

SAF5 Recommendations (extended version)

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1. Encourage interoperability; don't pick winners; deal properly with failures

Government policies based on models of technological change with strong evidential support will be more effective than those based on discredited models.

- Since technology evolves in a complex and largely unpredictable way, keep multiple technology options open (e.g. general purpose technologies) and avoid picking specific technological winners.
- New technologies are the major driver of economic growth and provide large national benefits. However, failures are inevitable with anything new. Thus government policies should deal more explicitly with failure – acknowledge it will occur, and prepare for it. Government should conduct proper experiments (declared as such with clear expectations, means of measurement, and a commitment to publish the results).
- New technologies often substantially improve the *average* welfare of the country, whilst at the same time harming the welfare of subsets of citizens. Policy which explicitly recognises these differential impacts (and mitigates them by social safety nets) removes a brake to progress.
- Much government regulation concerns technology. The evidence suggests Government should regulate by effects, rather than by technology.
- Technological standards can enhance interoperability which can improve outcomes for all. Governments should focus upon interoperability (rather than standardisation in itself), and be wary of dangers of premature lock-in (which can be a self-interested business model).

2. Align R&D Investment with Technological Trends

A widespread pattern of technological change is the lack of direct appropriability of the returns to new technologies. Technologically advanced economies nevertheless thrive because of the complex web of spill over effects, caused by labour and idea mobility. Continuing investment in R&D at the leading edge of new technologies remains necessary for the nation to thrive.

R&D investment in Australia is widely skewed away from the new technologies that are likely to underpin future economic growth. Government can improve the way R&D supports and underpins the development and adoption of new technologies by:

- Rebalancing the R&D spend to closer match the areas of importance to the economy, for example by directing scientific research organisations to look to the future more than the past. Bet heavily on current and future general purpose technologies.
- Expect transformation of industries and don't react defensively when existing industries, which resist transformation, wane.
- Signal an understanding of the lack of appropriability of the economic returns to the research institutions by not imposing onerous expectations for 'external revenue'.
- Aim for quality and depth. Stop being obsessed by collaboration and impact you can measure in the short term. The evidence from around the world is clear – hire the best people, signal what you expect, and leave them in peace to deliver the goods.

3. Invest in Skills for New Technologies

The benefits of new technologies in Australia will not be realised unless Australia has the people to develop and use the technologies effectively. A highly skilled workforce is needed to drive the invention, adoption, and adaption of new technologies. Government needs to ensure that:

- Australia maintains and grows broad technical expertise, especially in emerging general purpose technologies. Thus increasing investment in the breadth and depth of technological training (at all educational levels) should be a priority.
- Government should do more to encourage the development of skills for creativity. This can be done by requiring creative thinking, doing and making, in STEM education curricula at all levels.
- Risk taking and learning to fail can be taught. Putting the ‘E’ into STEM through the encouragement of “tinkering” could change the technological ethos of a generation.
- Understanding the central role that technological change plays in the development of the nation is central to a new ethos. Government can facilitate this by redressing the deficiency in the teaching of history of science and technology at the tertiary level.

4. Change the Way Technologies are Evaluated

The most important factor in the adoption of new technology is the evaluation of its value.

Government can facilitate better technological choices by improving the way technology evaluation is done. This can be achieved by:

- Since the value of a technology is extrinsic (depending upon the context and use), technology evaluation should be done specifically for the problem at hand.
- Cost-benefit analysis is the best starting point for technology evaluation. Explicitly conduct proper cost benefit analyses of new technologies using the findings and evidence in the report; for example, requiring the use of reference-class forecasting.
- Many countries have independent agencies to aid in the assessment of technologies to provide independent advice to citizens, governments and businesses. Government should ensure there exist mechanisms for such independent technology evaluation.

