (2017) predicts that up to half of the total productivity growth needed to ensure a 2.8 per cent growth in world GDP over the next 50 years will be driven by automation[60] and the Boston Consulting Group forecasts productivity improvements of 30 per cent over the next 10 years. In this growth, the role of the take up in robots by SMEs (as they become cheaper) is seen as being particularly important[61].

> A large number of recent empirical studies point to the productivity increasing attributes of increased automation and robotics

The other direct benefit of automation and its impact on productivity is in the ability of companies in high cost countries to bring back production to the domestic economy, known as reshoring. Examples of this have occurred where international firms such as Whirlpool, Caterpillar and Ford Motor Company in the US and Adidas in Germany have restructured their supply chains to enable them to bring back home parts of the previously offshored manufacturing process[62].

Studies undertaken by Citibank and the Oxford Martin School (2016) through a survey of 238 companies found that "70 per cent believed that automation would encourage companies to move their manufacturing closer to home and consolidate production" (Citibank and Oxford Martin School 2016, p. 13)[63]. Finally, the Reshoring Initiative in the US (2015) estimates that 250,000 jobs have been brought back to the country by reshoring and inward-bound foreign direct investment since 2010 because of robot-driven increases in domestic productivity[64]. Seventy per cent of respondents to their survey believed that automation would encourage companies to move their manufacturing closer to home and consolidate production (Citi and Oxford Martin School 2016).



3.7 External economies and diseconomies in the automation process

The work of Gorloch and Wessel (2008) support the notion that automation through robotics is simply another chapter of technological substitution, albeit distinguished by the greater industrial coverage than earlier episodes of technological change[65]. As with all these changes the fundamental attraction to the private sector is reduced costs and less direct (production) labour needs. However, even at this stage of development it is possible to observe indirect impacts (external economies and diseconomies) from the automation process. The chief external economies (spread both within and outside the impacted industries) are:

- Improved job mix for staff- according to alphaBeta "over two thirds of the shift towards automatable jobs will be driven by people changing the way they work not changing jobs"[66]
- Creation of new and spin-off jobs - the expected "income effect" with new jobs being created in skilled spin-off jobs from the automation process and from expanded personal services[67]
- Increased workforce morale - flowing from better job mix and new, more creative jobs
- Higher value adding - leading to higher wages. Theoretically higher productivity should lead to higher wages - this depends on the distribution of the productivity gains and the mechanisms reducing income inequality

Among the chief external economies (spread both within and outside the impacted industries), benefits of automation relate to increased workplace safety. Automation is currently best suited to replacing heavy repetitive and routine jobs which, according to workplace health and safety data are also the most dangerous occupations in terms of frequency and severity of workplace injuries. In descending order the 10 most dangerous jobs in manufacturing are:

- Fabricated metal products
- Food preparation
- Transportation equipment
- Machinery manufacturing (which is similar to fabricating metal, but often the fabrication is of smaller parts like gears and has complex assembly)
- Plastics and rubber – particularly processing and dyeing
- Manufacturing wood products involving using sharp cutting machines to carve the wood into the desired shape
- Primary metals – the process of taking metal ore and transforming it into a usable piece of metal requires incredibly hot furnaces and smelters. Workers are at an increased risk of heat related injuries
- Non-metallic minerals – creating products like concrete, clay, glass, and cement requires taking non-metallic minerals like sand and gravel and subjecting them to heat. Chemicals are also often used to affect composition
- Chemical – the chemical industry produces thousands of chemicals by complex processes. All types of hazards – like extreme heat, dangerous machinery, and exposure to toxic substances – are present for workers
- Furniture – furniture manufacturing is dangerous because workers use a wide variety of materials and processes. Dangerous tools, toxic chemicals, and heavy machinery are some of the most common threats to workplace safety

All these jobs are automatable which is likely therefore to lead to a decrease in accident propensity

The chief external diseconomies flow from:

- Job loss, particularly among the unskilled and those with routine tasks in their jobs. The extent to which displaced workers can transit to other jobs will be driven by age, retraining opportunities and the support for transition given by government
- Greater income inequality

The report from the Executive Office of the President of the United States (2016) stated that AI should be welcomed for its potential economic benefits but contrasts the earlier waves of industrialisation, which reduced income inequality, with the current changes, which benefit the educated and the skilled and may increase income inequality[68]. As computers are now able to do routine tasks, the demand for human labour performing these tasks has decreased.

> AI should be welcomed for its potential economic benefits

On the other hand, the demand for college educated labour has increased over the last decades. The effect is more pronounced in industries that are computer intensive. As a consequence of this, the employment share of the highest skill quartile has increased. In addition to more people being employed in the highest skill quartile, the real wage for this quartile has increased faster than the average real wage. Service occupations, which are non-routine, but also not well paid, have also seen an increase in employment share and in real hourly wage. Thus, both employment share and real wage, are U-shaped with respect to the skill level. The net effect of this is to exacerbate income inequality which was already increased as a result of wage stagnation.

3.8 Is the new automation different?

In the past, concerns about the employment impact of technology have centred around the "lump of labour" idea; that there was a fixed or quasi fixed stock of jobs and the more technology encroached, the less jobs were available for humans. This concept clearly flies in the face of history. Historically the income effect of technological change has outweighed the substitution effect. Job types and the distribution of income may have changed and some occupations have disappeared but the number of jobs historically have continued to rise. However, a number of recent scholars have questioned whether this will continue into the future. Innovator and computer scientist Thrun (2018) CEO of Kitty Hawk Corporation and chairman/co-founder of Udacity, has argued "no office job is safe". Kaplan (2015) in his book, *Humans need not apply*, sees serious short-term dislocation in the labour market and Ford (2016) in *The Rise of the Robots; Technology and a Jobless Future* predicts a jobless future.

They advance a number of reasons for this:

- The speed of change; previous periods of technological change were phased-in allowing for orderly adjustment in the labour market
- The universality of change; previous bouts of technological change were confined to one or two industries allowing displaced workers to move to other industries. The current automation trend goes across most industries
- The scope of change; previous technological progress was labour augmenting in that humans worked with technology to increase their productivity. The current process of automation, particularly involving AI, are labour replacing

The best know article about potential job loss is by Frey and Osbourne (2013)[69] who estimated the probability of current jobs (from a sample of over 700) being automated,. In this article, the authors combine elements from labour economics with techniques from machine learning to estimate how different jobs are able to be computerised. In doing so they modify the theoretical model of Autor et al. (2003)[70] by identifying three engineering bottlenecks that prevent the automation of given jobs; creative intelligence, social intelligence and perception and manipulation tasks. They then classify occupations according to the degree to which these bottlenecks persist with the implication that these bottlenecks will limit the impact of technological advances in job replacement in including machine learning (ML) developments in AI and mobile robotics (MR). Operationally this leads to a classification of the routineness (replicability) of particular jobs, from a four-way classification scheme which divides all jobs into:

- Routine manual (essential factory and process work)
- Non-routine manual
- Routine cognitive (regularity of tasks even at higher skill level)
- Non-routine manual (large degree of job discretion and variability)

The uniqueness of this approach is that it, in determining susceptibility to computerisation, distinguishes jobs by task (including the degree of computerisation) rather than human capital or formal job classification. *The Economist* provides the following useful illustration of how this may work[71]:

"Andrew Ng, a highly trained and specialist radiologist may now be in greater danger of being replaced by a machine than his own executive assistant – she does so many different things that I don't see a machine being able to automate everything she does soon"

As a result, the authors come up with some counter-intuitive results concerning the probability of all or part of a job being replaced by automation. A sub-sample of their results (top five at each end of the distribution) are shown below in Table 9.

Table 9 Probability of a Job being automated

Job	Probability of being replaced
Recreational therapists	0.003
Dentists	0.004
Athletic trainers	0.007
Clergy	0.008
Telemarketers	0.99
Accountants and Auditors	0.94
Retail salespersons	0.92
Technical writers	0.89
Real -estate sales agents	0.86

Source: Frey and Osbourne (2013)

The McKinsey Global Institute (2017)[72] has provided an aggregate evaluation of the potential of the workforce to be automated. For example, it finds the percentage of the total workforce under threat[73]:

- US (45.8 per cent)
- UK (42. 8 per cent)
- China (51.2 per cent)
- South Korea (51.9 per cent)
- Australia (44.9 per cent)
- Canada (47.0 per cent)

The work of Frey and Osbourne has come under a great deal of scrutiny, including a forensic examination by Brandes and Wattenhofer (2015). They offer broad support for Frey and Osbourne but, on a re-examination of the data and methodology, find there is a strong negative correlation between the level of education required for a job and its probability to be automated. The Reserve Bank of Australia comes to a similar conclusion. This relationship is highlighted in Figure 15.

This finding is somewhat at odds with the routine/non-routine/cognitive/manual task distinctions often used for gauging the likelihood of automation. The two methodologies are only consistent if education levels and degree of non-routineness are closely correlated. However, it is easy to think of examples (accountants) where tasks are relatively homogeneous across the occupation but where entry requires tertiary education.

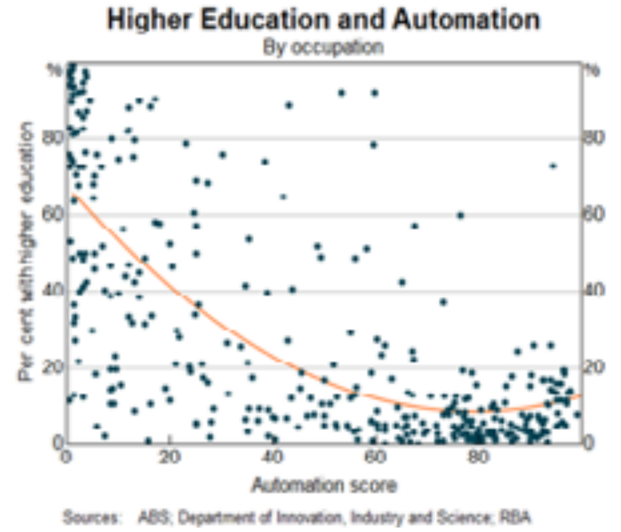
The "higher education" defence against automation potential is derived in part from a "task orientated" approach as opposed to the occupation-based approach of Frey and Osbourne (2013)[74].

This approach is used by Arntz, Gregory and Zierhan (2016). Under their methodology, automation only threatens specific tasks within an occupation rather than the occupation itself. As those with higher skills and qualifications tend to have more distinct tasks in their job mix than those with lower formal education, they are less likely to have the bulk of their job substituted by robots. This methodology highlights the labour augmentation properties of robots rather than the labour replacing impact.

