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The Impact of AI on the Future of Work and Workers

A discussion paper prepared by the Australian Institute of Machine Learning, University of Adelaide.

Summary

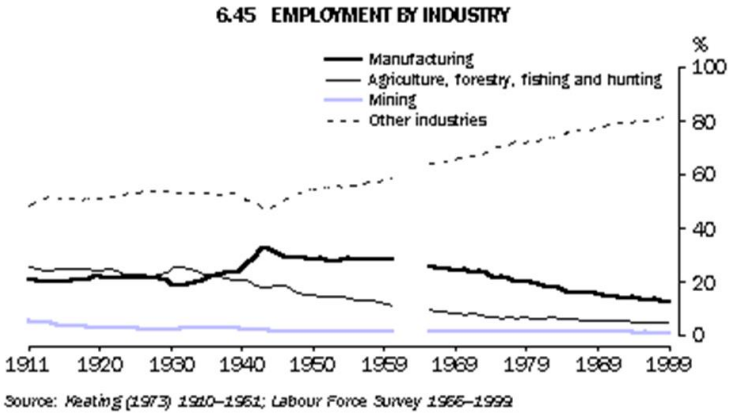
- The automation of work has been an ongoing process since the 1800s.
- Automation creates economic advantage, lowers the prices of goods and services, reduces the number of people in some occupations and allows for the creation of new jobs in new occupations.
- Labour tends to maintain its share of the economy in the long run despite automation, but requires investment in education and reskilling to ensure a smooth social and economic transition.
- Those countries who invest in research and development to take advantage of new waves of automation create global economic advantage for their industries which increases the wealth of those populations.
- Artificial intelligence is the automation of tasks normally requiring human intelligence.
- Artificial intelligence is the subject of much, and sometimes fantastical, speculation. But when companies who have adopted AI are surveyed, they report that AI delivers improvements in sales and efficiency, and results in new jobs and new roles within companies. This is just like all previous waves of automation.
- Artificial Intelligence is here, now, and will impact upon Australian jobs whatever Australia does. The question is whether we drive the process, or are driven.
- Artificial intelligence will be as disruptive and as beneficial as previous waves of automation: the steam engine, internal combustion engine, computers and the internet.
- Artificial intelligence has reached a global tipping point and we need to plan for it.
- It is clear that those companies and countries who invest in skills development and technical competence in AI will benefit. Those who don't may fall victim to it.
- Australia urgently needs a formal, national strategy for Artificial Intelligence to ensure that we are net beneficiaries and not simply powerless recipients of this exciting and disruptive new technology.

A brief history of automation

Automation has been increasing since the industrial revolution, starting with the steam engine, then increasing with the internal combustion engine, computers, internet and smart phones. At each step, human labour has been replaced with machines.

This increasing automation has reduced the need for some occupations. In the early 1900s, 25% of Australian workers were employed in agriculture. The proportion of people producing food has since fallen from the vast majority of workers to a few percent (Figure 1). With the advent of the steam engine, all cloth weavers became redundant. With the advent of the internal combustion engine and the motor vehicle, there was a huge loss of jobs related to maintenance and handling of horses.

