Technology and Australia's Future – a summary

Australia's past has been substantially shaped by technologies both old and new. Australia's *future* will also be substantially shaped by new technologies. The report *Technology and Australia's Future,*[1] which is summarised here, looked at such new technologies from a broad perspective and offered a range of actions that Australia can take to improve its future through the development, adoption and use of new technologies.

Technology is central to human existence and is of great importance to Australia both now and in the future. The history of technology and the history of human development are deeply entwined. Human beings have pursued technological opportunities in all of their activities – food production, comfort and safety, defence, transport, trade and commerce, information, media and communication, art and culture, health, sanitation, reproduction, manufacturing – everything. The study of technology development as an activity independent of the social and economic development of *Homo sapiens* would miss critical aspects of the evolution of technology and the impact it has on being human.

Technological *change* is a major driver of social change and the dominant source of economic growth. It encompasses the processes of invention, innovation and diffusion of technology. While often used, linear models of technological change (e.g. basic research leads to technological development which then leads to product commercialisation and diffusion), are rarely accurate. Technologies change through many feedback and feed-forward mechanisms. Interventions intended to enhance technological innovation are likely to be of little benefit if they are based on simplistic models. Technological change is comparable to biological evolution: it is unpredictable in detail, but there are general patterns that recur including dependence upon the particular historical path taken, multiple independent invention of a given technology, and the recombination of ideas (new technologies being new arrangements and combinations of older technologies). Technological change can be facilitated by enhancing the interoperability of technologies.

Old technologies continue to have a lasting influence through inertia and momentum, substantial parts of which are caused by those who derive benefit from current technologies resisting change that may lose them rents. Technology changes primarily through parts-assembly whereby existing components are combined together in new ways.

It is difficult to determine the impacts of technologies. A technology can cause many impacts and an impact can be caused by many technologies – directly, indirectly, individually or in combination. Impacts can depend upon social, cultural, geographical and historical context. Depending on context, technologies can produce results that are desirable or undesirable, and that change over time. Uses that are considered negative or threatening at one time may be considered beneficial at another. This tension is evident in the case of personal and national security, where the appropriate balance of privacy and surveillance remains contested.

---

[1] Robert C. Williamson, Michelle Nic Raghnaill, Kirsty Douglas and Dana Sanchez, *Technology and Australia's Future: New technologies and their role in Australia's security, cultural, democratic, social and economic systems*, Australian Council of Learned Academies, September 2015, URL.

Information and Communication Technologies (ICT) are the most general of general purpose technologies, and have very broad impact across Australia's social, cultural, democratic, security and economic systems. ICT platforms are valuable due to their generativity (their ability to enable and induce other changes), and facilitating this generativity can have a large positive effect. Data analytics is especially significant at present and can be expected to have large impacts across all areas of society.

Predicting future technologies and their impacts is uncertain. Within certain constraints and sufficiently short timescales, it is possible to predict narrow technological improvements, but one cannot accurately predict the long-term impact of a particular technology. There are however general patterns of change that are likely to recur as technologies develop. Acknowledging these patterns can help decision-makers plan for and adapt to change. Given the strengths and limits of prediction, it is valuable to identify the problems that need to be solved and allow technological innovators to find solutions, rather than attempting to forecast the impact of particular technologies.

Technologies can be understood in multiple ways. A technology is an object (a mobile phone), a component (the transistor in a mobile phone), a process (a production line), a service (electronic banking), a network (telecommunication towers), or all of these. Understanding the different levels of aggregation can help explain how technology changes. New technologies develop and are adapted from existing technological artefacts and processes. People can be unaware of the precursor technologies that create and inform new products and artefacts. The way a product or set of products is described can have implications for the way it is understood, evaluated and regulated.

Technologies mean different things to different people. Meanings, values and attitudes greatly influence the adoption of technologies. Personal experiences affect how technology is perceived, predicted and adopted. The way people think, feel and talk about technology makes a difference to how it is designed, evaluated and used. Therefore, decision-makers, policy developers, and innovators need to be aware of the plurality of beliefs about technology and how these might affect engagement with technology in Australia.