This has two empirical results, it lowers the estimated percentage of jobs that are potentially replaceable by automation and raises the status of formal education in preserving occupations[75]. According to the authors[76]:

> *"The study challenges the false alarmism that contributes to a culture of risk aversion and holds back technology adoption, innovation, and growth; this matters particularly to countries which already face structural productivity problems."*

Figure 15 Higher Education and Automation



Source: Department of Innovation, Industry and Science, cited Alexandra Health (2016) "The Changing Nature of the Australian Workforce", Reserve Bank of Australian Speeches September, https://www.rba.gov.au/speeches/2016/sp-so-2016-09-21.html

Key points

- Those that see the new wave of automation as being fundamentally different from past periods of technological change do so because they believe the changes in the labour market will be both more rapid and extend across the whole economy rather than particular industries and occupations
- To some extent they are right. The potential for automation is spread across the economy
- Early estimates of the potential for automation to impact on employment have used an occupation based approach and segmented occupations by degree of routineness and the level of cognitive input
- This produces a mix of occupations that at first may appear unlikely; accountants having virtually the same likelihood for automation as truck drivers
- This methodology plays down the importance of education as a means of protecting jobs
- The newer "task based" approach recognises that automation will replace tasks within jobs rather than the job itself
- It emphasises the partnership of robots and humans rather than the substitution possibilities
- As a result, the estimates of job vulnerability from automation are significantly reduced and the protective value of education increased

3.9 Potential benefits of automation and robotics in job creation, job scoping and workforce safety in an aging population

From its very beginning, the fourth industrial revolution has never presented manufacturers with an either or choice – robots or humans. It has always been about combining the talents of both

- The impact of robotics in German manufacturing in many ways exemplifies this trend. Today, German manufacturers deploy three times more robots than US companies, but they also still employ more humans. Relative to the size of its economy, the German manufacturing workforce is twice the size of America's. *The Economist* survey (2017) argues that the fourth industrial revolution has never presented manufacturers with an either or choice - robots or humans. It has always been about combining the talents of both[77]
- Ultimately, it is the convergence of artificial and human intelligence that will enable manufacturers to achieve a new era of speed, flexibility, efficiency and connectivity in the 21st century. Machines have the ability to assemble things faster than any human ever could, but humans possess the analytics, domain expertise and valuable knowledge required to solve problems and optimise factory floor production

The McKinsey Global Institute estimates that about 50 per cent of current work tasks have the potential to be automated by 2030 but modify this estimate by pointing out the technical economic and social factors will modify this rate of absorption[78]. Adjusting for these factors they believe the mid-range of substitution will be 15 per cent.

> In 2008 according to the US Bureau of Labor Statistics, there were 152,900 "computer-automated teller and office machine repairers employed in the US"

Offsetting these job losses will be the job creating aspects of automation. These take the form of:

- Augmentation of existing jobs/ creation of new jobs within the same or closely connected industry
- Creation of new jobs across the economy

The Price Waterhouse Coopers (PWC) 2016 report into "People Change and Robots" discusses transforming rather than replacing roles[79]. The stereotypical example of this relates to the introduction of Automated Teller Machines (ATMs) into the banking system. Fishman (2003) first studied the employment implications of ATMs with the banking industry within the United States. He found that:

> *"At the dawn of the self-service banking age in 1985, for example, the United States had 60,000 automated teller machines and 485,000 bank tellers. In 2002, the United States had 352,000 ATMs—and 527,000 bank tellers. ATMs notwithstanding, banks do a lot more than they used to and have a lot more branches than they used to" (Fishman)*[80].

The US Bureau of Labor Statistics (BLS) updated this data by reporting there were 600,500 bank tellers in 2008, which they expect to grow to 638,000 by 2018. Many more jobs were created in customer service, some for former tellers. Finally, the advent of the ATM also created demand for ATM maintenance workers. In the 2008 according to the BLS, there were 152,900 "computer, automated teller, and office machine repairers employed in the US[81].

PWC expects a similar pattern to be repeated across the Finance and Administrative Service Industries estimating the extent of changes in job task caused by robotic process automation (RPA) as shown in Table 10.

Table 10 RPA and the rate of job transformation

	2018	2019	2020
Management Business and Financial	40%	51%	64%
Professional and related	37%	48%	60%
Sales and related	32%	41%	52%
Office and Admin Support	32%	42%	52%

Source: Source PWC (2016)[82]

PWC expects these changes in job tasks to be labour augmenting rather than replacing with job growth driven by enhanced productivity and wealth effects.

3.10 Extent of robotics and automation in Australia and internationally

Information on the extent of robotics in Australia is limited[83]. The International Federation of Robotics (2017) report found that as of 2015, for the OECD, the number of robots per thousand employed persons was 1.6 (with a similar figure for the United States).

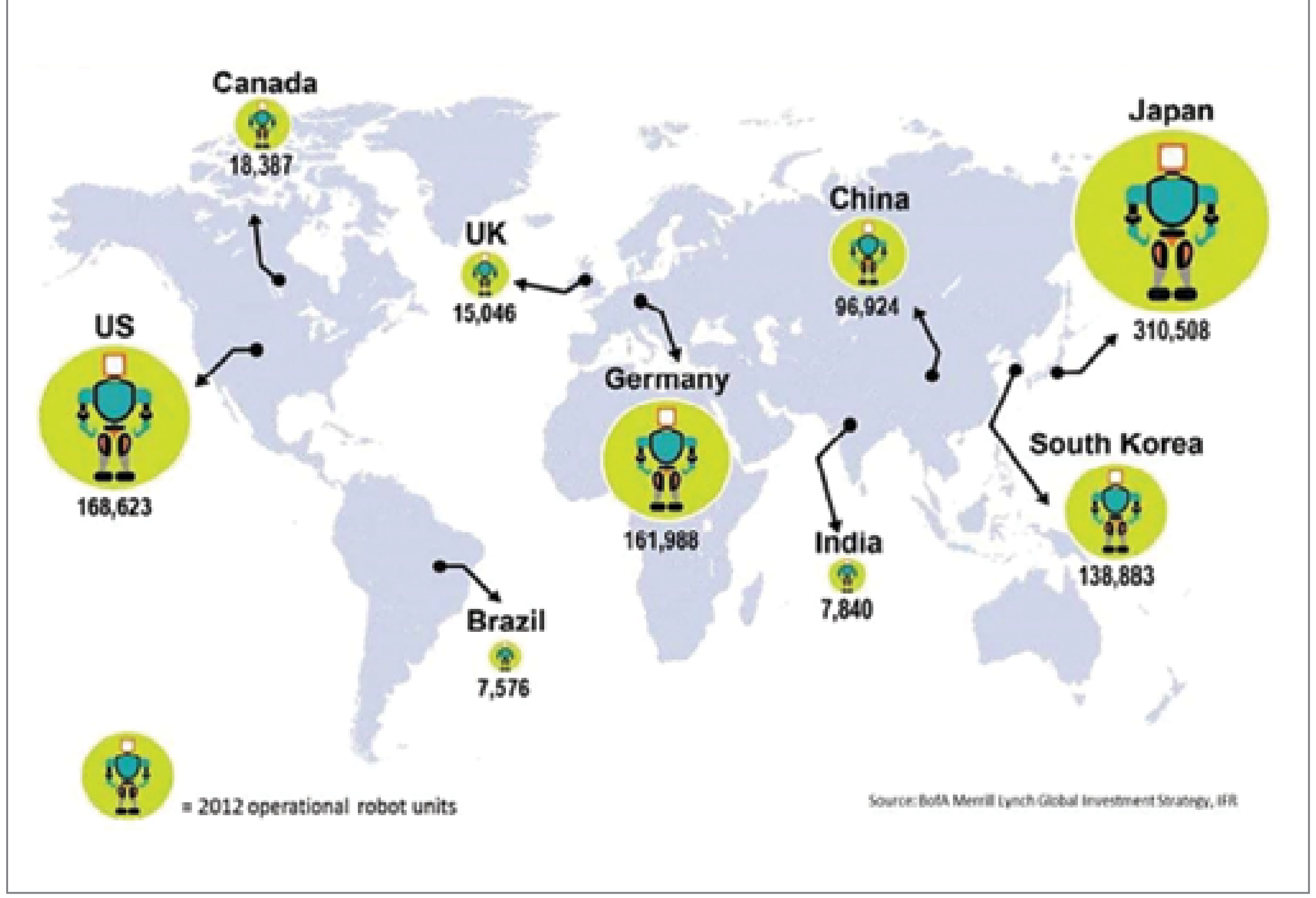
By way of comparison, the rate for Australia was 0.6 robots per thousand[84]. However, the rate of increase in robot density in Australia (a 300 per cent increase in density since 1996) had kept pace with international trends. "The number of robots per thousand employees in Australia has tripled in the last 20 years but still stands at a very low base" [BankWest-Curtain (2018) p 61].

However, most robotic use is in manufacturing and Australia is not a significant player.

Table 11 (over page) shows the top 10 uses of robotics manufacturing for 2015.

Part of the reason behind the relatively low penetration rate in Australia is industrial structure. Seventy per cent of industrial robots world-wide are in the automotive, electrical/electronics and metal and machinery sectors[85]. For example, in 2016, the electronics industry showed the strongest growth, up 18 per cent. It was followed closely by metals at 16 per cent and the automotive sector growing 10 per cent[86]. Australia is severely under-represented in these industries[87]:

Figure 16 Robot Density Across the World



As far as where Australia fits in to the world picture, we're a relatively small market in global robot terms due to our comparative size and, more importantly, the absence of the two main industries for robots: automotive and consumer electronics.

> the highest share of robots (over 40 per cent of the total number of robots) in Australia were employed in assembling and disassembling tasks

As of 2016, the highest share of robots (over 40 per cent of the total number of robots) in Australia were employed in assembling and disassembling tasks. Similarly, by far the highest share of robots in Australia are observed in the lowest skilled jobs compared to those with low-middle and middle skill levels (no robots employed in high-skilled jobs were observed in the data). Furthermore, these jobs have also seen the highest growth in robots in the preceding five years[88].

The one area of automation where Australia (and Queensland) appear to be well advanced is in intelligent software systems, where software that uses artificial intelligence is of major importance to business.