Figure 1 Employment by industry from 1911 to 1999

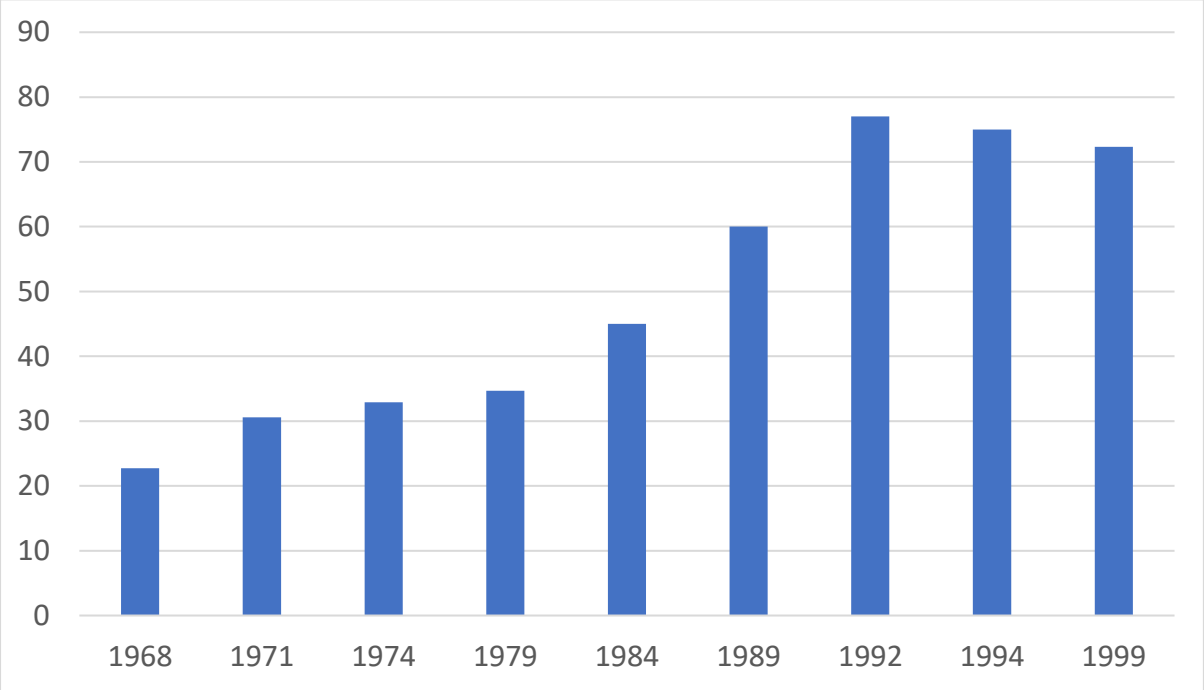


The way advanced economies have adapted to automation and these loss of occupations has been through:

1) reskilling and education of workers, and
2) investment in research and development to develop the technical skills and knowledge required to create competitive products and services around new automation technologies.

By giving workers new skills, new occupations have become possible and desirable. The proportion of the population who complete high school has increased from a quarter of the population in 1968 to three quarters of the population today.

Figure 2. Retention to Year 12 in Australia (Australian Bureau of Statistics)



Student enrolment in higher education has had a similarly dramatic increase. People and companies are creating new types of work and workers all of the time, as new skills and technologies create opportunities for the delivery of new products and services.

Over this period of increasing automation, unemployment has moved up and down, but has not been correlated with the huge increase in automation of work. But the productivity of workers, their corresponding income and the broader gross domestic product has risen sharply over the same period.

Figure 3 Changing unemployment rate in Australia over time

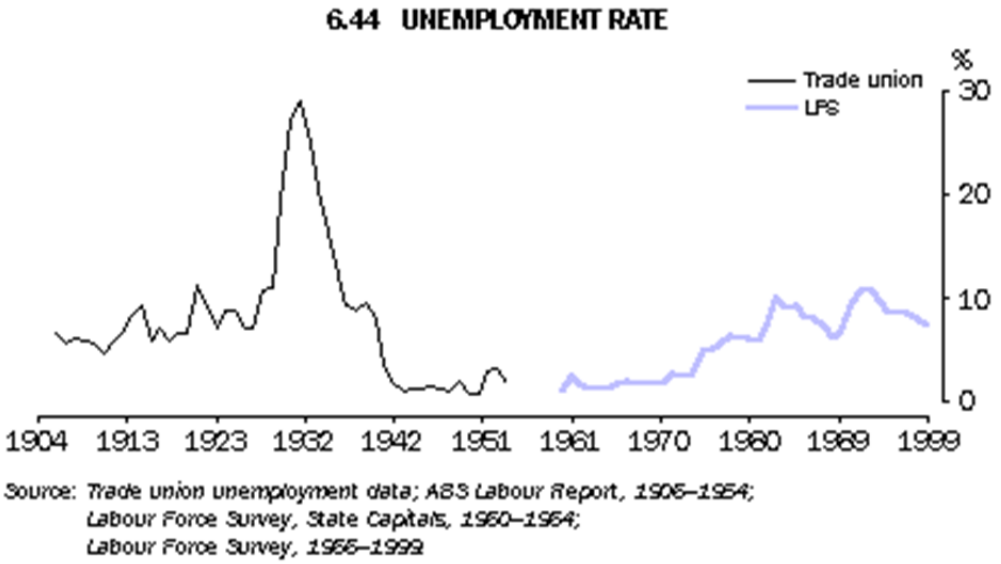
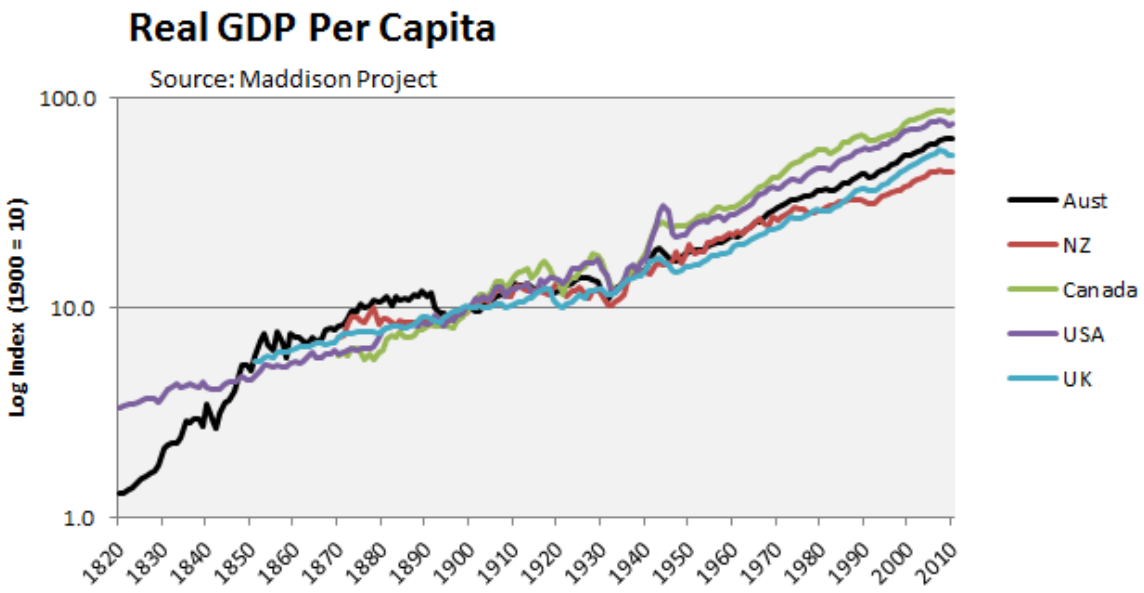