5. Inspire a New National Technological Narrative

How technologies are conceived and imagined, and the associated narrative affects attitudes, which in turn affects adoption. Consistently signalling an open, forward looking and optimistic narrative about new technologies could lift Australia’s creation and adoption of new technologies. Government can do this by:

- Signalling consistently that technological change is the major cause of improved standards of living.
- Inspiring collective action by setting grand technological challenges that many can contribute to (for example decarbonisation of energy supply; synthetic biology to replace the large (and harmful) land use for wool and cattle)
- Technologies are neither good nor bad (intrinsically); their worth is always context dependent, and depends upon how Australia chooses to use the technology. Government should signal this, and properly evaluate uses of technology with costs set against benefits for the case at hand.
- Repudiate the old story about Australian’s being good at inventing and poor at commercialising and collaborating. Replace it with something better.
- Vocational training should be refocussed on adaptability and the skills needed for jobs of tomorrow (rather than today or the past), by reducing the amount of rote and technique learning, and increasing the degree of conceptual learning and ability to change and adapt.

Appendix – Answers to Question 4 from the SAF5 report

For convenience, below is the text from the [report](#) answering the question: “What are the key determinants (in Australia now, and in the foreseeable future) of business and industry uptake of new technologies, and to what extent are these capable of influence by government policy?” Given the variety of factors involved, there are no universal prescriptions. The uptake of new technologies by business and industry is context-dependent. The 12 factors listed are all important to the uptake of new technologies.

Costs and benefits

A major determinant of technology adoption is the associated costs and benefits. Analysis of costs and benefits is usually not a simple matter, and there are considerable uncertainties, especially when predicting future costs or benefits.

Governments can influence costs, benefits and uncertainties by:

- Consistently signalling that technological change is indeed the main driver of economic growth in order to encourage more businesses to embrace new technologies, thus reducing prices.
- Modelling best practice in doing cost–benefit analyses for new technologies. Effective evaluation includes embracing transparency and openness, and minimising cognitive biases (e.g. by using reference class forecasting to increase evaluation accuracy).
- Removing tariff barriers and differential pricing to drive prices down.
- Reducing compliance burdens of regulation to reduce costs.
- Implementing programs for capital de-risking. The US Small Business Innovation Research program, for example, encourages domestic small businesses to engage in government-supported R&D that has the potential for commercialisation.
- Setting national challenges which will inspire technological development and adoption (such as the American space program). Ambitious targets to reduce carbon pollution, for example, can enhance innovative industries and create new job opportunities.

Policies, regulations and laws

Businesses are influenced by government policies, regulations and laws. If these are designed in ways that favour existing technologies over new ones, then businesses will have less incentive to invest in new technologies.

Governments can influence approaches to policies, regulations and laws by:

- Focusing on the desired goal, rather than the (technological) means – government policies and solutions should avoid endorsing particular technology or infrastructure choices. For example, rather than setting policy for specific technologies – such as carbon capture – policy should encourage decreasing carbon emissions, allowing innovative solutions to emerge.
- Investing in understanding new technologies and exploring their possible range of applications and consequences.
- Providing policy stability, for example, changing carbon pollution policy discourages long-term investment.
- Assessing the potential costs and benefits of technology using lifecycle assessment.
- Recognising that most problems to do with new uses of technology can be addressed by common law and do not require technology-specific laws.

Technological inertia

Technological inertia refers to resistance to technology change, whether deliberate or systemic. There are several causes of technological inertia which can delay or discourage industry adoption of new technologies:

- Vested interests (expressed through political influence and rent-seeking) can reduce the incentive of a business to invest in new technologies – if incumbents are afforded political protection, then it is not a good investment decision to embrace technologies which are contrary to the status quo.
- Within a business, management and workers can resist technological change if there are concerns they will be worse off under a new regime.
- A business can resist adopting technology because of concerns that the technology will damage its existing business model – the ‘innovator’s dilemma’.

Governments can influence technological inertia by:

- Limiting the political influence of businesses heavily vested in current technologies, and ensuring that new players have an equivalent voice.
- Publicly recognising that technological change can lead to new businesses that create jobs.
- Directly investing in basic research to encourage technology development and adoption.

Skills

The benefits of importing leading-edge technologies into Australia will not be realised unless Australia has the people to develop and use the technologies effectively. Workers who are provided with general problem-solving skills and trained to experiment and ‘learn by doing’ (hands-on practical experience with a technology) will be in a strong position to help Australian businesses adopt and adapt new technologies.