Table 11 The Major Users of Robotics in Manufacturing

Country	Robots per 1000 persons employed in Manufacturing (2015)
South Korea	3.47
Japan	3.39
Germany	2.61
Italy	1.59
Sweden	1.57
Denmark	1.45
United States	1.34
Spain	1.31
Finland	1.3
Taiwan	1.75

Source: https://www.wonderslist.com/10-countries-

Top of the list, and of most interest to Queensland, is the Mining industry with over 15 per cent of employers in this industry reporting that intelligent software systems are of major importance to their organisation. Other industries with a significant share (over 19 per cent) where employers report intelligent software systems to be of major importance are:

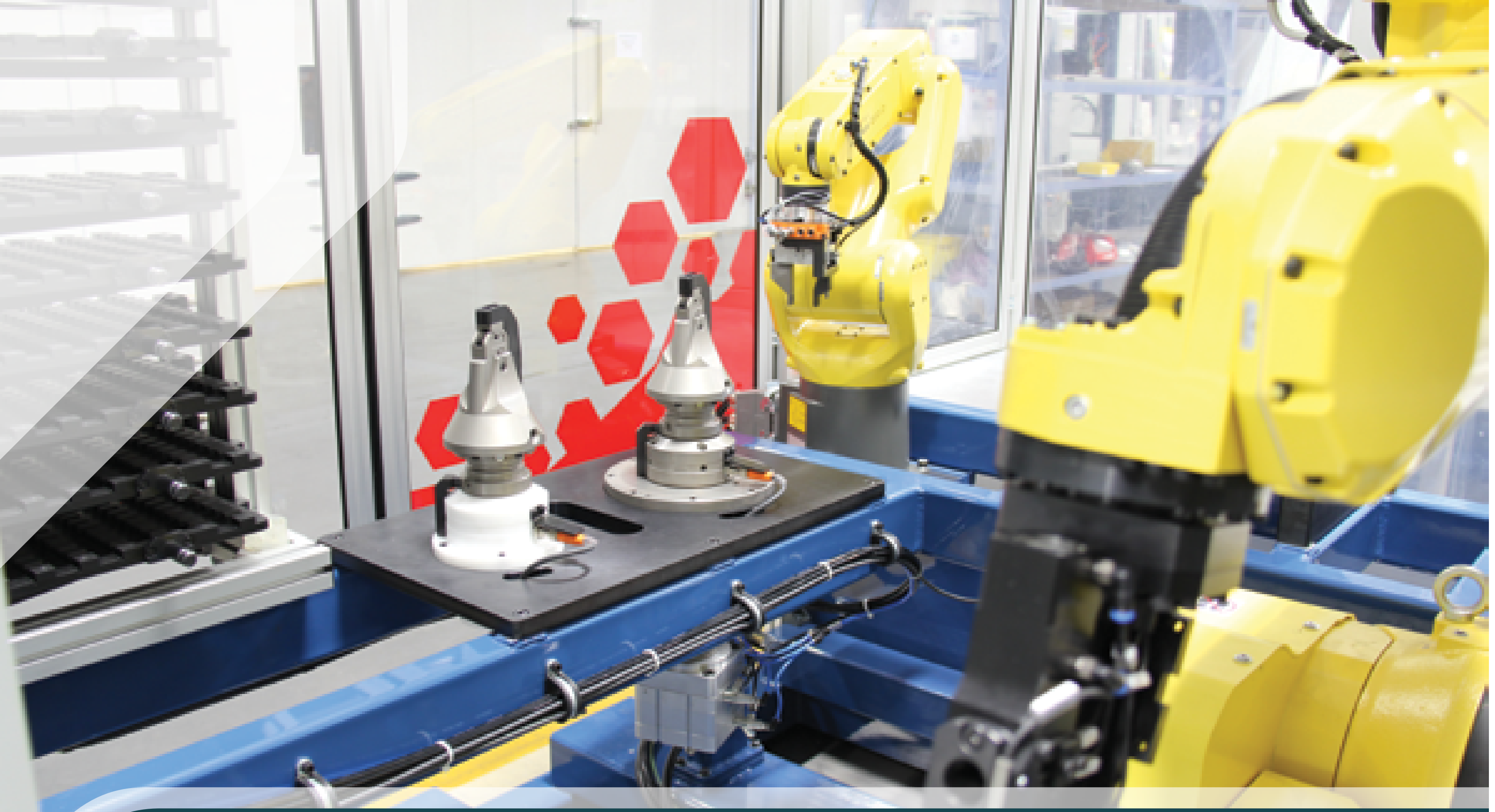
- Information, Media and Telecommunications
- Electricity, Gas, Water and Waste Services
- Retail Trade
- Rental, Hiring, and Real Estate Services

The importance of intelligent software systems is relatively low in Agriculture, Forestry and Fishing; and Accommodation and Food Services industries[89].

Significantly, as late as 2015-16, intelligent software systems had relatively low significance in Agriculture, Forestry and Fishing; and Accommodation and Food Services industries. The introduction of these systems into the above industries would seem to be the obvious place to increase the level of automation[90].

Key points

- Information on robotics in Australian industry is limited
- The penetration of robots in Australia (0.6) per thousand employed persons is low compared to the OECD average of 1.6
- However, rate of penetration in Australia has accelerated since 1996
- Most robots are in Electronics and the Automotive industries but largely in assembling/disassembling tasks
- Noticeable growth in autonomous vehicles in Mining
- However, Australia has well-developed intelligent software systems



4 The Queensland economy and automation

4.1 Growth opportunities of automation and technological change for Queensland

The Australian and Queensland manufacturing (over 90 per cent of manufacturing capacity) sectors are dominated by small to medium enterprises (SMEs). These enterprises tended to miss out on the first wave of automation because conventional industrial robots, such as those used in automotive manufacturing, are heavy, one-task orientated, fixed in place on the factory floor and expensive to buy, install, program and maintain.

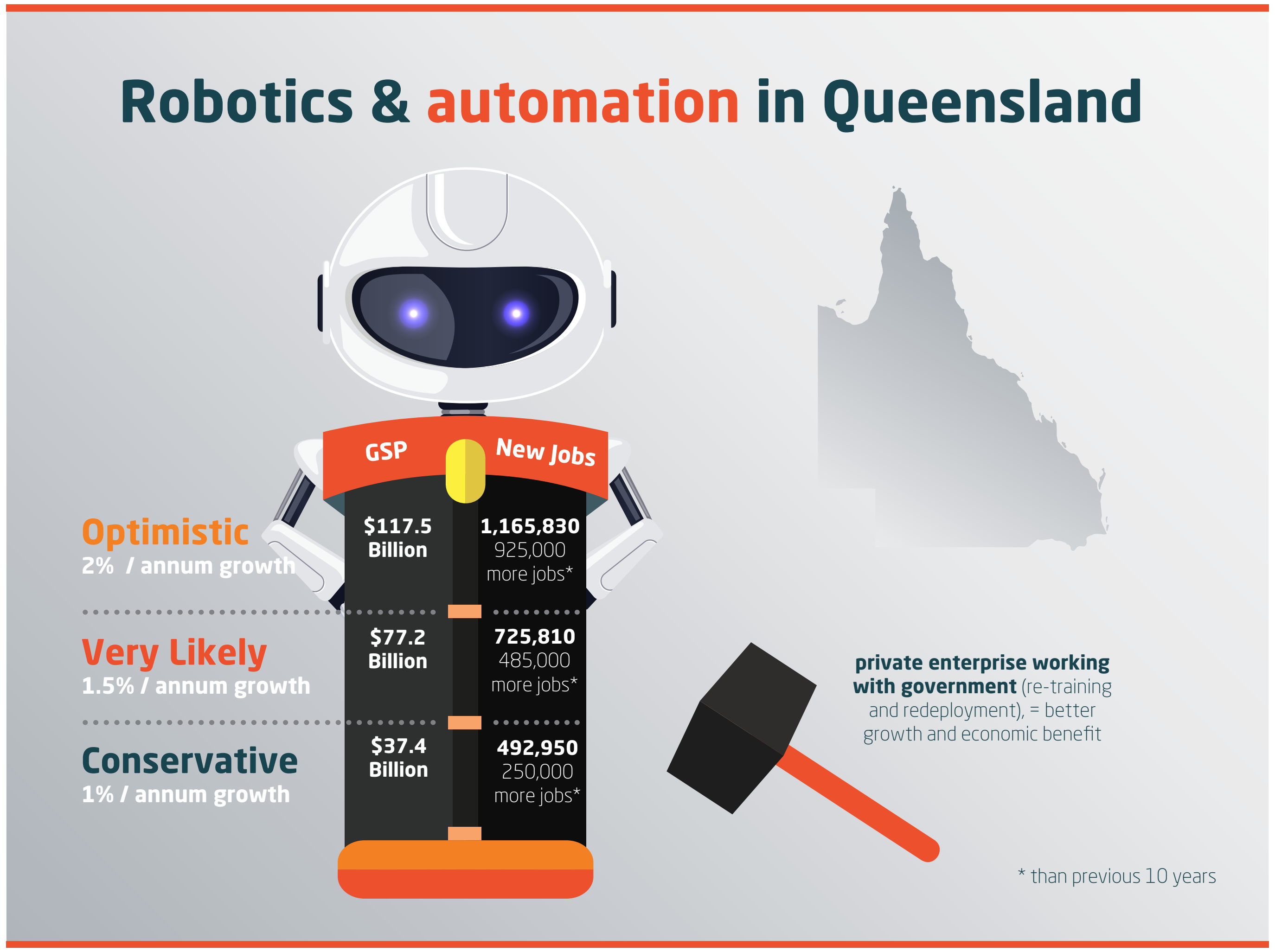
They are also potentially hazardous to humans, so workers are usually excluded from the robot workspace. But a new generation of lightweight, assistive robots looks to provide SMEs with new options to improve their competitiveness and meet the challenges of high costs and a shortage of skilled workers.

This will be of particular value in industries where Australia has a comparative advantage. These include Food, Beverage and Pharmaceutical industries, all of which are continuing to invest heavily in automation. In the past, packaging applications have been the main focus of robotics within the Food & Beverage and Pharmaceutical industries but there has been considerable progress in food-grade articulated robots able to handle raw food in processing applications.

This plays into Australia's competitive advantage. In Australia, the Food & Beverage sector is disproportionately bigger compared with most other countries that have more significant manufacturing industries (Bradbury, 2017)[91].

Lightweight robots can be integrated into the Queensland workplace as assistants to workers in three ways. The first is as "intelligent tools", which combine as co-workers with humans. These include:

- Mobile assistants
- Manipulators
- "Smart" picking[92]
- Lifting and handling systems
- Robotic welders, gluers and assemblers



All of these enable automation of short-run production processes and provide a flexible solution to increase efficiency of production. Robots can also be used in Queensland industry to increase the productivity and capacity of human workers in manufacturing processes. For example:

- Powered exoskeletons enable workers, regardless of age or gender, to lift and manipulate heavy loads safely
- Wearable machine vision systems can alert workers to workplace hazards in real-time, including hazards which can't be detected visually, such as radiation and high temperatures
- Mobile assistive robotic trainers and tele-immersive training systems enable experienced staff to remotely mentor workers who are new to a work environment

Robots can be used as "smart" field tools which enable human workers to manufacture items under hazardous or challenging conditions. For example:

- Tele-operated mobile tools and vehicles are already in use in the Mining industry, enabling work to be supervised remotely in an environment that is safe and comfortable for workers[93]
- Rigs which facilitate micro-manipulation and micro-assembly enable workers to conduct micro-assembly of complex items without strain to eyesight
- Virtual and augmented reality systems allow workers to manipulate tools remotely (away from the factory floor), therefore reducing risks of work-related injury such as repetitive strain and injuries from use of tools[94]

A number of technological advances have made this new generation of lightweight robots possible. The current and future generation of robots have a number of advantages over the first wave. For example, the next generation of robots can survey the workplace by use of advanced vision systems such a high precision sensors, stereo and infrared cameras and multi-modal imaging, and perception algorithms.