Technological literacy, creativity and skills are necessary in Australia for the successful adaptation, adoption and ongoing support of technologies developed elsewhere. In order for industries and businesses to remain competitive, they need the skills and know-how to adopt new technology as it becomes available and adapt their businesses. In addition, businesses need to have the capacity to adapt new technology to meet specific business needs, and to make adjustments and repairs to that technology as necessary. Australia's education systems must develop high levels of scientific and technological literacy, as well as inculcate creativity and a willingness to tinker, which can facilitate the 'learning by doing' that underpins technological change. This will encourage experimentation, giving people, communities and firms the confidence to innovate and adapt under conditions of change and uncertainty where failures will occur.

Australia has substantial opportunities to benefit from new and emerging technologies. The way Australians understand technology has profound implications for the development, uptake and use of technologies. Thus improving Australians' understanding of technology can have a substantial benefit.

There are no "good" or "bad" technologies. All technologies can be used for good or evil. All technologies have undesirable side effects. And all technologies affect different people differently, benefiting some and harming others. The benefits and costs can be hard to discern, and even harder to predict. Proponents of technologies (who stand to benefit from

them) often overstate the benefits and discount the costs. The costs are often harder to discern because of the delay in their effect.

There are many different levels of aggregation of technology, and confusing these levels can mislead. A given technology can be a system in its own right, or a component of a larger system. The most general level of aggregation is "General Purpose Technologies" such as steam power, electricity or Information and Communication Technology. These general purpose technologies, by their very generality, are easy to predict, but hard to be precise about.

General Purpose Technologies (old and new) will have substantial impact and are excellent foci for investment. Although one could not at the time have made precise predictions of *what* the impact of railways would be, one would have been able to say with certainty the impact would be large. Similarly, general purpose technologies that are gaining substantial prominence now (such as data analytics) are certain to have a large impact. They are subsequently a prime target for investment and training.

Specific labels given to technologies are fluid and changing and the more specific they are the less they should be relied upon in the formulation of policy. Technologies are not natural categories – such categories are imposed upon them. Some of the most impactful innovations occur at the boundaries and intersections of existing categories.

Technological progress and change is intrinsically uncertain, and policy interventions should reflect this by taking an explicitly experimental approach. Experimentation, plurality and rapid feedback cycles are better responses than ignoring the uncertainty intrinsic to technological change. The central feature of new technologies is that in their early incarnations they fail. Perfection takes much iteration, and technologists have developed robust processes to cope with such early failure. Policy interventions that are not designed to deal with failure will not be effective in such an environment; they typically deteriorate to blame-games. The mode of work of the practicing scientist or technologist offers the best guidance for how society more generally can deal with the inherent uncertainty of new technologies.

Early stage technology development is essential for long-term economic growth, but the economic returns of this are hard for the developer to appropriate. This widely accepted fact is why governments around the world continue to fund such early stage technological research and development. Such funding ultimately generates substantial returns to the country through indirect means (spillovers, including the movement of people trained in the latest technologies).

The choice of whether to adopt a technology depends critically on how it is evaluated, and especially the perception of its cost. There are well-known, but not universally adopted means, to improve the accuracy of technology evaluation, and the wider adoption of these methods could lead to substantially better decision making. Much assessment of technologies overestimates the benefits and underestimates the cost and underestimates the uncertainty in both (one of many cognitive biases prevalent in the evaluation if technologies). New technologies are often disadvantaged relative to incumbent technologies because the costs of the latter are merely taken for granted and not ascribed to the technology in question.

The impacts of technologies (whether new or existing) are remarkably difficult to discern and quantify. This difficulty is intrinsic because many technologies combine to have particular effects, and a given technology can contribute to many different effects. Nevertheless there remains a widespread belief that such effects are readily discernable

and predictable. In order to discern them better approaches to measurement and experimentation need to be adopted. Simplistic attributions of technological cause and effect should be always considered suspect.