Figure 4 Real GDP per capita since 1820 (log scale)



How are we getting richer if machines keep taking over our jobs?

Economic theory suggests that as more sectors of the economy are automated, their relative price declines, and their subsequent share of GDP also declines (Aghion et al., 2017). For example, the relative cost of food has fallen significantly as farmers became more efficient through automation, plant breeding and nutritional management (Note: while the price of foods has declined, the net income of farmers has increased enormously over the last 100 years).

Those sectors of the economy that are dependent on people maintain a relatively high share of the economy as the price of more automated goods and services drops (known as the Baumol effect). For example, while the cost of food has dropped, the cost of installing an electrical powerpoint seems to be very costly compared to other services we can buy today. That is because there has been very little improvement in the automation of powerpoint installation over the last 50 years.

While automation reduces the need for some occupations, it create the need for new ones, which are often higher paid. Since the 1980s, spreadsheet software has automated many of the tasks previously done by traditional book-keepers, accounting clerks and auditing clerks. The number of these jobs in the USA has declined by 44%. But this technology has allowed new value to be created and driven an increase in the number of accountants and auditors (+41%). The number of management analysts and financial manager jobs has increased four fold (Capgemini, 2018).

The car industry uses the largest number of industrial robots in the world. But there was little correlation between automation and the change in labour share in the car industry between 2004 and 2014 (Aghion et al., 2017). In some countries, capital share increased (US) and in others labour share increased (Italy) even as robots and automation were adopted. Individual occupations were lost but new ones were created. The relative price of cars has fallen, and those companies and countries who embraced automation achieved global competitive advantage. Those who did not lost market share because they could not compete on price and quality.

The role of Research and Development

Advanced economies have invested in research and development to take advantage of new waves of automation. The technical skills and knowledge that are learned through this research gives these countries an edge of their international competitors. The more technical capabilities it can create, the more it is capable of putting together complex ideas and technologies to create higher value, complex goods (Hausmann, 2010). It is no coincidence that those countries with the highest investment in R&D have some of the highest GDP per capita.

Some countries have focussed their R&D investment in particular sectors to gain global competitive advantage for their workers. Some examples include:

- The dependence of Silicon Valley technology companies on Stanford University to produce high quality students and technological break-throughs. This creates a self-perpetuating cycle where the best in the world want to work at Stanford and in Silicon Valley.
- The Netherlands is the second biggest food exporter by value in the world. It has been able to achieve this through investing in research into automated, under-cover food production through Wageningen University which now attracts the best companies and people in the Netherlands, who create technologies that are exported to the world.
- Ben Gurion University in Beersheba, Israel has a research focus on cybersecurity which has attracted companies such as EMC, Deutsche Telekom, PayPal, Oracle, IBM and Lockheed Martin and resulted in new local start-ups in this sector.
- The Melbourne Biomedical Precinct is made up of 30 hospitals, research, teaching and biotechnology organisations. It attracts most of Australia's biomedical research funds and has 53% of ASX listed life science companies based in that city.

