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Why do governments support research? The evolving role of the State

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Recently, the New Zealand Government published the National Statement of Science Investment (NSSI). This statement heralds a number of important changes particularly in the system of allocating public funding for science that hold considerable promise for science making a greater contribution to New Zealand and to New Zealand's capacity to make a greater impact globally. However the ultimate impact will depend on subsequent funding decisions. Like ours, science systems in many countries are undergoing change for a number of reasons and it is worth reflecting on some of the drivers of this transition.

Perhaps the most contentious questions in developing public policy for science and innovation systems are how they should be funded, on what basis and how much? The answers to these questions might seem self-evident but are caught up with the much deeper question of what are the core objectives of public investments in science. If we examine the recent global history of state funded science and innovation, it becomes apparent that the answers to these questions have changed over time and will continue to adapt and evolve.

A very brief historical overview

In the European context, the public investment in science largely started with an investment in imperial endeavours by European powers – the support of expeditions of discovery and in the support of the development of navigational knowledge, tools and equipment. Indeed Cook's rediscovery of New Zealand in 1759 was the outcome of the Crown seeking to measure the transit of Venus in Tahiti so as to improve navigational accuracy and his additional sealed instructions that would enable the push southward to discover new lands. Beyond these concerns for Empire, for much of 19th Century England, science was largely self-supported or was part of the developing museum sector. There were exceptions related to national needs in areas such as defining mineral resources (and coal in particular), metrology, and meteorology. Indeed the first governmental investments in New Zealand science were in mapping geological resources for mining.

The University was also a very different institution than the one we know today, with universities in Britain, France and Italy dating back to medieval times. But they were not institutions of experiment and discovery – rather they were designed to preserve religious tradition, hand down received knowledge and engage in philosophical debate. The concept of the *research* university was a German innovation, and was to spread through the USA and Britain during the latter part of the 19^{th} Century. Even so, much of the scientific enterprise remained more of a hobby than a core societal competency.

Technological development, notably through the industrial revolution and beyond, occurred not in Universities but from engineers and inventors, largely working within, or in association with, the private sector. That tradition of discovery science originating within the private sector continued well into the 20^{th} century, particularly in some US companies and remains so today. That the Bell Laboratories produced 7 Nobel laureates is perhaps the most notable example. And to the extent that there was recognisable 'public good' research, a considerable portion of this was supported by industrial philanthropists – Rockefeller, Carnegie and Ford are obvious examples, and their Foundations are still pivotal players in the US research system today.

State funding of broader aspects of scientific, technological and medical research largely grew out of military and imperial/strategic demands (for example the emergence of tropical medicine related to expansionist ventures such as building of the Panama canal). During World War 1 the reliance on science and technology grew. Governments increasingly turned to science; particularly that related to military technology and public health, medicine and agriculture, largely as part of a national security strategy.

Thus in the first two decades of the 20^{th} Century, the concept of state funded research universities was formalised in the UK, and a committee chaired by Richard Haldane identified that Government needed to fund two types of research: firstly research required by departments in the public or military service (ie the government as a direct end-user) and secondly, that of a more general nature. Haldane's recommendation was for the latter type to be funded by autonomous research councils so as to limit government influence. The first of these to be set up was the UK's Medical Research Council in 1913. In New Zealand the equivalent council was established in 1937 and although it initially used a rather informal allocation mechanism. The history of the so-called Haldane principle that is now interpreted as protecting certain types of research from political interference is complex (Edgerton 2009). In countries such as Australia and New Zealand, the domestic (eg agriculture) and technical requirements of war occupied much of the governmental research agenda, and so departments of scientific and industrial research grew. The research systems of the western world as we now know them consolidated after the Second World War. They were heavily influenced by the technological success of the scientific contributions to the war effort in the UK and the USA.

In the USA the public policy implications of government-supported science (both for public good and for economic growth) became increasingly apparent. In 1945 Vannevar Bush, who had led the US military scientific effort and was science advisor to President Roosevelt, released his notable report *Science: The Endless Frontier.* This report was to lead to the promotion of civilian science for the purposes of both advancement of knowledge on one hand and for economic growth on the other. It resulted in the development of the National Science Foundation in 1950. The Cold War and the Space Race both further accelerated governmental support of research and the spillover to private sector innovation became readily apparent to policy makers.