Governments have a role to play in technological change. Given the underlying importance of technological progress to ensure Australia's future prosperity, governments clearly have an interest in facilitating technological change. Governments are inherently risk averse and find it difficult to deal with the unpredictability of new technologies, the risks of failure and the need for experimentation. Consequently, in most cases governments should avoid the temptation to become directly involved in the development of specific technologies by picking technology winners. One exception is where the economies of scale have led to governments becoming the monopoly provider or purchaser of a technology, such as in electricity, telecommunications or defence, or large-scale research infrastructure (on the scale of supercomputers or synchrotrons). In these few instances governments have to invest in particular technologies, which subsequently may have flow-on effects for other technologies and businesses.

Governments should play a facilitative role in technological change by creating an economy, a culture, and a society where new technology is encouraged through multiple experiments. Governments can:

- Invest in an educated and skilled population able to embrace and adapt to the opportunities that new technologies provide, through supporting STEM and ICT training from at all levels of education.
- Invest in a strong research and development base and require research institutions to be more open with the IP they generate.
- Rather than trying to pick technologies, seek solutions to problems that appreciate the inter-relationships between technology and humanity.
- Regulate the effects of the use of a technology rather than regulate the technology itself. Attempting to regulate a specific technology rather than its use is likely stifle technological progress, without tackling the underlying risks.
- Mitigate negative social impacts of technology; for example by regulation, by strengthening the social welfare safety net, through improved re-skilling, or by assisting with the transition to alternative employment opportunities.
- Require that technology evaluation is open, transparent and independent. Evaluation of new technologies should take a broad perspective and compare the new technologies to the whole-of-life benefits and costs of existing technologies.
- Facilitate interoperability; technologies, systems and organisations can encourage standards that allow the assembly of different parts. This "modularity" can encourage innovation and help to avoid the negative effects of technological lock-in.
- Implement mechanisms that allow for explicit, efficient and adaptive experiments and trials, which will help deal with uncertainty and unforeseen (and unforeseeable) impacts.

Technological change does not just happen – it arises from choices that are made. Societies, including Australia, have a choice. Resisting technological change is a common response, especially to those elements of society that are heavily vested (and invested) in older technologies. By embracing new technologies, and recognising the dynamic and fluid nature of technological change, Australia has the opportunity to choose a brighter future, one built upon adaptation, resilience, pluralistic approaches, and a recognition of the transformative power of modern general purpose technologies.

Ultimately Australia faces a simple choice in the presence of the ever-present power and promise of technological change: adapt or wither.

Findings from the main report

The following 18 findings are reproduced from the main report.

F1. Technological change is the major driver of long-term economic growth. In an environment of uncertainty, ongoing investment in the skills and organisational capacities that allow effective technology development, evaluation, adoption and adaptation will help solve social, economic and environmental challenges, leading to a prosperous and healthy future.

F2. Technology and humanity shape each other. To solve Australia's social challenges, government policies and programs should understand the interrelationships between technology and humanity – solutions to complex problems will never be solely technological.

F3. The way technology is categorised affects how it is imagined, evaluated, funded, adopted and used. Encouraging crossover between diverse areas and looking beyond narrow categories, sectors, and disciplines for inspiration will increase opportunities for technological innovation in Australia.

F4. Public policy is often based on assumptions of stability, predictability, and linear progress. Policies which take into account the dynamic and multidimensional nature of technology will encourage adoption rather than protecting and favouring the status quo, allowing Australians to make better decisions to prepare for, and capture benefit from, technological change. Australia's technological future is open, and not pre-determined.

F5. Predicting future technology and its impact with any accuracy is extremely difficult. Recognising that general patterns of technological change will persist can help governments, businesses and communities facilitate and adapt to change. Attention should be focused upon problems that need to be solved and on helping innovators find solutions.

F6. Technologies for data, especially data analytics, will play a substantial role in solving most social problems, and will augment and transform most existing technologies. In order to maximise the benefit of this technology, Australia needs to ensure it has the advanced skills and capabilities to create and use this technology.