Artificial Intelligence: a major new wave of automation

Artificial intelligence enables the automation of tasks that would normally require human intelligence. Some examples of the use of artificial intelligence include:

- Being able to translate human spoken language into a set of instructions (Siri is an example)
- Computer vision and object tracking from video, enabling driverless cars for example
- Deep analysis of large datasets to find patterns and relationships (e.g. predicting the stock market)
- Control of robotics in manufacturing
- Chatbots, which unfortunately still don't work very well in 2018!

Currently, artificial intelligence uses mathematical tools and huge amounts of computer power to learn how to become really good at a single task. This makes artificial intelligence very powerful for undertaking a defined task, but helpless at learning tasks on its own. Research at the Australian Institute for Machine Learning aims to develop the next generation of AI which will be able to learn how to learn. This will make machines much more useful and powerful at augmenting our own learned capabilities, and will make us all even more productive – leading to greater wealth. The Baumol effect will tend towards maintaining labour's share of GDP regardless, but this may be dependent on corresponding investments in education and research and the structure of the labour market.

AI has reach a tipping point

The development of powerful mathematical tools and the increase in computer power has combined to make AI economically useful for a wide range of tasks. AI has now reached a tipping point.

- Global spending on AI will increase from $12 billion in 2017 to $56 billion in 2021 (Deloittes, 2018).
- The number of machine learning chips in data centres that power artificial intelligence is going to increase from 200,000 in 2016 to 800,000 in 2018
- The number of machine learning pilots and implementations will double from 2017 to 2018 and double again from 2018 to 2020.

What we see today is only the beginning of AI's capabilities, and the speed of innovation and transformation of the global economy is only going to accelerate.

What AI means for work and workers in Australia

AI has the potential to increase Australia's productivity by ~40 per cent (PWC, 2017). The impact on productivity will be competitively transformative – businesses that fail to adapt and adopt will quickly find themselves uncompetitive.

Yet currently two thirds of Australian organisations are having difficulties in finding suitable staff to lead AI technology integration and 75% of IT decision makers felt that the executive team in their organization needs formal training on the implications of AI technologies (Leadership in the Age of AI – Infosys 2018)

An Artificial Intelligence (AI) capability for the Australian economy is essential to leverage current investments, maintain our high quality of life, and create an AI-enabled economy – a compelling ecosystem of high-tech businesses and highly productive workers in both private and public sectors.

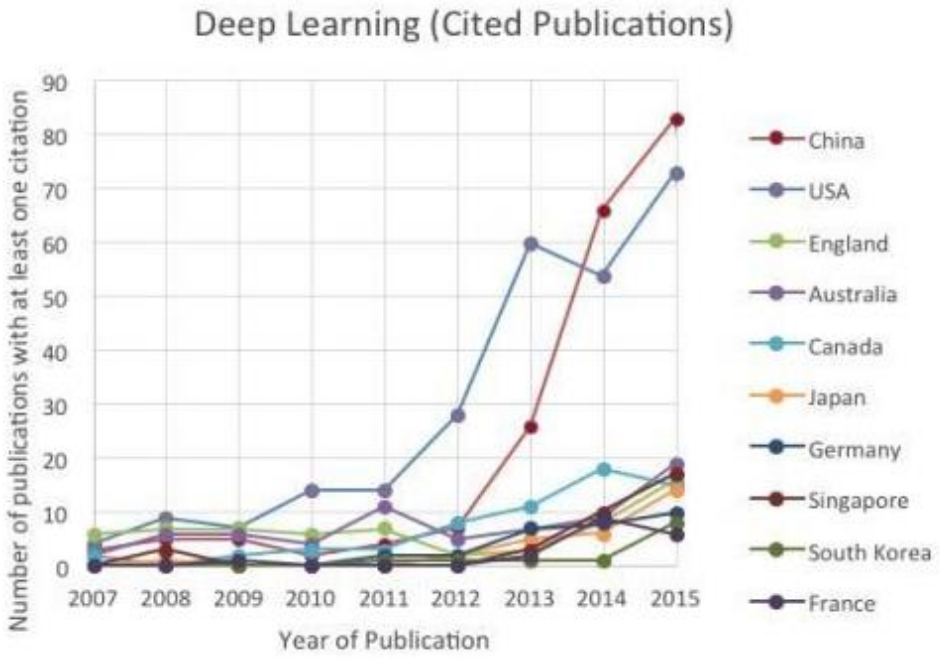
AI is already changing the global economy, the question is whether Australia will participate in the resulting opportunities. Competitiveness in this sector is not achieved by driving salaries lower, but is rather based on quality of life considerations. Australia is peculiarly well placed to capitalise, but needs to do so quickly as other countries are investing heavily.