In 1987 Robert Solow was to receive the Nobel Prize in economics for demonstrating the critical role that the technological developments that followed from investments in knowledge had played in promoting economic growth in the USA. Indeed recent analyses[1] continue to show the critical role that governmental funding of discovery research plays in both the pharmaceutical and ICT sectors in the USA and other countries.

With these social and political changes the modern dual structure of State funding of discovery research (mostly within universities), alongside State commissioning of required applied research, was well established in the Western democracies. The latter remained largely administered in a mostly top-down manner, where money was allocated through ministries in domains such as agriculture, defence, energy, minerals and space and delivered through the agencies themselves via dedicated institutes or external contracts. Philanthropy continued to play a major role particularly in the promotion of medical and public health research in many countries; as it still does especially in the UK (eg the Wellcome Trust) and the USA (eg Howard Hughes Foundation, Bill and Melinda Gates Foundation).

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[1] See Mariana Mazzucato's Entrepreneurial State: *http://marianamazzucato.com/the-entrepreneurial-state/*

But as the research university enterprise grew, inevitably tensions emerged as to the role of universities, the role of dedicated research institutes, and the mechanisms to meet governments' knowledge needs. Different countries approached the search for equilibrium in very different ways: In Denmark, about a decade ago, virtually all the research institutes were merged back into Universities. At the other extreme, New Zealand broke up the government's principal research department, the DSIR, in 1992 to form the Crown Research Institutes (CRIs). These were created as eight crown owned companies. An Act of Parliament, a governance structure and a separate funding agency were established to more clearly distinguish policy development (the Ministry), the funder (FRST) and the research provider (the CRIs). This split of responsibilities was driven by the ideology of the time in which funder–provider separation was promoted for many government services.

At its outset the Foundation of Research, Science and Technology (FRST) was only open to contestable research applications from the CRIs. Only later were Universities able to apply into the fund. The Marsden fund which was formed at the same time was in part a policy response to the demands of the University sector that the ring-fencing of FRST money for the CRIs was unfair and, in part, a recognition of the importance of promoting basic research. When FRST was initially formed it had two distinct funds – one for discovery-orientated research (NERF) and one for end-user orientated research (RFI) but that distinction was lost a decade ago - with the net effect of encouraging a shift to more end-user focused research.

The CRIs, for their part, having been set up as Crown owned companies, had the challenge of meeting a return on the State's investment while also meeting their scientific purposes which included a strong focus on the end-user. Initially CRIs were financed solely through funds obtained by competitive grants and by contracts and partnerships with the private sector. This created management dilemmas in balancing multiple (and potentially conflicting) demands, which included: public good activities of the CRIs (eg in environmental research); the delivery of non-commercialisable know-how to the private sector (eg to farmers for productivity enhancement in areas such as animal husbandry); defensive research (eg biosecurity research) and the provision of appropriable knowledge to the end-user (whether the private sector or the government) while undertaking that upstream research that is necessary for their sectors. All of this had to be done while still providing a return on investment (ROI). The concern over the effects of this complexity of tasks on constraining CRI strategy, including their ability to maintain capacity and capability, led in 2011 to the decision to shift some of the contestable funding into a core-fund for each CRI. The expected ROI was also adjusted. This move enhanced the autonomy of CRI boards and executives, though the Crown maintained processes to convey the shareholders' interests and expectations. But without any significant new money being added to the research system overall, these moves occurred largely at the expense of the contestable funding system.

Over time, the contestable funding model within FRST (which, in 2011, with the merger of FRST back into the science ministry became the Ministry of Business Innovation and Employment's contestable fund) itself became increasingly problematic as policy expectations led to tightly defined portfolios that effectively limited the potential of science to explore new boundaries. The nature of the assessment was such that it tended to lock in long-term funding especially to CRIs, from the so-called contestable pool.

But a further set of policy changes was occurring in parallel. As the tertiary education sector grew - particularly after the 1960s – the demand within the public R&D sector also grew, and governments responded to both by increasing support to universities and, in time, linking that support to research performance. In New Zealand this was the origin of the Performance-Based Research Fund (PBRF) that is calculated from research metrics and assessment, and sits alongside funding based on student numbers to create the dual funding system of our Universities. But the bulk of the PBRF is used within Universities to meet institutional needs such as core services, maintain infrastructure and pay staff so the actual amount going to directly support discretionary academic research is a small proportion of the PBRF.