Secondly, the new generation of robots are much more mobile than early iterations and can navigate using localisation and mapping technologies such as Wi-Fi localisation, beacon-based navigation, simultaneous localisation and mapping (SLAM), and accurate 2D or 3D modelling[95].

The advantages of these innovations are that workers and robots can much more easily communicate via voice and visual gesture recognition. Further, the development of human-robot interactive interfaces allows shared autonomy and human supervisory control. Virtual reality robotic systems allow workers to work remotely in hazardous or physically demanding environments and to tele-operate and tele-supervise remote equipment provided adequate wireless communication systems are available. Other advances in robotics which will greatly assist their spread throughout Queensland are:

- Manipulation technologies, including force-amplifying exoskeletons[96]
- Dexterous manipulation (grasping and moving complex objects using robotic "fingers" or claws)
- Multi-robot cooperation
- Robotic tools similar to existing micro-surgery rigs enabling workers to perform miniature component manufacturing and assembly tasks with precision and dexterity – without risk to their health

Finally, the new generation of robots would not be possible without smart fabrication. Miniaturisation and smart and lightweight materials make for small, light, smart robots. These needs will spawn new industrial demand within the advanced manufacturing sector.

4.1.1 The sensitivity and capacity for the Queensland economy to absorb automation and digital change

The job loss impacts of technological change are immediate, obvious and generally concentrated in particular industries and occupations. The job producing impacts are less immediate, dispersed over the whole economy and include new occupations.

Section 2 of the report has shown that the Queensland economy and particularly the Queensland labour market absorbed considerable structural change over the last two decades. Since 1999, Agriculture, Forestry and Fishing, Manufacturing Wholesale and Retail Trade have all had noticeable reductions in their relative share of employment, to be replaced by compensating jobs in skilled service industries such as Health Care and Social Assistance, Administrative and Support Services, Education and Training and Public Administration and Safety. This shift in industrial employment has been reflected in the shift into skilled and professional employment, largely of a non-routine nature, replacing unskilled and routine occupations.

The causes of this structural change were varied, including globalisation and supply side pressures from a more educated workforce that has changed the job/qualification mix. Technolgical change also played a major role in job loss and reallocation in Agriculture, Manufacturing and within Wholesale and Retail Trade. Despite these changes, total employment in Queensland rose by 793,000 (approximately 50 per cent) between 1999 and 2017. Even in industries that saw a decline in their relative importance, such as Retail Trade and Manufacturing, actual employment in 2017 exceeded that in 1999. Only Agriculture, Forestry and Fishing and Wholesale Trade experienced both relative and absolute decline in employment numbers.

In 1999 the 12-month average unemployment rate in Queensland was 7.7 per cent compared to 6.2 per cent[97] in 2017/18. This is further indication that, despite large scale structural change, the Queensland labour market expanded by 50 per cent. Over the same period the GSP of Queensland went from A$93 billion to A$298 billion.

This pattern of job and wealth growth during periods of high levels of technological change has been repeated in most developed countries over a similar period.

The lesson of the Queensland economy and from the countries highlighted in table over the last two decades is that technological change will add to rather than cost total employment. However, there will be changes in job and task mix within each industry, creation of new types of job and the likelihood of relative employment declines in some industries. This is the nature of the job creation and destruction process as observed in most economies over time. The important issue in the job outcome equation from automation is net wealth creation, principally through productivity growth.

Table 12 Employment and GDP Growth during periods of technological change- selected countries

Country	Job increase	Economic growth $Bn
United States	21, 680,000 (+15.5%)	321.3 (40%)
United Kingdom	4,880,000 (+17.7%)	184.5 (43%)
Germany	5,010,000 (+13.8%)	223.5 (46%)
Canada	2,980,000 (16.1%)	170.4 (38%)

Source: Compiled from OECD data 1999- 2017.

4.1.2 Which occupations and industries will be the most impacted?

The impact of automation will be widespread and impact across the economy. However, most authorities recognise that the actual absorption rate within each industry will depend upon a combination of technological, economic and social factors[98]. These factors include;

A number of factors will influence the propensity of industries to be most impacted by automation. These include:

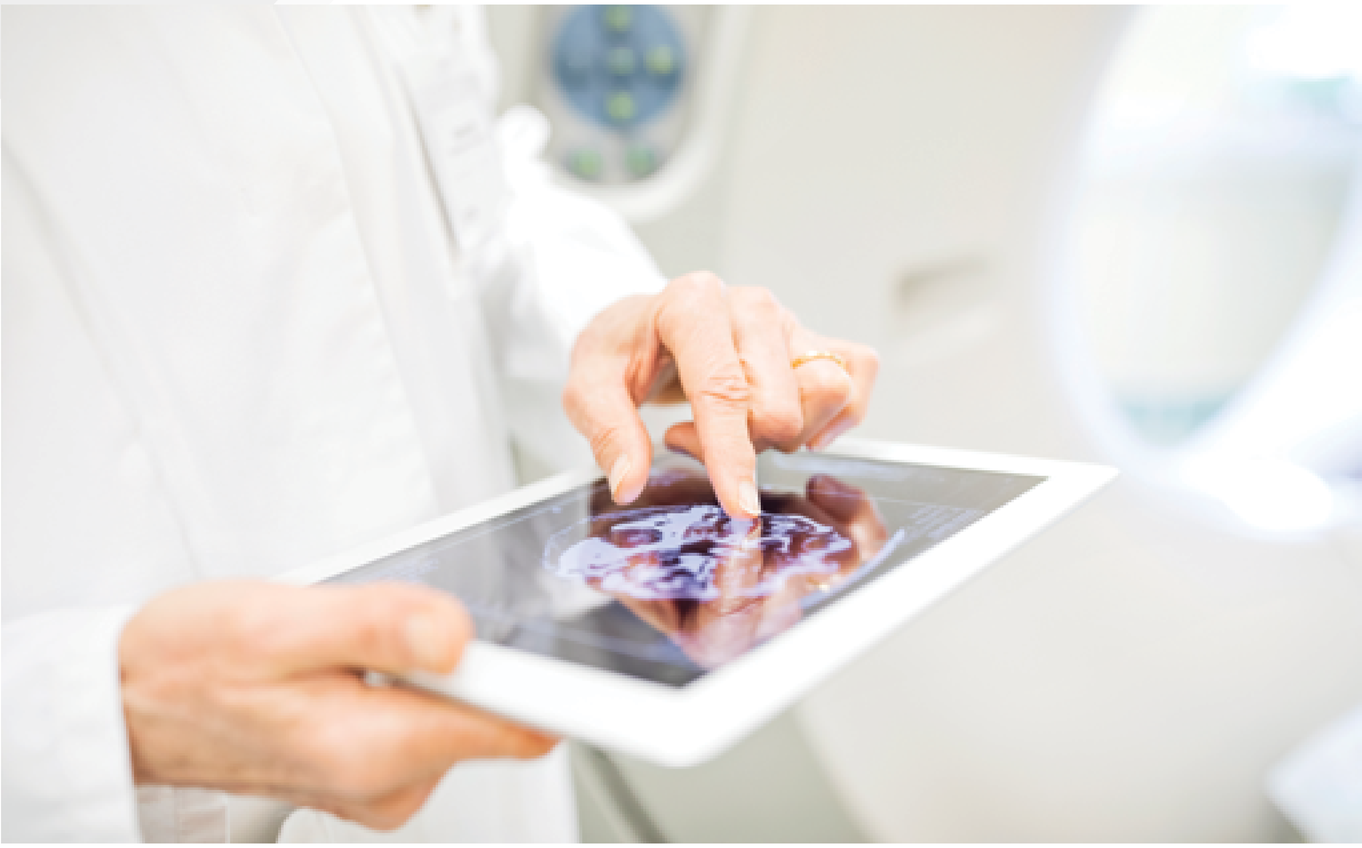
- The degree of routineness of tasks within the occupation
- Technical feasibility for automation and digitalisation
- The relative cost of labour
- Availability of skilled labour to complement the automation process
- Supportive financing, regulatory and training packages

On this basis, almost all Queensland industries will be impacted to some degree but a number stand out for the most rapid automation. These include:

- Transport - principally in autonomous vehicles in Mining, Agriculture and Personal Transport, Warehousing and Logistics
- Administrative and Support services, including clerical services
- Process manufacturing
- Wholesale Trade
- Finance and Insurance including automation of tasks and reductions in compliance work resulting from block chains

> Technological change despite the long-term benefits can be disruptive in the short term

The cornerstone industries of Mining (capital labour ratio of 64 per cent) and Agriculture, Forestry and Fishing already have high capital/labour ratios and are essentially low employment and to some extent the new wave of automation will represent capital improvement rather than capital substitution. Nevertheless, Mining in Australia is currently at the forefront of automated transport systems and faces high labour costs.



4.1.3 Coping with short-term dislocation

Technological change, despite the long-term benefits, can be disruptive in the short term. A standard answer to this form of disruption is to look to government for remedial activity especially in terms of the placement of displaced labour. However, this type of approach is reactive, often wasteful and possibly unnecessary. It is unlikely the governments know more about the probable outcomes of technological change than the companies themselves. Adner and Kapoor (2016) in their influential Harvard Business Review paper argue that disruption is caused not so much by the technology per se as by the timing of its introduction[99]:

> *"Our understanding of the shifts that disrupt businesses, industries, and sectors has profoundly improved over the past 20 years: We know far more about how to identify those shifts and what dangers they pose to incumbent firms. But the timing of technological change remains a mystery"*

Their analysis takes place at the company level, which is where new technology is introduced, rather than at the industry level.

The authors point out some technologies and enterprises seem to take off overnight such as ride sharing and Uber; social networking and Twitter, while others take decades to unfold (high-definition TV, cloud computing). They argue that poor timing, adopting too soon or too late, accounts for a large part of any disruption.

This is because technologies are not to be considered in isolation but as part of a broader ecosystem that supports its introduction and the competition that takes place between the new and the old ecosystems, rather than between the technologies themselves.

Technologies are not to be considered in isolation but as part of a broader ecosystem that supports their introduction

This perspective can help managers better predict the timing of transitions, craft more coherent strategies for prioritising threats and opportunities and ultimately make wiser decisions about when and where to allocate organisational resources and lower potential labour force dislocation[100]. The elements within an ecosystem include the degree of reliance on complementary technology and marketing systems and the extent to which old technology is able to maintain itself in spite of the existence of superior technology.