As AI-driven automation lowers the cost of production, Australia could once again become competitive in manufacturing goods that are currently produced cheaply elsewhere because of low wages in other countries. But we will need to encourage investment in new-generation automation to take advantage of this new trade opportunity, and ensure we have the education, training and research in place to capitalise.

AI has a particular role to play in our defence sector. In the last few decades, a major source of funding for AI research has been the Defense Advanced Research Project Agency (DARPA), which is agency of the Department of Defense of the United States of America responsible for the development of new technologies for use by the military (The Hague Centre for Strategic Studies, 2017). There is an emerging arms race in artificial intelligence for military applications (Cummings, 2017), but the defence sector is struggling to match the salaries of the commercial sector.

There is a large and growing national market for AI-based combat services and cyber-security applications that are particularly suited to smaller countries such as Australia who cannot leverage off domestic aerospace and large manufacturing industries. We have the potential to compete and become suppliers to the global defence market in AI-applications because we are so strong in AI related research expertise. Australia is only behind China and the United States in the levels of cited research in 'deep learning' (Figure 1). We have an immediate opportunity to take advantage of this world-leading technical expertise to protect Australia's national interest and underpin rapid growth in jobs and prosperity in the defence sector over the next decades.

Figure 1. Journal articles mentioning "deep learning or "deep neural networks", by nation



US Office of Science and Technology Policy/ White House.

What about the predictions of rising income inequality and mass unemployment?

Recent IMF reports have modelled the impacts of the greater integration of robots and AI in to the economy (IMF 2018 a,b). These model outputs predict income inequality and mass unemployment as a result of adoption of AI and robotics. The models that they used to make their prediction assumes that robots become an almost perfect substitute for human labour. In one of these papers, they describe robots as "the sort featured in the Hollywood movie Terminator 2: Judgement Day—such perfect substitutes for humans that they are indistinguishable." This is not reflective of the capabilities of AI and robots in the foreseeable future. Both are still very limited in what they can do. They take a lot of time to train to do a simple task, and this is expensive because AI programmers are expensive to hire. The capacity of AI and robots will continue to improve rapidly, but it is still hard to see a time in our lifetimes when they will be as skilled at humans in all of the capabilities that we currently have.

In one of the papers, the authors admit themselves that "in real life, many jobs do seem safe, at least for now."

There are more technical arguments as to why these papers produce unrealistic conclusions including that they have assumed a constant elasticity of substitution between all factors, including capital/labour and robot-capital/labour. This is obviously nonsense given that automation will have a stronger ability to replace some functions than others. In fairness to the authors, trying to model a more realistic set of circumstances would be incredibly complex and we don't have the data to inform the assumptions.

Based on the simplified models and assumptions in the IMF papers, occupations that can be replaced by AI and robots will be vulnerable. This has been true for the last 200 years of technological innovation and is hardly a surprise. There is not much call for typists anymore. Nor horse husbandry. These jobs have been taken over by machines. No doubt AI will substantially replace some occupations. But we have also learned from history that despite ever increasing automation from machines such as engines and computers, the total amount of employment has increased and average wealth has increased remarkably. The capacity of countries to adapt to greater automation has required retraining and investment in education and research on a mass scale so as to build the capacity of the workforce to make best use of the new technologies developed. During periods of

significant economic restructuring, there can be very high rates of unemployment (such as in the UK in the 1980s when there was unemployment of skilled people such as shipyard workers whose skills are no longer required). The critical question becomes not about whether robots and machine learning should improve productivity, but how we deal with weakly skilled workers who are no longer in demand. Society needs to plan for such restructuring and make investments to ensure workers can adapt to a workplace that includes AI. Professionals, trades and labourers will need to become adept at using AI tools to augment their abilities. Those who learn these skills - we think will thrive. Those who don't may find it increasingly difficult to sell their labour. The time to start this planning is right now.

It is interesting to note that the authors argued in one of these papers that we currently have the opposite problem to runaway productivity growth as a result of automation. "Productivity growth has in fact been low in recent years - leading to low wage growth. And technology does not seem to be the culprit for the rise in inequality in many countries" (IMF 2018a). This suggests that finding ways to increase worker productivity is one pathway to improving wage growth.

We believe that AI is just another step along the road towards the greater automation of work, and the solutions of the past will be just as effective in the future. Given that AI is a qualitatively new type of technology that does have the capacity to disrupt existing occupations, we would argue that all countries need to develop their own national strategy for AI technology to ensure that their populations and economies benefit. Countries like the USA, China, UK, India and Canada have all developed such a strategy (Appendix A). Such a strategy should include mass investment into education and research, policies to protect people from the malicious use of AI technology, and policies to maximise the benefits that can be achieved from this new and powerful technology. Integrating AI into our current workplaces can lead to benefits that include better detection of disease, more productive agriculture, and more effective crime fighting (as just some examples). We should remain optimistic that we can do so without large-scale social disruption, as long as we also invest as a society in the policies, education and research to underpin the adoption of this exciting new technology.