In most western economies from the 1980s and onwards, aggressive policies and programmes emerged to promote both private sector uptake of research and private investment in research and development. This was primarily due to the growing recognition of the essential relationship between scientific innovation and private sector economic growth. In the USA, the Bayh-Dole Act of 1980 was a major influence: it allowed universities to patent intellectual property their researchers developed using public funds, thus encouraging universities themselves to exploit those patents by pursuing development opportunities with the private sector. This resulted in the first technology transfer offices and organisations appearing in the 1980s. For instance, the University of Auckland was to found Auckland UniServices Ltd (its wholly owned technology transfer company) in 1989.

The biotechnology revolution of the 1980s, which started in the San Francisco Bay Area, began with academics, many of whom found the enormous potential to continue with their research in partnership with the venture capital sector and moved into the private sector. This story was soon to be repeated in the ICT sector. The resulting companies recognised the importance of discovery research, having themselves largely emerged from universities. Is it any wonder that today's massive ICT anchors – Google, Microsoft – organise themselves into 'campuses' and provide an ongoing learning environment for employees? Governments across the developed world stimulated the development of private sector R&D further through tax credits, vouchers, grants, loans, advisory services and other subsidies to industry. The actual mix used in different countries varies and is influenced by many policy factors including company size, sector, stage of development, culture and context.

The relationship between science and society

In parallel there have been enormous changes in the place of science within society – from being marginal to being central to society addressing every challenge that it (and therefore governments) face. And this too impacts on policies regarding public science. The information and communication age has made science and innovation accessible to nearly all, while the issue of climate change in particular is making us all more aware of the need for good science to inform environmental, energy and other decisions. Indeed no one would deny the central place of science in our lives today.

However, as I have written about extensively elsewhere, this does not mean that there are not understandable tensions between the pace of innovation and societal concerns. Increasingly it is apparent that societal voices must be represented in determining what science is done and how it is used and determining the limits on the application of any technology. These are quickly evolving areas of ethics and knowledge governance worldwide. The nature of post-normal science is to engage with issues for which the science is complex and values are in dispute, and an increasing amount of science in the public interest is of this type. Again, how scientists behave and communicate and how that induces a variety of responses is beyond the focus of this essay but is discussed elsewhere[2].

But as we are now unequivocally in the "science age", the question remains, how should the State support and manage research and development it and society needs? The range of possible answers is not without controversy and many countries have experienced some tension between the expectations of publically funded scientists and the policy sector.

While the pathway to present systems within advanced economies took variable routes reflecting context and culture, all successful innovation-based nations have ended with the non-defence R&D being supported by the public sector to a high degree. Generally the public investment in R&D in advanced economies now ranges between 0.5 and 1.0% of GDP (New Zealand is towards the lower end of this range but is slowly increasing), along with various other more indirect subsidies (eg using

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[2] *http://www.pmcsa.org.nz/wp-content/uploads/NZAS-Speech_Trusting-the-scientist.pdf/*

the tax system) to promote private sector R&D which can range up from 0.5 to 3% of GDP (in New Zealand it is ~0.6% of GDP).

But importantly there has also been an evolving rationale for why governments support R&D. Beyond economic, and defence and public safety imperatives, there is a growing public expectation that governments will promote research in public health, in environmental matters and that policy development itself, especially in social and environmental matters, will be supported by robust research and data. Governments also need to support research that is broadly defensive by addressing risks and promoting resilience, whether it be to address a potential animal or human pandemic or dealing with natural hazards.

The policy dilemmas for small advanced countries

What I have described above, through a rather potted history, is largely a reflection of the influence of the large western democracies, but smaller countries have also followed these trends and policy settings. They also have had greater challenges in doing so. How can they thrive in a technological world when so much development occurs in the dominant global economies? But small economies do have a proven role in generating new disruptive knowledge and cannot simply rely on exploiting the knowledge generated by others. But because the assertion that public investment in science drives economic growth is technically difficult to formally demonstrate everywhere, some policy makers in finance ministries have been skeptical of the priority that science should be given.