The timing of introduction is also of major importance in dealing with the issue of the displacement of labour. Adner and Kapoor (2016) offer up the following advice;

- If your company is introducing a potentially transformative innovation, the full value will not be realised until all bottlenecks in the ecosystem are resolved. It may pay to focus a little less on perfecting the technology itself and a little more on resolving the most pressing problems in the ecosystem
- If you are a threatened incumbent, it pays to analyse not just the emerging technology itself but also the ecosystem that supports it. The greater the ecosystem-emergence challenge for the new technology, the more time you have to strengthen your own performance
- Strengthening incumbent performance may mean improving the old technology - but it can just as easily mean improving aspects of the ecosystem that supports it
- Every time the old technology's performance gets better, the performance threshold for the new technology goes up

A core element of both successful introduction of new technology and the reduction of any potential disruption is to remove any labour constraints, especially in skilled labour. Gorloch and Wessel (2008) in their well- known "Tesla" example show the constraints placed on plans for technological change without ensuring adequate skilled labour availability. In short, companies need to implement human resource programs, including workforce retraining, to ensure successful introduction[101].

However, job dislocation can also be brought on domestic industry by imports from overseas from countries that have been quicker to adapt to the new technology than Queensland firms. Australia is lagging in the introduction of robotics and this form of dislocation may occur. In these cases, old-fashioned macro policies to disrupt trade have been discredited and the role of the government and industry associations must be to facilitate local technological change as quickly as possible.

5 Potential economic benefits for Queensland

5.0 Quantifying benefits

A number of studies cited in this report have attested to the potential economic gains associated with automation[102]. These gains derive primarily from labour productivity gains but also include the creation of new types of employment and the reshoring of activities that had previously moved offshore[103].

Predicting the size of these productivity impacts and their subsequent impact on economic growth rates has been the source of interest and some disagreement among economists over the last decade. In one of the earlier studies that attempted to quantify the potential gains from automation, economists Whitaker and Kinson, examined the initial deployment of industrial robots (1990-2005) and argued that their impact on economic growth in the OECD was approximately 10 per cent or 0.66 percentage points per year, but that this was probably a conservative estimate[104]. The estimates of the potential impacts from greater automation have grown considerably as the use of automation and robotics have spread beyond industrial processing into a greater range of activities across the economy.

For example, Frontier Economics (2016) predicted that automation will increase labour productivity by 40 per cent and double Gross Value Added for a number of developed countries over the period between 2017 and 2030[105]. This represents an effective (automation induced) growth rate of over five per cent per annum for those countries. Similarly, the McKinsey Global Institute (2017) suggests that automation induced productivity growth in the US would be boost GDP annually by between 0.8 and 1.4 per cent[106]. Consultants, alphaBeta have estimated a 51 per cent growth in labour productivity and a $2.2 trillion rise in GDP by 2030 if Australia achieved the same degree of automation as in the US[107]. This would equate to economic growth of 4-5 per cent annually. Finally, the Boston Consulting Group (2016) forecasts productivity improvements of 30 per cent over the next 10 years, which would translate into an additional two per cent growth rate in the US over that period[108].

In summary, while some differences exist in the scope and results of these studies, the consensus is that automation offers short to medium term average benefits of between one per cent and three per cent increases in GDP (GSP) over a 10-year period for countries that undertake rapid automation. These studies provide a guide to the potential benefits available to the Queensland economy

Nevertheless, accurately quantifying the potential gains from rapid automation in the Queensland economy presents considerable difficulties for formal economic modelling. Chief among these would be gaining detailed information on the take-up rate of automation by different industries, sub-industries and the occupational mix within those industries. As well, most economic models make assumptions about industrial structure and factor proportions within their specifications. They predict the future, in part, based on these past relationships[109]. However, automation and robotics are, in a sense, disrupters of established production patterns making past technological relationships less reliable as predictors of the future. Nevertheless, by making use of the potential productivity gains reported in the studies cited above, concentrating on the potential productivity benefits across the economy as a whole and adopting conservative assumptions, it is possible to provide a plausible scenario of the benefits that would flow from the rapid introduction of automation to the Queensland economy.

In undertaking this scenario analysis, note should be taken of the considerable progress in robotics and automation that has already taken place in Queensland[110].

5.1 Methodology

In the following scenario modelling growth in GSP in Queensland is modelled through an exponential growth equation of the form:

$x_{(t)} = x_0 \cdot (1 + r)^t$ *where;*

$x_{(t)}$ is the value at time t.
x_0 is the initial value at time t=0.
r is the growth rate when r ranges between 3 and 5
t is the time in discrete intervals and selected time units

Shifts in growth rate are driven by the increased utilisation of automation and robotics. At the current level of automation, a baseline underlying growth rate of three per cent for Queensland is assumed. It is noted that the Queensland economy experienced a real growth between 2007/8 to 2016/7 less than three per cent (2.35 per cent). However, that period included the end of the mining boom and the Global Financial Crisis, which helped cancel out some of the benefits from the level of automation that was occurring within the Queensland economy during that period.

> Over the past 10 years, the Queensland economy has yielded a net increase of approximately 240,000 jobs

Over a longer period (1992-2017), the Queensland economy averaged a growth rate of 3.9 per cent[111]. Moreover, the Queensland Government has predicted a growth rate of 2.75 per cent over the next three years[112], all of which suggests that the assumption of a baseline growth rate of three per cent is supported. However, a specification of the exact baseline rate of growth is not essential to the exercise. This scenario sets out to examine the potential impact of the two central questions regarding automation:

(a) What are the potential benefits of rapid automation in terms of boosts to GSP for Queensland?

(b) How much of these benefits, in terms of potential employment creation, will be displaced by automation?

Over the past 10 years, the Queensland economy has yielded a net increase of approximately 240,000 jobs and this number may be used as a means of comparison with the potential for job growth under a scenario of increased automation. To estimate the potential benefits of automation to the Queensland economy three scenarios are examined

- Scenario 1: automation is assumed to increase the rate of GSP growth by one per cent per annum
- Scenario 2: automation is assumed to increase the rate of GSP growth by 1.5 per cent per annum
- Scenario 3: automation is assumed to increase the rate of GSP growth by two per cent per annum

Note: The reported growth impacts from automation refer to the direct impacts through productivity growth. Additionally, with the more rapid adoption of automation, still further economic growth will emerge from indirect or 'endogenous' effects such as spillover and learning effects.

These estimated impacts of automation on growth rates are conservative and at the lower end of estimates discussed above. Importantly, the job replacement/dislocation aspects of automation also needed to be included in the scenario analysis, as job displacement is the primary concern from rapid automation.

To examine this issue, the job displacement potential of the various industries estimated by McKinsey Global (2017), are used to adjust downwards the employment impacts of the productivity growth potential of automation[113]. These estimates are at the high end of job replacing potential of automation. Finally, the income (wealth) creating aspects of automation are included in the analysis by using the type 1A employment multipliers for Queensland, estimated from the Queensland Non Linear Model (QNLM)[114]. These are traditionally used to estimate flow-on employment impacts from new job creation and will pick up both the traditional flow-on effects of wealth creation and the new (types) of jobs likely to flow from automation. On this basis, the impact of rapid introduction of automation can best be estimated through expected productivity effects, the rate of technological substitution and the creation of new jobs.

5.2 Economic benefits

Table 13 shows the potential impact of productivity and indirect or endogenous growth benefits to the Queensland economy as well as estimating the extent of short-term job dislocation that may occur. GSP growth estimates in Table 13 do not isolate the impact of accelerated automation, these estimates are provided in Figure 17.

By comparison with the previous 10-year period in Queensland, the results in Table 13 indicate that even conservative estimates of productivity growth through automation show that more significant GSP and employment gains can be achieved. Specifically, over a 10-year period the results suggest:

- Scenario 1: a 1 per cent addition to GSP over a 10-year period through automation will provide an additional A$37.4 billion in GSP and 492,950 jobs (250,000 above the previous 10 years)
- Scenario 2: a 1.5 per cent addition to GSP over a 10-year period through automation will provide an additional A$77.2 billion in GSP and 725,810 jobs (485,000 above the previous 10 years)
- Scenario 3: a 2.0 per cent addition to GSP through automation provides an additional A$117.5 billion in GSP and 1,165,830 jobs (925,000 above the previous 10 years)

Note: In addition to Scenario 2 and Scenario 3 the more rapid adoption of automation yields indirect or endogenous growth impacts of 0.4 per cent per annum and 0.9 per cent per annum respectively.

The data also shows that some job dislocation will occur. Significantly, the lower the rate of economic growth, the greater the degree of job dislocation. For example, impact at the lower end of automation (one per cent growth rate augmentation) coincides with job dislocation of 485,950 jobs, whereas growth augmentation of two per cent leads to approximately 300,000 jobs dislocated. This is due to the fact that the greater the rate of growth, the greater the wealth (income) effects and therefore the greater the capacity for the new technology to alter rather than replace jobs. At this stage, while the level of net job creation may be estimated, the scenario modelling is unable to determine the distribution of these job gains by industry or occupation. To do this would require greater knowledge of the creation of new jobs (by type) and the extent to which each industry and occupation will utilise available technology. Modelling of this type, if sufficient data were available, would most likely be of the form of CGE modelling.