A National AI Strategy for Australia

We propose that it is a matter of urgency that a National AI Strategy is developed by a Panel of Experts for Australia to build on our existing expertise and provide the impetus to successfully transition Australia to an AI-enabled, 21st Century economy. In our view, such a strategy should at least include the following elements.

- **Upskill Australian workers.** Since the beginning of the industrial revolution, occupations have been lost to automation. The workplace of 2018 looks vastly different to that of 1968 or 1918. As some occupations have declined, others have expanded. Education and skills training has been key to adapting the workforce to increasing automation. We need to proactively upskill workers of the future through 1) education and training in STEM subjects at school level; and 2) machine learning and its application to artificial intelligence at a sub-degree, degree and post-graduate level, with pathways built to existing VET and Foundation courses.
- **Policy development** to ensure safe and effective adoption of AI-systems in the broader economy. All areas of government policy, including health, defence, social security, education, national security, transport, trade, etc., need to consider the implications of AI for their portfolio.
- **Support Australian government agencies** to cost-effectively adopt AI to lower costs and improve service delivery, putting them at the forefront of public service adoption of this new technology globally.
- **Up-scale investment in research and development** in machine learning. This underpins all other areas of the strategy. Without a globally competitive research sector, Australia is unlikely to be able to create and control our own products, and will need to import the expertise and programs of other countries. It is the students and engineers who are trained in research labs who power innovative new product development and lead the adoption of AI in the broader economy.
- **Development of ethical AI systems** that are programmed to achieve outcomes consistent with human values that are agreed to by the broader community up-front. The development of such systems need to

be done carefully to ensure that the overhead costs on innovation do not become onerous, especially when compared to other countries.

- **A focus on the development of AI in cyber-security and combat systems for Australia** is a matter of national importance and will be a critical component of an effective national strategy. There are related commercial opportunities for Australian business to leverage our research expertise to build a globally competitive AI-defence industry sector.
- **Support for Australian businesses** to develop new products based on AI and connect them to global distribution channels to achieve rapid commercial success, creating jobs and prosperity for Australians and transforming Australia into a truly 21st century economy. This could be a standalone program, or a particular focus of existing industry support programs.

To maintain a technical capability in Australia that can support home-grown innovations and respond intelligently to international trends, we recommend a major Australian Government investment into a National Artificial Intelligence Research Network, with responsibility for bringing together the leading research groups into Australia under one umbrella to create the critical mass required to build internationally competitive research expertise. The Network will also:

- coordinate a national teaching and learning program across the partner universities
- support government in policy development and adoption of AI
- develop ethical AI policies and protocols
- provide a one-stop-shop for Australian businesses with an interest in developing AI products for their own businesses and for export
- Work closely with defence and security organisations to ensure the safe use of AI in Australian security and combat systems.

What is in it for Australia?

AI will drive enormous budget savings in health, education, national security, infrastructure and government administration, improving outcomes and allowing sustainable improvements in the budget position and a lowering of taxes.

It will give our workers, companies and government a global competitive advantage in being able to adapt to a world powered by Artificial Intelligence.

It will attract the world's best and brightest to come and work and study here in Australia, lifting the prosperity of all Australians. Inbound students are a significant export for Australia, and world-class education in artificial intelligence and machine learning is going to be in high demand globally, and we have a chance to be seen as one of the 'go to' destinations.

The National Artificial Intelligence Research Network would identify Australia as an international leader in artificial intelligence research and innovation. The Network would promote the adoption of AI in government, industry and education and would be a resource for all of these sectors to draw upon.

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This Discussion Paper was prepared by the Australian Institute of Machine Learning (AIML) at the University of Adelaide. The University has world leading research expertise in Machine Learning and Artificial Intelligence. Despite substantially greater investment in the US, China and Europe, AIML has grown to be one of the best Artificial Intelligence and Machine Learning research groups, built by a critical mass of high-quality research with 70 members and growing.