A further issue has been created by the very different cultures of different countries – some have an entrepreneurial character, others such as NZ have been far more conservative. In previous essays[3], I have explored these cultural differences and what they have meant for the public role of scientists. But the question of their impact on the way countries fund public science is important.

In small advanced economies, it is generally accepted that governments must support a broad range of discovery research because that is where the fountain of innovation is sourced. It is also a cultural expectation that an advanced economy will contribute to the body of global knowledge. But governments have also seen the need to support research in specific areas where the public good is evident – environmental, social and health research are most obvious.

[3] *http://www.pmcsa.org.nz/blog/the-public-role-of-scientists-is-changing/*; *http://www.pmcsa.org.nz/blog/innovation-and-society-license-and-precautions/*

While the public good motives of such research are apparent, governments have often struggled with establishing and reconciling the intervention logic and the policy tools that are needed to do so. As the institutional arrangements have changed and economic conditions have changed, the emergence of the direct economic justification for research has come to dominate in much public policy. But there has been a mistaken tendency to conflate the types of research designed to meet very different objectives. The allocative systems have tended to merge both public good research and research that is expected to lead to direct economic outcomes largely within the private sector.

The public policy settings are further complicated because many policy makers globally still assume a linear model between discovery, application and exploitation: a model that is clearly inappropriate. Innovation does not arise in a linear fashion from discovery as has been well documented, particularly in the case of disruptive innovation. All this leaves a complex and confusing set of policy pressures and many countries struggle with optimising their science system strategy.

To complicate matters further, science itself is undergoing revolutionary change with the impact of big data shifting much research from hypothesis driven to hypothesis generating, multidisciplinarity, and large research groups. Issues of the scientific culture are being affected by the growth of the tertiary education system, the 'publish or perish' culture of universities, and pervasive stresses of the journal impact-factor, academic performance metrics, and pressures on the public science budget. The massive expansion of tertiary education has led to a commensurate expansion of scientific output. But as the scholarly factory cranks out papers at an unprecedented rate, questions arise as to their actual value (based on subsequent citations, a surprisingly high number of papers are never cited except by their author).

The impact agenda

Against this background, governments are looking more carefully at where they expend the taxpayers' money - a global trend across the advanced democracies. The public expenditure on science and innovation thus is getting greater attention – and the language of investment is increasingly used. Perhaps inevitably, the outcome has been a greater attention paid to the impact question – in other words what will governments get in return for their investment? What is the potential and actual *impact* of the research"?

Inherently there is nothing wrong with this question (it is taxpayers' money after all) provided that the definition of "impact" is broad and inclusive. But the temptation of some contemporary policy makers is, too often, to define it narrowly in terms of economic growth, despite the obligations of the State in research being much broader. Given the importance of a broad definition, a collective of small advanced economies undertook in 2013/14 to look at the definition of impact and developed a broader taxonomy. The figure below that is from that report[4] sums up the key features of the suggested taxonomy. The National Statement of Science Investment released last week uses a rather similar approach.

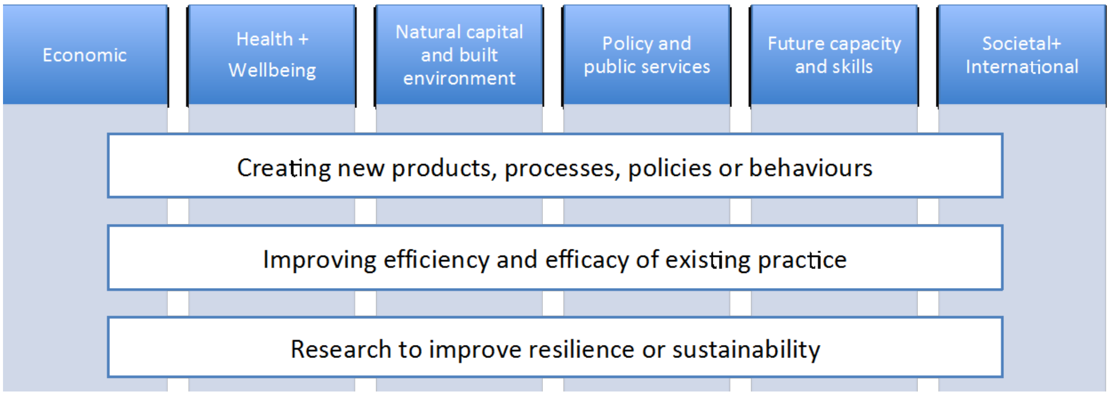

Figure 1: *Taxonomy of impact – it can be defined in 6 major categories (pillars) but there are three cross cutting dimensions of research that lead to innovation (broadly defined). Further expansion and detail can be found at http://www.smalladvancedeconomies.org/wp-content/uploads/SAEI_Impact-Framework_Feb_2015_Issue2.pdf*

