Draft Government Research, Science and Innovation Strategy

Royal Society Te Apārangi Submission

November 2019

Mandate

Royal Society Te Apārangi (the Society) welcomes the opportunity to comment on the Government's draft Research, Science and Innovation (RSI) strategy, drawing on the accumulated experience of the Society's activities in the research system.

Royal Society Te Apārangi is independent and operates under a private Act of Parliament to advance and promote science, technology, and the Humanities in New Zealand. The Society's membership includes New Zealand's top researchers, research-system leaders, and constituent organisations.

Functions under the Society's Act include providing expert advice on important public issues to the Government and the community, and supporting researchers and research infrastructure. The Society is also a service provider to government and manages the Marsden and other research funds on the government's behalf.

The Society's Council has approved this submission.

Summary[1]

Strategy framing

- The Society supports the development of the RSI strategy to guide priority setting and government investment in research science and innovation over the foreseeable future. The strategy will be most effective if it has non-partisan support across the political spectrum and the Society encourages MBIE to develop the strategy with that intent in mind
- The vision and priorities could usefully acknowledge important goals which it serves such as meeting the United Nations Sustainable Development Goals and managing our international interests and obligations in the extended continental shelf, the Pacific and parts of Antarctica
- The strategy could be usefully aligned with the Living Standards Framework including recognising Human and Intellectual Capital as the value created from research, science and technology, and also an indigenous approach to such a Framework. The strategy should explicitly acknowledge Human Capital development, and its critical role in absorbing and using global knowledge, as a valid and valuable research impact.
- In line with this, the strategy should acknowledge more clearly the significant amount of support work that is needed to gain impact from research (realise the value of intellectual capital) over time and which is a valid

[1] Comments in this submission do not exactly follow the question order in the draft strategy submission as many issues are related and benefit from discussion in related contexts

part of the research investment, including for example, collecting data, monitoring systems, develop of software tools, building relationships, holding and transferring knowledge.

- The Society notes the inherent difficulties in defining excellence, impact and connections generically when they are highly context dependent. It would be helpful if the strategy acknowledged the distinct characteristics and objectives of excellent and impactful blue-skies research, mission-led research, commercialisation of New Zealand research, and demand-led industry research. Making these distinctions would also make the roles and rationale for types of organisations and networks clearer in the strategy.
- Freedom and responsibility of researchers, and public trust in research and research organisations through effective community engagement, should be explicitly acknowledged as a sixth priority in the strategy as part of a global best-practice research system.

Priorities

- The Society strongly supports the intention in the strategy to do more work in regard to Mātauranga Māori and Rangahau[2]. That work should recognise the likely future value from further development of Mātauranga for advancing Māori communities, as well as recognising the wider benefits for Aotearoa/New Zealand.
- A major priority should be to address long-term shortcomings in research infrastructure investment, including data, people and equipment (e.g. biological diversity and collections). There has been long term under-investment in monitoring, managing and protecting the Natural Capital of our land and marine environments.
- The Society supports the focus on connections where they help build and transfer Human and Intellectual capital within the local and global research and end-user communities. New Zealand's economic geography and location demands greater government support to incentivise connectivity than other similar countries.
- The Society supports continued effort to build a strong high-technology sector alongside our existing industries to lift productivity and support our economic aspirations, There is scope to increase connectivity and Human Capital development by further incentivising connections between research organisations and firms and other end users; for example aligning pre- and post-graduate education with New Zealand end-user needs, and incentivising transfer of skilled people into industry and end-user environments.

Evidence-informed policy

- The Society suggests that a new initiative/fund be established to support government policy-related research to support the public sector services component of the strategy.

Overarching Commentary

Strategy longevity

Research, Science and Innovation are long-term endeavours that necessarily transcend particular governments. Similar strategies have been developed by previous governments over the years, many addressing the same or similar issues. However, it is not helpful to the long term interests of the system, and the certainty for people and organisations working within it, if strategies are revised and or redone too often.

[2] Rangahau is the traditional method for generating knowledge (Mātauranga).

The proposed strategy is ambitious, with a time horizon of 2027, and to be successful there must be continuity and certainty for the RSI system over that period and beyond. The Society therefore encourages MBIE to develop the strategy with non-partisan support across the political spectrum in mind.

Strategy objectives

It would be helpful for the vision to be more specific about high-level obligations and objectives that the strategy will support (e.g. United Nations Sustainable Development Goals, Paris climate change commitments [1], managing our exclusive economic zone and continental shelf, including biodiversity [2], and meeting our international obligations in the Pacific and Antarctica [3]).