- The workforce, including management, is often trained in particular ways of doing things for a set of contemporary technologies and processes, rather than acquiring general problem-solving skills.
- Lack of worker mobility can slow the spread of skills that allow businesses to exploit new technologies.
- Occupational obsolescence can be mitigated by ensuring that vocational training targets tomorrow’s jobs rather than yesterday’s. The development of trainees’ adaptive capacity may require a shift in vocational training from its present focus on highly job-specific competencies in favour of vocational streams which group a number of closely related occupations.
- Different technologies sometimes necessitate different business models or organisational structures. The inability to cope with organisational change that results from adoption of new technologies will limit a business’s capacity to adopt some new technologies.

Governments can influence skills by:

- Influencing training and education schemes to encourage flexibility, creativity and the ability to try new things, including encouraging an increased focus on technology and engineering to complement science and mathematics training.
- Minimising constraints on worker mobility.
- Supporting the skill-development role of R&D institutions and recognising that mobility of highly trained technologists is crucial to industry adoption.

- Supporting management of education and training opportunities for Australian businesses by ensuring the training content is sufficiently generic to enable workers to adapt to the evolving job requirements imposed by new technologies, rather than highly specific content that is focused on the old technologies employed in past jobs.
- Ensuring that skills-accreditation organisations do not become change-averse gatekeepers.

Openness

Operating new technologies requires new knowledge and information. Businesses can be restricted in their ability to adopt new technologies through lack of access to published research or relevant data. They can also be restricted by strong patent provisions, poor standards, constrained or segmented supply chains, and trade barriers. Due to the interdependence of technologies, businesses need to integrate into increasingly global technological supply chains which span traditional industry sectors.

Governments can influence openness by:

- Enhancing the open-access provisions of publicly funded research and rejecting complaints of commercial publishers who would restrict access to the publicly funded research that can aid technology development and adoption.
- Ensuring public sector data is open to facilitate new technologies that depend upon it
- Ensuring patent systems do not act as a brake to innovation (e.g. adapting systems to mitigate against patent trolls).
- Minimising trade barriers – much new technology originates overseas.
- Designing innovation policy that is not based on existing industry sectors, as to do so will put barriers in the way of inter-industry interaction and will entrench old systems, infrastructures and behaviour.

Attitudes

Technology adoption can be substantially influenced by attitudes, from both business and customer perspectives. These attitudes can be ingrained, contradictory, and tacit. Collective attitudes (workplace cultures and norms) can also have a substantial influence on the adoption of new technology. Many aspects of technology evaluation are affected by cognitive biases of various sorts, and these can influence assessment of technologies and their adoption.

Governments can influence these factors by:

- Modelling good practice in technology assessment, for example, by using reference class forecasting and by taking a broader context into account. If a technology causes some harm, it should be calibrated against other technologies and the harm they cause, rather than viewing the harm of one particular case in isolation.
- Serving as an honest broker for the provision of information on new technologies (recognising that interested parties will not necessarily present balanced evidence).
- Mitigating against negative attitudes to new technology in general (influenced for example by fear of occupational obsolescence) by ensuring that there are effective retraining schemes and social safety nets for affected workers
- Introducing a culture which embraces the opportunities offered by technological change in primary and secondary education and vocational training, so that technological change is expected and welcomed

- Widening the focus of technical education from a description of what presently works, to a deeper understanding of why it works. If workers understand better why things work, their ability to understand and adapt to new technologies will be significantly expanded.

Approach to risk and failure

Technologies are never perfect when first introduced, and thus businesses and industries that wish to adopt new technologies need to be able to deal effectively with failures. A risk-averse business will be less inclined to adopt new technologies.

Governments can influence approaches to risk and failure by:

- Modelling best practice when dealing with problems that involve new technologies, and recognising that failure is an inevitable part of learning, improvement and progress.
- Influencing STEM education efforts to ensure that students learn how to experiment properly, and how to learn from and benefit from failures.
- Encouraging universities to offer technology education for all graduates (technology in society for example, where students can learn some common patterns of technological change).
- Implementing programs such as the US Small Business Innovation Research program which enables small businesses to explore their technological potential and provides the incentive to profit from commercialisation.
- Encouraging innovators to experiment with multiple technological options for a given problem, recognising that it is unlikely there is only one solution.