The AIML Artificial Intelligence Machine Learning team are global leaders. They are world-leading in many areas:

- pedestrian detection (crucial for driverless cars),
- 3D from 2D (used in Augmented Reality etc.),
- semantic segmentation (driverless cars),
- Tracking ReID (video surveillance),
- overhead image classification (agriculture, defence),
- faces in the wild (defence);

They are top four in global competitions and research:

- Ranked in the top 2 computer vision groups in the world by publications (see CSRankings.org, a metrics-based computer science research ranking system).
- Led the team to win the hotly contested international Facebook's Visual Question Answering 2.0 Challenge 2017– currently VQA is the cutting edge of AI.
- Topped the CityScapes leaderboard again in 2017 - a Scene Parsing benchmark designed to test driverless car technology.
- Came second in the ImageNet Scene Parsing Challenge in 2016, beating Oxford, Samsung, Shanghai Jiao Tong, KAIST, The Chinese Academy of Sciences, Penn. State, and many more

AIML is a remarkable South Australian success story with a strong track record of high-tech development for industry

- spinning out two start-ups and supporting local SA companies Maptek, Sydac, Signostics and LBT Innovations (SA Science Excellence Award in 2017 for industry collaboration) and
- partnering with international companies such as Microsoft, Facebook, BHP Billiton, Google, Bayer, Samsung, BAE Systems and Canon.

The AIML are offering to work with the Australian Government and key researchers around Australia to develop a national Strategy in AI and design and establish an National Artificial Intelligence Research Network. We have strong and positive relationships in the research and education community in Australia and overseas, and also with businesses who have an interest in the adoption of Artificial Intelligence into their businesses.

We believe that AI can represent a great challenge, or a great opportunity for Australia. Capturing the opportunity will require a concerted response.

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Appendix A. Global AI Strategies

Because of the potential to transform economies and create global economic advantage, the United States, China, Canada, UK and India have all adopted a national strategy to fast-track the development of an AI-enabled economy.

United States

The United States launched two strategic documents related to Artificial Intelligence in 2016.

1) The **Preparing for the Future of Artificial Intelligence** report made 22 recommendations related to government policy, including:

- encouraging adoption of AI inside government,
- encouraging safe integration of autonomous vehicles,
- prioritisation of long term research,
- ensuring an AI literate workforce
- safe adoption of AI-systems in the broader economy
- international relations
- cyber-security and use of AI in combat.

2) the **National Artificial Intelligence Research and Development Strategic Plan** has a focus on research areas that industry is unlikely to address. The intention of the US Strategic Plan is to produce new AI knowledge and technologies that provide a range of positive benefits to society, while minimizing the negative impacts. The Strategic Plan includes seven strategies and 2 recommendations

Strategy 1: Make long-term investments in AI research.

Strategy 2: Develop effective methods for human-AI collaboration.

Strategy 3: Understand and address the ethical, legal, and societal implications of AI.

Strategy 4: Ensure the safety and security of AI systems.

Strategy 5: Develop shared public datasets and environments for AI training and testing.

Strategy 6: Measure and evaluate AI technologies through standards and benchmarks.

Strategy 7: Better understand the national AI R&D workforce needs.

The plans call for a significant increase in investment in AI and a consideration of the wide-ranging impact that AI is likely to have on all areas of the economy and government services.

China

China has launched a major new AI strategy in 2017 with the aim to become the global leader in artificial intelligence by 2030. The key principles of its strategy are:

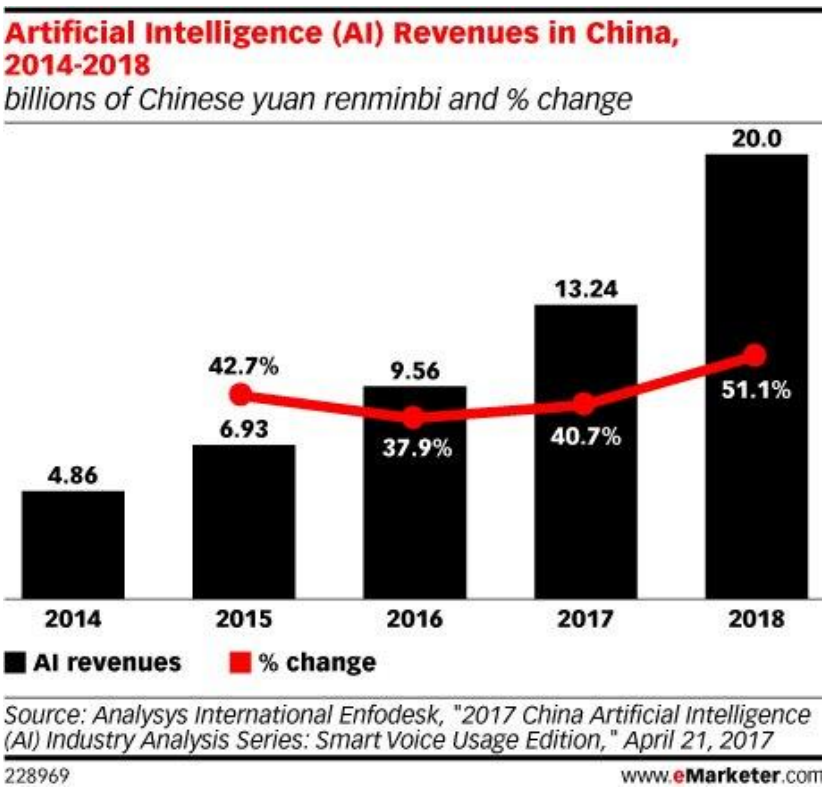
- Take the lead in AI research and development
- Use the power of the Chinese government to promote local technology
- Accelerate the commercialisation of AI technology applications
- Advocate open source data management
- Encourage cross-sector sharing of information between military and civilian sectors