Figure 17 Additional Growth Contribution from Automation (per cent) and GSP Growth ($billion)

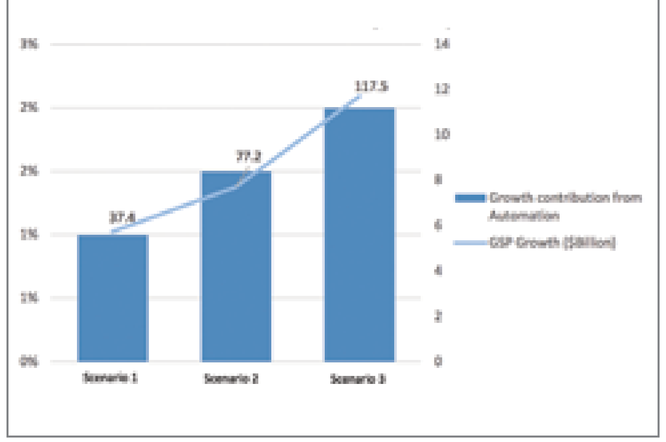


Figure 18 Automation Jobs

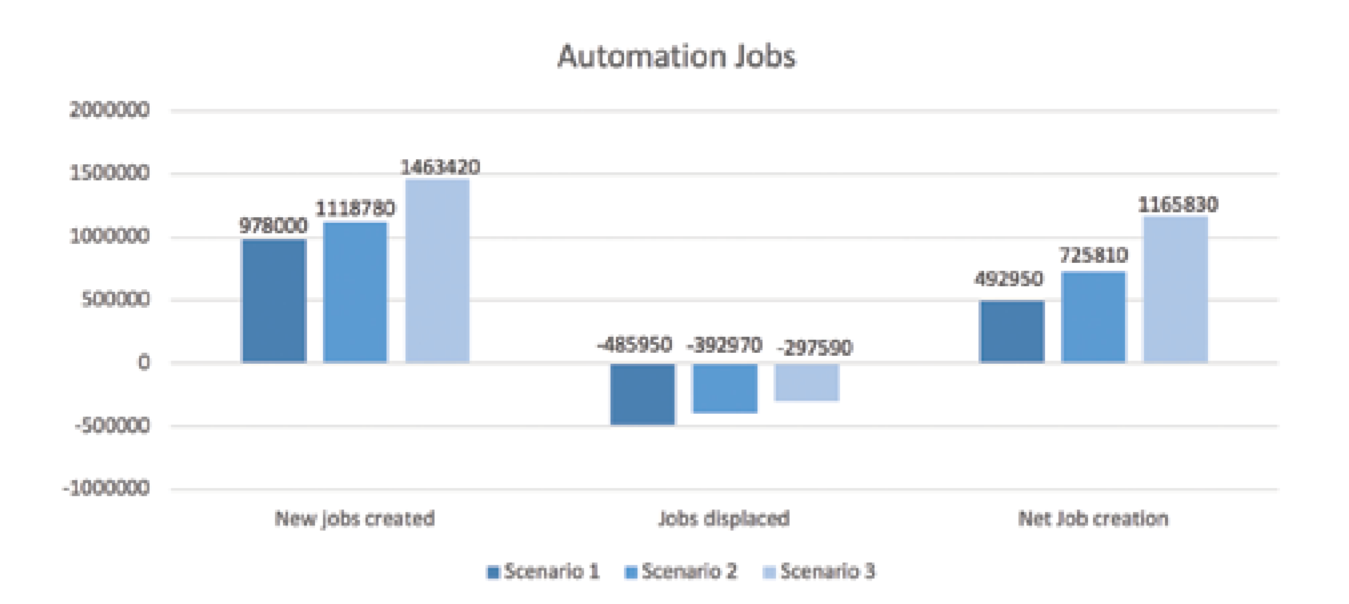


Table 13 Growth potential for Queensland economy from 10 years of accelerated automation

Scenario	Direct Growth contribution from Automation	GSP Growth[115] $billion	New jobs created[116]	Jobs displaced[117]	Net Job creation
1. Conservative	1%	108.20	978000	-485950	492950
2. Very Likely	1.5%	148.00	1118780	-392970	725810
3. Optimistic	2%	188.30	1463420	-297590	1165830

Note: The term 'Direct Growth contribution from Automation' relates only to the direct impacts from automation or growth. In addition to these impacts, indirect or endogenous growth also arises from automation and is included in the calculation of the total GSP Growth in each scenario.

Source: Estimated from AIBE scenario modelling

Future work will fall into one of three categories

People who work FOR machines
(eg drivers, online store pickers)

People who work WITH machines
(eg surgeons)

People who work ON machines
(eg programmers, designers)

5.3 The Doomsday Strategy: consequences of not automating?

Earlier chapters in this report have shown that Australia (Queensland) is under-developed in terms of robotics and automation albeit that much of this is due to the industrial structure of Queensland with its lack of heavy manufacturing, which has been the initial center of automation. Section 5.3 shows the value to the Queensland economy of a rapid increase in the levels of automation. For example, under conservative assumptions, the Queensland economy after 10 years of rapid uptake of automation could benefit by a minimum of A$37.4 billion in GSP and approximately 492,950 jobs[118]. The alternative strategy is to fall further behind world levels of automation and face the consequences that technological obsolescence always brings. Initially, this will take the form of an opportunity cost of the extent shown in Table 13. However, inaction on the automation front in Queensland while the rest of the world automates will lead to a sustained drop in competitiveness. Economies may be divided into two sectors; traded and non-traded sectors. Gradually, the proportion of the economy taken up by the traded sector, principally through the expansion of tradeable services and the division is blurring as previously non-traded items become traded. Currently the trade sector in Queensland is valued at A$119 billion (2016/17) with exports at A$69.8 billion and imports at A$50 billion. The consequence of technological obsolescence in the Queensland economy is shown diagrammatically.

Figure 19 shows that the traded sector will feel the initial impacts of technological obsolescence, which will manifest in a number of ways;

/ A loss in competitiveness decline in the terms of trade

/ Lower productivity growth

/ Increased imports, particularly competing imports

/ Reduced growth and job opportunities

Under conservative assumptions, the Queensland economy after 10 years of rapid uptake of automation could benefit by a minimum of A$37.4 billion in GSP and approximately 492,950 jobs

Declining productivity and loss of competitiveness will mean a loss of export revenue, either through reduced or lowering prices to keep market share. In the medium to long term, there will be an increase in the rate of offshore investment and an outflow of skilled labour and a decline in job opportunities. In the long term, the non-traded sector will be impacted.

Figure 19 The Sequential Impact of Technological Obsolescence

Tax revenues from the decline in exports and the loss of productivity gains will fall, reducing the ability for governments and other inbuilt stabilisers to limit the damage of technological obsolescence.

Costing this scenario is difficult and requires full-scale and data intensive CGE modelling. However, a number of plausible estimates may be made of the potential costs over a 10-year period

/ Opportunity costs in the next 10-year period of at least A$37.4 billion in lost GSP and 492,950 jobs

/ Net decline in the real value of exports[119]

/ A rise in the relative share of competing imports as a consequence of the loss of competitiveness[120]

/ Resultant pressure on tax receipts and government spending

/ Net outflow of skilled labour seeking opportunities in robotics and automation industries

The above conclusions are subject to the extent to which other countries take up the automation opportunities described in this report. Knowledge of the relative position of Queensland industry in the move towards automation and robotics would be need before more formal modelling of the consequences could be attempted.

6 Policy options - creating long-term growth opportunities

Section 3.5 has identified the large potential gains achievable through successful automation. This was expanded in Section 5 to include plausible estimates of the scale of benefits available.

In brief, the Queensland and Australian economies have much to gain from successful adaption of robotics and automation. However, the industrial structure of Queensland differs from many of the OECD countries identified in the cited studies. To gain maximum advantage from the automation process in Queensland, emphasis will need to be placed on those areas of the economy where there is comparative advantage.

6.1 Leveraging the current industrial base in Queensland and identifying areas of comparative advantage

In the short term, Queensland's comparative advantage would seem to lie in Mining, Agriculture (including Food Technology) and Hospitality and Tourism related activities. In the medium to long term, considerable opportunities exist in the SME side of manufacturing using light robotics and expanding opportunities to gain a foothold in the Asian value chain. Section 2.6 identified the range of automation and robotics that are available to be applied to the cornerstone industries of Queensland in a technological sense. However, technological issues are only one component of an automation and robotics mix that will need to be developed if Queensland is to fully leverage the benefits of automation.

Other key components are:

/ Appropriate technical advice - especially to small and medium sized enterprises (SMEs), particularly concerning the optimum time for the introduction and management of the automation process and creating the required ecosystems

/ Adequate funding (including seed funding) for technical development

/ Developing a skilled workforce capable of making best use of available technologies

/ Developing industry specific readjustment packages to cope with any short-term dislocations

6.2 Appropriate technical advice

It is generally assumed that companies are responsible for their own capital investment and labour force management issues. However, as Adner and Kapoor (2016) have shown, the timing and management of technological change is important in generating overall success. The overwhelming requirement is for successful innovation[121]. According to Tunney (2016), innovation has now become one of the key elements within a business[122]:

> *Innovation therefore needs to transcend all areas of operation - production, finance, planning, human resource management and marketing. However, in the small business many of these functions are carried out by the owner manager and thus often leads to a lack of realisation of the processes needed to implement innovation within the small business*

Tunney identifies a number of barriers small businesses face in innovation. These include:

/ A general lack of suitably qualified technical specialists within small firms which makes them generally unable to support a formal R&D effort on an appreciable scale

/ Small businesses often lack the time and resources to identify and use external sources of information, technical and scientific expertise. Therefore, they often are unable to access new technological developments

/ Small to medium enterprises (SMEs) often experience great difficulty in attracting capital, especially risk capital

/ As a result, innovation will generally represent a disproportionately large financial risk for the small business and therefore more often than not becomes impossible to fund

/ Small businesses lack the ability to spread the risk over a portfolio of projects due to their limited resources

6.3 Adequate funding

All of these factors resonate in Queensland and will impact SMEs' ability to successfully introduce and manage the automation process. In such situations, government programs such as Small Business Digital Grants Queensland are of great potential benefit in increasing the absorption rate of new technology. In Canada and the UK, industry associations also work directly with government in attracting venture and start-up capital and achieving tax concessions for technological development.

In the short term, Queensland's comparative advantage would seem to lie in Mining, Agriculture (including Food Technology) and Hospitality and Tourism related activities

Canada's SRED or R&D Tax credit (the Scientific Research and Experimental Development Tax Credit), provides Canadian companies with money to undertake capital expenditure to reduce costs and generates marketing dollars to promote commercialisation efforts. All members of G7 countries have an R&D tax credit program in place. Canada's SRED tax credit program offers Canadian companies up to a 45 per cent tax refund in some provinces[123].

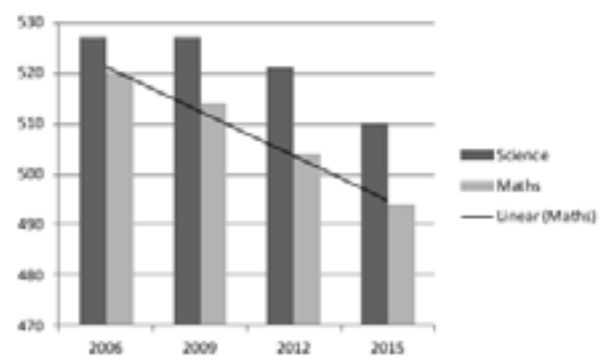
The SRED program is just one of the number of specific policies in place in Canadian provinces to boost automation. The results of these policies are that Canada is home to a small, innovative cluster of industrial automation companies that generate approximately US$2 billion annually in revenues from Canadian and international sources[124].

6.4 Developing a skilled workforce capable of making best use of available technologies

The strength of Queensland's Science, Technology, Engineering and Mathematics sector (STEM) will indicate how well the state will adapt to the challenges of automation. International comparative data for Queensland is not available, but the data in Figure 20 examines PISA rankings. In 2015, Australia had a PISA score of 510, well above the OECD average of 410 but ranks 14th overall in the world behind New Zealand and Canada and well below the leading country Singapore (589). However, Australia's relative performance has declined consistently since 2006[125].