Appropriating economic returns of early stage technology research and development

Businesses may avoid investment in early stage technology development because of a concern of lack of appropriation of economic returns (capturing the financial rewards of an innovation for the innovator), or simply a lack of knowledge of new technologies.

Governments can encourage early stage technology research and development by:

- Recognising that indirect spillovers from early stage technology R&D have a very large positive long-term effect on the economy. There are widespread social and economic benefits to rewarding R&D.
- Mitigating the lack of appropriation by providing increased long-term stable investment in early stage R&D organisations, which can be done in a budget-positive way when the returns from R&D are accounted for.
- Not requiring government funded R&D organisations themselves to try and appropriate the returns (that gets in the way of technology transfer to industry).
- Encouraging existing institutions such as universities to free up their IP arrangements to enable the IP to be more freely used.
- Facilitating close industry engagement with R&D centres which develop new technologies in order to enhance industry's ability to incorporate new technological knowledge.
- Offering motivating prizes for solutions to challenging problems through the development and adoption of new technologies. For example, the United Kingdom's Longitude Prize offers large sums of money for a solution to a specific problem.
- Considering other innovative solutions from around the world such as Patent Box, a tax incentive of the United Kingdom government, which provides local incentives for the

manufacture of new-to-market products and supports research and development by providing benefits to businesses taking a product, process or service from concept to commercialisation.

Market structure

Market structures can hamper business and industry motivation to adopt new technologies. Structures that reduce negative externalities (such as pollution) can only be economically viable if businesses can capture the economic benefits of that reduction. Deeply entrenched monopolies (for example current taxi licences) can serve to discourage new technology adoption by businesses.

Governments can influence the impacts of market structure by:

- Explicitly pricing negative externalities through taxes or fines.
- Monitoring and intervening when monopolies become too powerful.
- Ensuring that market mechanisms such as the national energy market do not implicitly work against innovative new technologies (for example, by having artificially high scale barriers to entry).

Standards and interoperability

Businesses can be less inclined to adopt new technologies in the absence of adequate standards. Standards which facilitate interoperability and market efficiency aid businesses. Conversely, adoption of de facto standards too early can lock in an industry in a manner that is hard to change.

Governments can influence standards and interoperability by:

- Sponsoring the development and adoption of simple, interoperable and (where possible) global standards.
- Monitoring business practice to mitigate against adversarial lock-in via the exploitation of monopolies.
- Promoting the adoption of standards by mandating their use in government procurement of technologies.
- Encouraging the development of gateway technologies that allow multiple standards to interoperate, rather than by default insisting upon single universal (and hence sometimes unwieldy) standards.
- Promoting the use of platform technologies that facilitate the development of other technologies and business opportunities.

Dependence upon infrastructure and other technologies

All technologies rely upon other technologies, and all of the above points apply to predecessor technologies. New technologies can be held back by the weakest link (e.g. a component, process, system) that is not keeping up with the front of technological advance. This is particularly the case with regard to infrastructure.

Governments can enhance the use of infrastructure and other technologies by:

- Ensuring that infrastructure investments make the best use of existing technologies and services whilst allowing for future flexibility (e.g. simple and flexible standards that allow for interoperability);
- Facilitating knowledge flows about other technologies through enhanced education and training;

- Discouraging categorisation of infrastructure into sectors, instead encouraging cross-overs from different technologies (e.g. to improve the transport network, use computers not just concrete).

Government's role as a purchaser of new technologies

The Australian Government is a major purchaser of new technologies in markets such as defence, telecommunications and agriculture. Government purchasing and investment decisions can directly influence the business opportunities for the adoption of new technologies.

Governments can influence this factor by:

- Explicitly recognising the direct power they hold in this regard, and using it as a lever to speed technological development by encouraging the supply of new and better technologies