The key tasks that the Chinese Government will undertake are:

1. Build an open and collaborative artificial intelligence technology innovation system
2. Become proficient in all of the systems that underpin artificial intelligence, both software and hardware
3. Accelerate training in AI
4. Invest in AI innovation pilots including a National Artificial Intelligence Industrial Park.
5. Ensure a safe and efficient information infrastructure for data transfer
6. Invest in major science and technology projects.

China has already applied for over 15,000 patents in AI. Revenues are growing rapidly and the new national strategy will invest billions of dollars into AI research and development.

Figure 2 Artificial intelligence revenues in China 2014 - 2018



United Kingdom

The UK government's Industrial Strategy Challenge Fund will bring researchers and businesses to work together to tackle major industrial challenges: Robotics, AI, electric vehicles, aerospace materials, and satellites.

- £93m will be made available for AI and robotic systems that can be used in extreme environments for offshore energy, space, and deep mining, and £38m for AI and control systems for driverless cars.
- £42m is for fundamental research.

Canada

The Canadian Government initially invested $125 million into a Pan-Canadian Artificial Intelligence Strategy. The funding will go into research to support Canada becoming the world leader in artificial intelligence. Components of this strategy are:

- research grants designed to stop a ‘brain drain’ and ensure that top computing talent and academics remain in the country,

- nurture post-graduate trainees and researchers who wish to study artificial intelligence.
- bring together Canada's main centres of computer expertise.

It recently also announced an investment of $200M into a national AI research facility – the Vector Institute – to drive excellence and leadership in Canada's knowledge, creation, and use of artificial intelligence (AI) to foster economic growth and improve the lives of Canadians.

India

The Indian Government recently released a report from the AI Task Force that outlines the key challenges for India in integrating AI into its economy and society and made the following recommendations:

- Investment into awareness raising, research and support for entrepreneurship
- Establishing large databanks of data
- Set operation standards for AI
- Develop enabling policies
- Develop and implement an AI education policy and reskilling strategy
- Shape international rule-setting
- Establish bilateral cooperation with other countries.

Global Corporations

Technology giants spent between $20B and $30B on AI in 2016, with 90% spent on R&D and deployment and 10% of AI acquisitions. 66% of these funds were spent in the US, and 17% in China, but China's investment is growing faster.

IBM will invest US$240 million over 10 years in a partnership with Massachusetts Institute of Technology (MIT) to create an artificial intelligence (AI) laboratory, aiming to conduct advanced research and explore the implications of the technology on industries such as health care and cybersecurity as well as on society (IBM blog).

Google launched is AI-first strategy in 2016, appointing a new research group dedicated to machine learning. Currently AI drives the search algorithm, the Google Translate function, the smartphone assistant and for self-driving cars (for example).

Apple uses machine learning in virtually all its new products. The Siri watch face customizes content in real time — including everything from traffic information and news to smart home controls and anything else the virtual assistant thinks might be relevant. Apple has recently announced a set of new machine learning tools and APIs created by Apple for iOS 11, called Core ML.

Amazon acquired Kiva, a robotics company that automates picking and packing reducing "Click to ship" cycle time, which ranged from 60 to 75 minutes with humans, fell to 15 minutes with Kiva, while inventory capacity increased by 50%. Operating costs fell an estimated 20%, giving a return of close to 40% on the original investment

Uber uses artificial intelligence to figure out how much customers are willing to pay for their journey

Salesforce Einstein allows businesses that use Salesforce's CRM software to analyse every aspect of a customer's relationship – from initial contact to ongoing engagement touch points – to build much more detailed profiles of customers and identify crucial moments in the sales process.

If Australia is to transform into a fast-growing, prosperous, economy and keep pace with the technology-advancement that other countries have committed to, we must be nimble, inventive and exceptionally capable in the adoption of Artificial Intelligence.