The goals of state funding of research in the 21st century

Given the discussion above, one can parse four major but overlapping reasons why a government must invest in science and a mature national science and innovation system must provide for all of these.

a. *Cultural (broadly defined) and reputational*. By 'cultural', I refer to science's core cultural value. It serves a basic human drive to know more about the world around us and within us. But at the same time advanced nations must also project themselves as clever and innovative, contributing to the global stock of knowledge; this is increasingly a tool of diplomacy, national identity and vision. Further, it is becoming clear that innovative countries prefer to interact with other innovative countries and that such a profile can overcome other barriers.

b. *To meet society's needs for knowledge* so individuals, companies and NGOs can make better decisions – this in general the production of non-

[4] http://www.smalladvancedeconomies.org/wp-content/uploads/SAEI_Impact-Framework_Feb_2015_Issue2.pdf

appropriable knowledge. There are many needs for scientific knowledge within an advanced society. The most obvious is to support higher education and human capital development. But advanced science is required both to adopt technologies and to inform the many decisions that citizens must make as individuals, through companies and collectively through public policy makers. Examples of these are public health measures, the flow–through effects of medical research to the quality of health carers, and the adoption or regulation of new technologies. The growing understanding of the importance of environmental science is obvious as a public good. The public rightly expects the complexities of the natural environment and human interaction to be understood so that well-informed decisions can be made in balancing conservation and development drivers. Many private sector stakeholders, including farmers and local government also need (and are now calling for) information to ensure reliable production that fulfils market demand eg around sustainability and biosecurity.

c. *For the State's own needs as a major end-user of knowledge* in virtually every domain. The State itself is an enormously important and large end-user of science. This is reflected in the growing use of science advice across government departments on the policy process. This is most easily demonstrated in areas such as natural hazards identification, assessment and management, cybersecurity and defence science, application of biosecurity measures and regulatory (eg food safety, agricultural chemicals) safeguards. Environmental science is critical for multiple levels of decision-making by central and local government. The role of social science in informing effective government investment in the social sector should not be underestimated. All of this requires that continual new knowledge is generated in the local context; this certainly cannot be obtained from elsewhere. Science plays a growing role in trade dispute resolution and negotiations and in diplomacy. The role of science has been of obvious value in developing New Zealand's international position: the Global Research Alliance on Agricultural Greenhouse Gases and our Antarctic programme being two obvious examples.

d. *To promote science-based innovation for social, environmental and economic benefit*. There are multiple ways that public funds support and advance private sector productivity:

   Firstly there is a great deal of pre-competitive knowledge generated from publicly funded science that informs the private sector. An example would be the great deal of agricultural research that is transferred not as products, but as ideas and know-how to modern land-based production systems. Other areas include the production of environmental information (eg extensive time-series databases) that informs many private sector decisions in areas such as fish stock assessments. Similarly, routine geophysical surveys provide important information for private-sector mineral industries etc. Social data are vital for both NGOs and the service industries.

All public science systems have the challenge of needing to support non-appropriable research even where the benefit will often eventually accrue to the private sector and therefore lead to economic growth. Internationally, governments - large and small - accept the centrality of doing this. This is well demonstrated in the ICT sector where many analyses have shown that the ultimate success of Silicon Valley depended on significant prior publically funded scientific and technological advances. In New Zealand similar results can be readily seen in the primary sector where the end-user is effectively a small business (the farmer).

Secondly there is the well-recognised transfer of know-how and intellectual property through technology-transfer mechanisms from public researchers to the private sector. A further subsidy is provided by the State supporting the production of well-trained graduates to enter the private sector.

Thirdly is the direct support to private sector research, development and innovation through subsidies, grants, loans, tax credits etc in the accepted belief that both the direct and the spill-over benefits to the national economy and broader society merit such assistance.