F7. The value of a technology always depends upon context and use. Judging technologies as intrinsically beneficial or detrimental limits the opportunities to make the best use of them. To improve the design, assessment and effectiveness of technology or any technological intervention, consider the technology in its historical, cultural, geographical, political and social contexts.

F8. The adoption of any new technology in Australia will affect people differently. Costs and benefits of a technology should take into account the different impacts a technology will have on different sections of society.

F9. Meanings associated with technology are deeply tied to values, beliefs, experiences and cultural setting, and as a result vary enormously. The meanings people ascribe to a

technology substantially influence its adoption and use, and therefore cannot be ignored in any technological intervention.

F10. Attitudes towards technology do not always reflect behaviour. Effective government policy to encourage new technologies should reflect the different reasons people have for engaging with technology.

F11. Adaptability and creativity are key skills in creating, assimilating and adopting new technology. The adoption of new technology and its effective use depends on people with diverse skills playing a variety of roles. Enhancing technological literacy, including fostering skills appropriate to engaging with technology in all levels of education, can enhance Australia's ability to adopt and adapt new technologies. Promoting technology as a creative enterprise may serve to inspire a greater engagement with technology. Enhancing the tinkering aspect of STEM education at all levels (K-12, and tertiary) could create a culture that embraces technological change.

F12. Technology evaluation is of central importance to technology adoption. The costs of a technology are complex to determine, context-dependent, variable, and contested. Governments can facilitate better technology evaluation by adopting international best practice and by minimising the role vested interests play in technology evaluation.

F13. Cognitive biases play a major role in the evaluation of technologies, which in turn is a major determinant of adoption and use. The impacts of these biases can be substantially mitigated by adopting methods designed to counter them, including independent assessors, and readily available empirical data.

F14. The difficulty of appropriating economic returns from early stage technology research and development means that substantial ongoing government investment in research is warranted. Increased investment in high quality scientific and technological research will lead to greater commercial and economic outcomes for Australia. Such research should be focussed upon general purpose technologies, rather than particular technology winners. Having research institutions that are more willing to share their IP will create a more effective innovation system.

F15. Government policy and legislation should focus on the effects due to the use of new technology, or the effects arising from new uses of technology, rather than on the technology itself in order to minimise regulatory impediments.

F16. Interoperability allows the more rapid adoption of new technologies. Interoperability is facilitated by standards and gateway and platform technologies. Diffusion of technology in Australia can be aided by simple standards that lead to easier parts assembly. Adopting global standards will facilitate integration of a technology into global supply-chains.

F17. Accepting that failure can occur in any attempt to do something new and removing its stigma will facilitate and accelerate technology development and adoption. Training managers in business and government to acknowledge uncertainty, take risks, and deal constructively with failure will improve Australia's entrepreneurial and innovative culture.

F18. The uncertainty and unpredictability inherent in the development and adoption of technology require a considered experimental approach. The adoption of the scientific method of 'test-learn-adapt' can improve Australia's ability to develop, adapt and embrace new technologies.

The report elucidates the above findings, and provides detailed answers to the questions posed in the commissioning of the report. Furthermore it provides a detailed and evidence-based summary of what can be said about new technologies organised within 7 chapters:

1. **What technology is** and the approach taken in producing the report.
2. **How technology changes** – the speed of technological change, its evolution, technology as a parts-assembly process, technological momentum and inertia, 'disruptive' technologies and the intrinsic uncertainty of technology change.
3. **The prediction of new technologies** – why they are predicting, how it is done, how accurate it is, reframing technological prediction that the rational envisioning of the technological future.
4. **The impacts of technology** – how can one understand impacts in an environment of complexity and interdependence, differential impacts, the anticipation of and reaction to impacts.
5. **Meanings, attitudes and behaviour –** the significance of meaning for the adoption of technology, how technology defines people's identity, attitudes to technology, the way people interact with technology and why technological meanings matter.
6. **The evaluation of technology** – how technologies are evaluated, their failings, and how such evaluation can be improved and how this can lead to better technological choices.
7. **Interventions** that can be made in response to the challenges posed by new technologies – how their quality can be improved, the importance of creativity in using technology, educational interventions, the significance of failure and attitudes to failure, how an avowed experimental approach can aid in the adaptation to new technologies, the importance of technological interoperability, how technologies are regulated, and the importance of government investment in technological research and development.