This downward trend in key educational areas has been identified as an important constraint in the development of skilled labour to facilitate adequate progress in automation. Changing educational direction and student performance is difficult and while no clear statistical relationship exists between educational performance and the level of automation absorption, it is notable that high scoring PISA countries such as Singapore (first in 2015 PISA ranking) and South Korea (4th in 2015 PISA ranking) also rank highly in terms of the absorption of robotics.

Figure 20 Australian PISA scores over times (OECD, 2015)

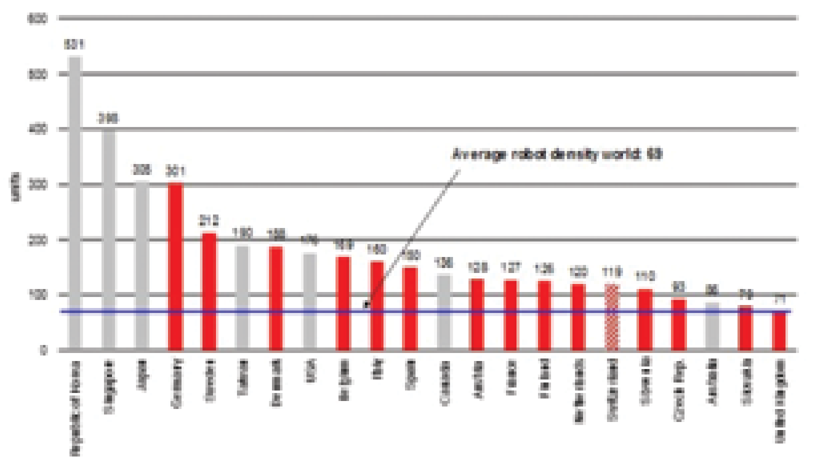


Source: Heath, A,. (2016) "The Changing Nature of the Australian Workforce" Reserve Bank of Australia Speechs September 21, https://www.rba.gov.au/speeches/2016/sp-so-2016-09-21.html

Worldwide, the Republic of Korea has by far the highest robot density in the manufacturing industry and has held that position since 2010. The country's robot density is eight times higher than the global average (631 units). The causes of this high growth rate are the continued installation of a high volume of robots particularly in the electrical/electronics industry and in the automotive industry and the availability of skilled labour.

Similarly, Singapore, which follows in second place with a rate of 488 robots per 10,000 employees in 2016, combines high rates of robotic penetration, particularly in electronics, with high PISA performance. Another country with high joint PISA/Robotics combinations is Japan which ranked fourth in the world in 2016. However, the correlation is not fixed. Germany (overall PISA score in 2016 of 506) is roughly equal with Australia in PISA performance but employs much more in the way of robotics (probably because of its manufacturing base). Consequently, PISA scores should be seen as a necessary but not sufficient condition for the introduction of automation

Figure 21 Number of multipurpose industrial robots (all types) per 10,000 employees in the manufacturing industry



Source: https://mashable.com/2017/05/25/south-korea-robots/

Future work will fall into one of three categories, according to Deloitte managing partner, Robert Hillard:

- Firstly, people who work for machines such as drivers, online store pickers and some health professionals who are working to a schedule," Mr Hillard says
- Secondly, people who work with machines such as surgeons using machines to help with diagnosis
- Thirdly, people who work on the machines, such as programmers and designers

The educational key to servicing these three types of partnerships, according to Thorpe (2017) is[126]:

> *"Broad, basic education with a strong STEM focus (science, technology, engineering, mathematics) will provide the core skills and flexibility that people will need."*

6.5 Developing industry specific readjustment packages to cope with any short-term dislocation

Governments, particularly at the state level, are not well suited to intervening in specific markets. However, they will play an influential role in helping to reduce short-term dislocation caused in the labour market through the automation process. In particular, governments can be most effective in:

- Facilitating the development of appropriate ecosystems for businesses, especially small and medium size, to gain knowledge and expertise in emerging technologies
- Limited direct assistance through tax breaks, venture capital and technical assistance
- Assistance in labour force planning including developing appropriate skills, re-training and redeployment of displaced staff

Short-term dislocation in some occupations is to be expected and is a normal part of the economic trade cycle. In the early 1990s Queensland unemployment rates reached 10.5 per cent. This lead to effective government policy, which, along with a recovering economy, reduced unemployment to 4.5 per cent by 2006[127].

The principal difference between standard downturns and any automation-led dislocation in the labour market is that most unemployment will be structural, rather than demand deficient, with some workers being replaced by automation rather than a decline in the demand for the product. This is beneficial for government as the net wealth creation in the state will continue and the issue will become one of re-training and re-deployment rather than "pump priming" or demand stimulation.

References cited

1. See, What is Automation? "https://www.isa.org/about-isa/what-is-automation/"
2. See, Quartz "The Optimists Guide to the Robot's Apocalypse " https://qz.com/904285/the-optimists-guide-to-the-robot-apocalypse/"
3. See, Gordon, R. (2013) "The Rise and Fall of American Productivity", Princeton Economic Series of the Western World, Princeton.
4. See, Australian Centre for Robotic Vision (2018) "A Robotics Roadmap for Australia" QUT, Mineo
5. See, The Economist (2012) " The Third Industrial Revolution" April 12 and Ferro, S (2015) " Bill Gates: We're in the Fastest period of Technological Change Ever and no one knows how that will affect the economy" Tech Insider, https://www.businessinsider.com.au/bill-gates-were-in-the-fastest-period-of-technological-innovation-ever-2015-6?r=US&IR=T
6. Gordon, R. (2013).
7. See The Economist (2015) "Automation Angst fears that Machines will put Humans out of work), August 15th
8. See, for example, Pratt, G. (2015). "Is a Cambrian Explosion Coming for Robotics?" Journal of Economic Perspectives, 29 (3): 51-60
9. A variety of sources will be used to provide a brief but comprehensive review of the Queensland economy including recent works by Deloitte-Access economics, Queensland Treasury, Queensland Treasury Corporation, The Australian Bureau of Statistics and recent work by Synergies and UQ, including Mangan (2018) " The Queensland Labour Market – Synergies study undertaken for Jobs Queensland (forthcoming) and ISSR 2016 "The Future of Manufacturing Jobs in Queensland"
10. By world standards, this is a comparatively high but it is below the Australian average. . For example, the share of labour in the US has fallen from 67 per cent in 1990 to 47 per cent in 2016. See, Merler, S (2017) "The Decline of Labour's Share of Income" http://bruegel.org/2017/04/the-decline-of-the-labour-share-of-income
11. See Mangan, J, Milosovich, F. and Markey-Towler, B (2018) Wage Stagnation and its implications for consumption in Australia, Australian Institute for Business and Economics, February 2018.
12. Queensland Government Statistician's Office (2016). Small business in Queensland, June 2016; See: http://www.qgso.qld.gov.au/products/reports/small-business-qld/small-business-qld-201606.pdf
13. Although this category lost some share of relative importance.
14. The methodology for this is shown in Synergies (2018). Queensland Labour Market Analysis 2002-2017, Prepared for Jobs Queensland.
15. Gorloch, L and Wessel, O. (2008). "Optimum Level of Automation in the Automotive Industry" Engineering Letters 16(1).
16. Revision to this classification have been put forward by and are considered later on in the report. See, Brandes, P and Wattenhofer, R (2016). "Opening the Frey/Osborne Black Box: Which Tasks of a Job are Susceptible to Computerization?" Computers and Society (2) Cornell University https://arxiv.org/pdf/1604.08823.pdf
17. Gorloch, L and Wessel, O. (2008).
18. Refer section 2 of this report for a discussion
19. Queensland Government Statistician's Office (2017) Employed persons (a) by occupation (b), Queensland, 2006–07 to 2016–17 (c); http://www.qgso.qld.gov.au/products/tables/employed-persons-occupation-qld/index.php
20. "Robotics in Agriculture; Types and Applications https://www.robotics.org/blog-article.cfm/Robo
21. See, "Robotics in Agriculture; Types and Applications https://www.robotics.org/blog-article.cfm/Robo
22. See, Inforobotics (2018)" Robots in Agriculture" https://www.intorobotics.com/35-robots-in-agri
23. Kendall (2018), Cited in Jones, K (2018) "Robots are coming to the Construction site" https://www.constructconnect.com/blog/construction
24. Kendall (2018), Cited in Jones, K (2018) "Robots are coming to the Construction site" https://www.constructconnect.com/blog/construction
25. https://blog.robotiq.com/top-10-robotic-applica
26. Latimer, C (2015) "Mining Automation; the be all and end all" Australian Mining, September 8th
27. Simonite, T (2016) "Mining 24 Hours a Day with Robots" MIT Technology Review, December 2016.
28. IBIS World Industry Reports (2018) "Mining"http://clients1.ibisworld.com.au/reports/au/industry/ataglance.aspx?entid=55
29. In 2018, the average wage in Australian Mining was $183,000 which is approximately 2,8 times the Australian average wage for all employees, See IBIS World (2018) p. 5.
30. See, Government Statistician's Office (2017) " Gross State Product at Factor Cost by Industry and Nain Component" https://data.qld.gov.au/dataset/gsp-factor-cost-industry-components/resource/99f59524-db21-465a-8898-a9686b55deba
31. Estimated from Synergies Non-Linear Economic model
32. See, "RPA and the Utilities Industry- & Reasons Why They Make a Good Match" https://www.cigen.com.au/cigenblog/rpa-utilities-industry-7-reasons-why-they-make-good-match
33. IMB Insights on Business (2016) "Developing Trends in Wholesale Distribution , Robotics and Industrial Connectivity "and St, Germain, P (2017) Facing the Forces of Change, IBM
34. Underwood, C (2017) " Robots in Retail – Examples of Real Industry Applications, Techemergence,p.2 https://www.techemergence.com/robots-in-retail
35. Hospitality Technology (2017) "Robots in Hospitality: Five trends on the Horizon" that free up hotel staff to spend more time assisting guests. October, https://hospitalitytech.com/robots-hospitality-five-trends-horizon
36. Ibid
37. World Economic Forum: Artificial Intelligence and Robotics (2108) "How AI, IoT and cybersecurity will fuel growth for tech and media companies" https://www.weforum.org/agenda/2017/01/how-ai-iot-and-cybersecurity-will-fuel-growth-for-tech-and-media-companies/
38. Deloitte (2017) "How Robotics and Cognitive automation will change the Insurance Industry" https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-cons-how-robotics-and-cognitive-automation-will-transform-the-insurance-industry.pdf
39. Beckerman, M (2017) "Will Robots Steal the Jobs of Commercial Real Estate Professionals?" http://michaelbeckermansblog.com/blog/will-robots-steal-jobs-from-commercial-real-estate-professionals
40. Marr, B (2016) "Surprisingly, These 10 Professional jobs are under threat from big data' Forbes.com https://www.forbes.com/sites/bernardmarr/2016/04/25/surprisingly-these-10-professional-jobs-are-under-threat-from-big-data/#75aedf257426
41. Price Waterhouse Coopers (2016) "Will Robots Steal our Jobs; The Potential Threat of Automation on the UK and Other Major Economies. https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf
42. Williams, Y (2016) "Robots will never be able to teach English Literature" ww.tes.com/news/robots-will-never-be-able-teach-english-literature
43. These will include a comprehensive but compact review of contemporary literature including Swartz et/al (2017), OECD (2018, 2017 (a), 2017 (b), 2017 (c) and McKinsey Global Institute (2017 (a) , 2017(b) and available Australian literature
44. Davis, S., Haltwanger, J. and Schuh, S. (1998) Job creation and destruction' MIT Press Chicago.
45. Effectively, simultaneously raising marginal productivity but lowering the stock of labour needed
46. https://www.techopedia.com/definition
47. See, discussion in Section 4 of the report.
48. OECD (2017). "Artificial Intelligence and the Labour Market; Should we be worried or excited?" October, http://www.oecd.org/els/emp/future-of-work/artificial-intelligence-and-the-labour-market-should-we-be-worried-or-excited.htm
49. Executive Office of the President (2016) "Artificial Intelligence, Automation, and the Economy, Washington 2016"
50. Comanor, W. and Scherer, F, (1972) "Patents as a measure of technical progress" Journal of Political Economy (76) 392, 397.
51. Comanor, W. and Scherer, F, (1972) "Patents as a measure of technical progress" Journal of Political Economy (76) 392, 397.
52. See, Rogers, E (2003). Diffusion of Innovations, 5th edition, Free Press.
53. See, alphaBeta Strategy Economics (2017) "The Automation Advantage" p.19.
54. Gorloch, L and Wessel, O. (2008) "Optimum Level of Automation I the Automotive Industry" Engineering Letters 16(1).
55. IFR (2017) "The Impact of Robotics on Productivity, Employment and Jobs" Positioning paper by the International Federation of Robotics, https://ifr.org/img/office/IFR_The_Im