Translation to policy

But even if the broad range of purposes of public funding and the broader definition of impact is accepted, the question remains how to translate that into effective policy for science systems. It is important that a national science and innovation system seeks the right balance across the four overlapping sets of purpose described above. There is an obvious minimal set of questions and none of them is easy and they are, of course, not mutually exclusive:

- On what principles should a national research agenda be prioritised and on what basis and with what granularity, given that society expects a greater stake in science?
- How much to invest in applied R&D to directly benefit end-users vs. focusing on upstream discovery science?
- How can research agenda-setting and prioritisation address the competing needs for both direct economic returns and a public-good (often non-commercialisable) knowledge base? Are new policy tools and techniques needed?
- How to incentivise research that might lead to disruptive innovation?
- How much to bundle funding within a mission-led umbrella vs. providing open funding for pursuit of investigator-led ideas? That is, to what extent will traditional bottom-up research activity be displaced by top-down "grand challenge" approaches? And what will this mean for traditional academic disciplines in structuring and responding to research questions?
- Should funding tools prioritise tightly defined projects (short-term, limited resources) or strategic programmes (large multi-year research platforms), and what are the research governance implications?
- Should funding tools prioritise talent (developing science careers, recruiting and retaining key scientists) and at what career stage, or prioritise ideas? How to balance established activities versus new entrants?
- What is the right balance between funding public sector science and providing publicly-funded R&D grants to the private sector to stimulate innovation? Are there other tools that should be developed to incentivise the private sector (for example Israel extensively uses private sector loans from the State rather than grants).
- What are the respective roles of universities and dedicated research institutes and other providers in a changing knowledge landscape?

These are not easy questions to answer and indeed different countries, because of history and culture, answer them differently. And nothing is static. But public policy settings everywhere are always difficult to shift and are influenced by path dependency.

New Zealand, like other countries, is grappling with these issues and it is doing so against the background of having had relatively low 'science capital'. Science capital describes both the relative importance that society affords to the scientific endeavour and the general level of science literacy within the population. There is much reason to believe that it is now on the increase in NZ. As discussed above the CRI model grew out of the old DSIR that had its origins in the science effort of the colonial enterprise and the Second World War. It developed at a time when NZ had no university based research effort. But as our universities have become much more research intensive in recent decades and also engaged with the private sector, the boundaries between the two types of public research provider (Universities and CRIs) become more complex.

Our CRIs have several obvious roles – part is undoubtedly to support the private sector by providing both precompetitive knowledge and contract/partnership research for sectorial industries. But all the CRIs also have a core role in public good research, especially in areas such as policy- and regulatory- relevant environmental research. Some of this is discovery research where the infrastructure and capabilities may be distinct from or overlap with the university sector. Indeed, since 2010, many CRIs have developed formal training opportunities (eg graduate schools) and much closer relationships with universities (hopefully enhanced by the National Science Challenges). The other core role is somewhat analogous to serving the private sector but here the Crown is the immediate 'client' – for example the role of Landcare in supporting planning decisions. But the CRIs also must support research in domains where information is needed in a prospective and sentinel sense, for future needs and ongoing monitoring. This is true of much environmental and natural heritage research.

In a parallel but separate discussion, the move to more integrated administrative data and the growing importance of evidence informed policy development in areas such as the social sector is also changing how government ministries view their own role as funders and end-users of science. The development of departmental science advisors is both a reflection of this shift but also an impetus for further change.

Final remarks

Science is critical for a country's direct and indirect economic growth and this needs an adequate investment by both the government and private sector. But science is also critical for multiple other public objectives including, not just protecting ourselves and our environment, but also fulfilling the basic human desire to ask questions about ourselves and our universe and thereby advance our knowledge. But while the level of public funding needs to increase, more funding alone is not the only challenge; it is also a question of how it is apportioned. Science systems will continue to evolve and science institutions and scientists must accept change. But any change must be responsive to the multiple demands that an increasingly science-aware society puts on science. The National Statement of Science Investment prompts our further thinking about these difficult and ongoing policy decisions and reflects the significant progression underway in our development as an advanced economy. Its publication is indeed a further step in an important conversation about science and its role in New Zealand’s future.