Additionally there are detailed case studies that examine particular aspects of new technology, as well as an extensive tabulation of the impacts of old and new technologies.

Robert C. Williamson FAA
Australian National University and Data61
Bob.williamson@anu.edu.au

4th September 2015

Politician's summary of the report (1 page long)

Technology has had, and will continue to have, an enormous influence on Australia. New technologies will largely shape Australia's future. Technologies are diverse, complex and embedded in society, and understanding their impact is complex. The report *Technology and Australia's Future* considered new technologies, their predictability, impacts, and meaning to people, and made many findings relevant to how governments can make better technological choices. The seven chapters of the report are summarised below.

1. Technology is complex and difficult to categorise, and above all dependent heavily on its past. In order to peer into its future, one needs to deeply understand its past.
2. Technology changes in an evolutionary manner, in fits and starts, branching and recombining. It is primarily a process of parts assembly where different components are recombined in new ways. The evolutionary nature causes phenomena such as lock-in and inertia. Apparently transformative technologies are not so intrinsically, but because of their effects. There is irreducible uncertainty in technological change.
3. Consequently future technologies are difficult to predict, especially their impacts. On sufficiently short time scale, narrow aspects are predictable. But the broader impacts are not predictable with precision. General-purpose technologies can be predicted broadly, and technologies for data, especially data analytics, are likely to have the largest foreseeable impact.
4. The determination of the impacts of technology are complicated by the deep and complex interdependence of different technologies. A given technology impacts different people in different ways. All technologies carry benefits and harm, and all technologies have the potential to be used for good or evil.
5. Technology is part of what makes us human, and consequently the meanings we ascribe to technologies matter deeply for its adoption and use. Meanings affect attitudes, and they are also shaped by ever-present and difficult to avoid cognitive biases.
6. Technological choices are greatly influenced by how technologies are evaluated, especially costs. The determination of the costs of a given technology is difficult, not only because of technological interdependence, uncertainty and lack of predictability, but because of self-interest and strategic misrepresentation. There are good practices, which if widely adopted would improve the quality of technology evaluation.
7. Notwithstanding all the above difficulties and complexity there are several clear and compelling interventions that can be made that can improve Australia's ability to develop, adopt and benefit from new technologies. These include changing the nature of technological education to deal with technological change, by encouraging creativity, enhancing adaptability and the means of dealing with failure, by encouraging and facilitating interoperability and modularity of technologies, improving and simplifying the regulation of technology, and supporting early stage technological development by funding.

The report made 18 specific findings covering the above aspects. Australia's future society and its prosperity will be greatly shaped by the technological choices we make now and how we adapt to technological change. We either adapt or wither.

One paragraph elevator pitch

Technology has substantially shaped Australia's past and will largely determine its future. Technology is complex, and cannot be viewed as separate to the society it lives within. It changes in an evolutionary manner and that means it is hard to predict. It is part of what makes us human and thus it's meaning to us matters and shapes our attitudes and behaviours. The way we evaluate technologies affect our choices, and there are good ways to evaluate technologies that lead to better choices. The dynamic and fluid nature of technological change does not preclude sensible policy interventions, and most important of them are adaptability, willingness to do proper experiments, education that embraces the experimental and creative nature of technology, ensuring interoperability and efficient regulation, and ongoing support for early-stage technology development. Technology is not determined, but it is shaped by our choices. We can either adapt or wither.

SMS message (160 characters including spaces)

Technology is central to Australia's future. It evolves, is hard to predict and evaluate, is imbued with meaning but there are effective adaptive interventions.

Bumper Sticker

New Technologies Create Australia's Future – Adapt or wither!

Wearable button

Tech4Oz'sFuture

Morse Code Fragment

_ ····_ ·_