56. Graetz, G, and Michaels, G. (2015) "Robots at Work". Centre for Economic Performance, London School of Economic Centre for Economics and Business performance https://cebr.com/?s=robots

57. Centre for Economics and Business Research (2017), The impact of automation A report for Redwood https://cebr.com/wp/wp-content/uploads/2017/03/Impact_of_automation_report_23_01_2017_FINAL.pdf

58. Andes, S and Muro, M. (2015) "Don't blame the robots for lost manufacturing jobs" Brookings Advanced Industries Series, April 29 https://www.brookings.edu/blog/the-avenue/2015/04/29/dont-blame-the-robots-for-lost-manufacturing-jobs/

59. Accenture 9 and Frontier Economics). 2016. Why Artificial Intelligence Is the Future of Growth. Accenture

60. Boston Consulting Group. 2015. The Robotics Revolution

61. Global Institute. 2017. A Future That Works Automation, Employment and Productivity.

62. Cited In IRF (2017) p.3

63. Citi and Oxford Martin School. 2016. Technology at Work V2.0

64. Reshoring Initiative. (2015). Reshoring Initiative Data Report 2015. http://reshorenow.org/content/pdf/2015_Data_Summary.pdf.

65. Gorloch and Wessel (2008).

66. alphaBeta (2017) p. 13

67. See McKinsey (2017) p, 13

68. Executive Office of the President (2016) "Artificial Intelligence, Automation, and the Economy, Washington 2016"

69. Frey, C and Osbourne, M (2017) "The Future of Employment; How Susceptible are jobs to Computerisation" Technological Forecasting and Social Change, 114 (1) 254-280.

70. Autor, D., Levy, F. and Murane, J. (2003) "The Skill Content of Recent Technological Change: An Empirical Exploration" Quarterly Journal of Economics, 118 (4), 1279–1333.

71. The Economist (2018) "Automation and anxiety' Special Report London.

72. Cited in Harvard Business Review April 17 2017.

73. There are some similarities in these estimates to those by Frey and Osbourne, for example the US, but significant differences over the UK (Frey and Osbourne estimate 63 per cent). They also place countries such as Ethiopia at very high risk (85 per cent).

74. Frey, C and Osbourne, M (2017).

75. For example the authors find the propensity for automation by 2030 in the OECD to average 15 per cent much lower than the estimates by both Frey and Osbourne (2013) or the Mckinsey Global Institute (2017) who use the occupation-based approach

76. Arntz, et.al 2016, p 2.

77. The Economist (2016) "Automation and Anxiety; will smart machines cause mass unemployment?", 25th June, https://www.economist.com/special-report/2016/06/25/automation-and-anxiety

78. McKinsey Global Institute (2017) "Jobs Lost, Jobs Gained; Workforce Transitions in a Time of Automation"

79. Price Waterhouse Coopers (2016) "People, Change and Robots" https://www.pwc.com.au/pdf/robotic-process-automation-people-change-and-robots.pdf

80. Fishman, C. (2004) (not 2003) "The Toll of a New Machine" FastWorks, January 5th https://www.fastcompany.com/49359/toll-new-machine

81. Cited in The Economist, 15th June 2011

82. Price Waterhouse Coopers (2016)

83. Best sources include, The International Federation of Robotics(2017) , World Robotics, BankWest-Curtain Economics Centre (2018) "Future of Work in Australia; Preparing For Tomorrows' World and the Australian Bureau of Statistics

84. See International Federation of Robotics (2017).

85. See, Elfes (2013) "Why Australia Needs the next generation of Robots" The Conversation February 2013

86. Market Report(2017) – "The Rise of Industrial Robots" http://www.auspack.com.au/market-report-rise-industrial-robots"

87. Cited in Market Report (2017).

88. BankWest-Curtain Economics (2018): The Future of Work in Australia" p.62

89. Data gathered from Australian Bureau of Statistics (2016), "Business Use of Information Technology", and ABS Cat No. 8190.0.

90. Digital Journal (2018) "Automating Agriculture with Lightweight Robots" http://www.digitaljournal.com/tech-and-science/technology

91. Bradbury (2017) - cited in "Robots at AUSPACK 2017" Food and Beverage industry News February 6, p2.

92. See CATCH Project for automated picking of cucumbers for an example of smart picking in practice.

93. Baggeley, k (2018) Robots are replacing Humans in Mining, MACH Dec 21 2017

94. See. "Nine tasks that Robots can do that might surprise you: The Smithsonian https://www.smithsonianmag.com/innovation/nine-t

95. Science and Technology (2017) "Robots and Mobility" https://scienceandtechnology.jpl.nasa.gov/research/research-topics-list/spacecraft-technologies/mobility-robotics

96. Frameworks worn by workers to provide mobility and lifting assistance

97. See, "Employment, Growth and Unemployment Queensland and Australia 1978-1979 to 2016-2017, http://www.qgso.qld.gov.au/products/tables/employment-growth-unemployment-qld/index.php

98. Price Waterhouse Coopers (2016) People, Change and Robots" https://www.pwc.com.au/pdf/robotic-process-automation-people-change-and-robots.pdf.

99. Adner, R. and Kapoor, R (2016) "Right Tech, Wrong Time": Harvard Business Review, November 2016, p1

100. Ibid, p.2.

101. Gorloch, I, and Wessel, O., (2008) "Optimal Level of Automation in the Automotive industry" Engineering Letters 16 (1) 1, 21.

102. See for example Prettner, K (2016). "The implications of automation for economic growth and the labor share of income," ECON WPS - Vienna University of Technology Working Papers in Economic Theory and Policy 04/2016 and Rotman, D (2017) " The Relentless Pace of Automation, MIT Technology Review, February

103. The productivity boost is a constant theme, see, McKinsey Global Institute. (2017). A Future That Works Automation, Employment and Productivity. and alphaBeta (2017) "The Automation Advantage"

104. Cited in McSweeney, K.(2017) " Industrial Robots are good for the Economy" Robotics, March p, 1

105. Frontier Economics (2016). 2016. "Why Artificial Intelligence Is the Future of Growth" cited in. https://www.accenture.com/.../Accenture-Why-AI-is-the-Future-of-Growth.PDFla=enAccenture

106. McKinsey Global Institute. (2017)." A Future That Works Automation, Employment and Productivity"

107. alphaBeta (2017) " The Automation Advantage " http://www.alphabeta.com/wp-content/uploads/2017/08/The-Automation-Advantage.pdf

108. Boston Consulting Group. 2015. The Robotics Revolution

109. Although it is possible to change technical relationships

110. See, Keay, S. "Why is Brisbane becoming Australia's Robotics Hub?" http://www.choosebrisbane.com.au/invest/the-brisbane-report/articles/brisbane-robotics-hub-sue-keay?sc_lang=en-au

111. See http://www.qgso.qld.gov.au/products/tables/economic-growth-qld-rest-aust-aust/index.php

112. Queensland Government (2018), Queensland Budget Paper No 2

113. For example, the McKinsey estimates of the job replacing potential of automation, by industry, are approximately double those of Price Waterhouse Coopers (2015) and larger than those cited in The Economist (2017)

114. These IA employment impacts in a non-linear (marginal coefficients model) are also on the conservative side, A feature of these models is their reduced employment aspects in comparison to traditional models.

115. Assuming underlying growth rate of 2.15 per cent + automation effect

116. Proportionate growth without job displacement

117. Estimated using McKinsey (2017) potential for job displacement data

118. Difference between baseline GSP and previous decade job growth and GSP and job growth over scenario 1 in table

119. 10 per cent decline based on current price elasticities, especially in coal, would not be unrealistic but this depends upon the take-up rate of automation in competing countries.

120. Approximately 5 per cent but subject to the same caveats listed in footnote 7

121. Adner, R and Kapoor, R. (2016) "Right Tech Wrong Time" Harvard Business review November 2016, https://hbr.org/2016/11/right-tech-wrong-time

122. Tunney, M (2016) "Innovation in Small Business" Dublin City Local Enterprise Office

123. See, "Canadian SRED Tax Credits" http://technology-tax-credits.com/sred-in-canada/

124. See "Mapping Canada's Industrial Automation Industry" http://www.digcompass.ca/intelligent-industrialization-the-next-wave/mapping-canadas-industrial-automation-industry/

125. See, OECD (2015) PISA Key 2015 findings for Australia, http://www.oecd.org/australia/pisa-2015-australia.htm

126. Quotes by Thorpe and Hillard cited in O'Neil, M. (2017) "Artificial and Automation are Coming so what are we all going to do for work?, ABC On-Line August 10 2017

127. See, Queensland Statistician's Office 2017 http://www.qgso.qld.gov.au/products/tables/employment-growth-unemployment-qld/index.php

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