The strategy might also specifically address pressing long-term environmental needs such as the research and monitoring shortcomings reported by the Parliamentary Commissioner for the Environment [4], and addressing major health and social issues such as diabetes, cancer, asthma, housing and mental health (or at least refer to the goals of the Health Research Strategy [5]).

Alongside this it might be helpful to leave out the current government's priorities (they could be referred to in accompanying material at launch). These are more likely to vary in the short term and, if included as drivers of the strategy, will make it harder to achieve non-partisan support and long-term stability in the strategy.

Overall, these suggestions would help make the case for additional investment over the next ten years stronger, bearing in mind that the target of 2% of GDP invested in R&D is a proxy for successful creation of value through government investment, not an end in itself.

Strategy framing

While mentioned later in the draft strategy, the Society sees benefit in framing the RSI strategy more in line with the Living Standards Framework[3] as an indigenous approach to the Framework [6]. There are benefits in acknowledging that research, science and innovation are means for converting Financial Capital into Human Capital (the extra value that a person who has undergone development to become a competent independent and knowledgeable researcher brings) and Intellectual Capital[4] (the value of new knowledge, be it know-what or know-how)[5]. These often go together; higher Human Capital value provides more opportunities for creating new valuable Intellectual Capital and a RSI system that is rich in Intellectual Capital is likely to offer greater opportunities for Human Capital development (and hence be more effective at retaining and attracting talent) [7].

With this framing, the goal of the RSI strategy is maximising the total of Human and Intellectual Capital for the benefit of Aotearoa/New Zealand and its people.

Taking the above into account, essential elements of the RS&I strategy should be to:

[3] https://treasury.govt.nz/information-and-services/nz-economy/living-standards/our-living-standards-framework

[4] In the Living Standards Framework, Intellectual Capital refers to knowledge-based capital that is part of fixed assets created by research and development, software and databases, mineral exploration and evaluation.

[5] Intellectual Capital is not the same as intellectual property. IP disclosures and defence of patents may be a barrier to many SMEs that characterise our innovation sector. A small economy with a low capital base is more likely to rely on keeping its Intellectual Capital value as confidential know-how, and for much longer. Hence IP indicators on which we appear low compared to other countries may be no more than a consequence of the absence of significant numbers of large firms.

- Protect the environment, advance the health of New Zealanders, and address social and cultural issues;
- Incentivise R&D investment, and supply suitable Human Capital to the private sector, contribute to economically valuable Intellectual Capital creation for the primary sector, and invest in research that will support new frontier start-ups into the private sector (see Appendix A for explanatory rationale);
- Support the further development of Mātauranga to benefit Māori communities, and also Aotearoa more generally;
- Recognise the need for underpinning amenities and support systems that enable the research system to operate effectively, and to leverage value and investment from bigger international RS&I budgets than New Zealand's;
- Recognise the need for government investment in science and research as an enabler for government policy implementation, and also as a pre-requisite for evidence-based policy formation;
- Ensure that Aotearoa applies contemporary research practices, including recognising the responsibilities of the research community to the public interest.

RSI as an Enabler of Policy

Much legislation and regulation needs to stay relevant in the face of changing practices and technologies. This requires knowledge to inform the regulator, but also often increasingly sophisticated means of measurement. For example, in environmental management and reporting there is a need to keep researching new measurement methods, but also a need to measure comprehensive sets of data that are fit for purpose [4]. This aspect seems to be under-recognised in the strategy.

Additionally, government departments need adequate funding to develop the evidence bases for policy formation. We support explicit inclusion of such an element in the strategy.

Social Responsibility and Research Practice

A result of the digital revolution has been the growth of the dissemination of manipulated, biased or fabricated information lacking editorial processes for ensuring accuracy and credibility of information [8]. Furthermore, the politicization of some issues at the science-society interface has contributed to the emergent "post-truth" and to the adoption of ideological positions or anti-scientific stances on topics such as climate change, GMOs, and vaccination that are opposed to, and in conflict with, the scientific consensus. Public surveys have indicated reasonably good levels of trust in researchers, but nevertheless, the research community has not helped its case by instances of fraud, fabrication and falsification, and lack of reproducibility [9].

Research integrity and engagement/partnership are a fundamental necessity for public trust in research, science and innovation. The ability to uphold the free flow of ideas and information, as well as fostering an open, informed debate on matters of public interest, is central to building and maintaining a democratic and inclusive society. Further, citizens expect to participate in discussion and debate on important public issues. Better-informed communities, that are comfortable with research and new and innovative ideas, will have greater capacity and capability to critically assess and absorb new knowledge, and make well-informed decisions [10].

Researchers, as members of a professional community, have an implicit obligation to act in society's long-term interest through the integrity of their work and engagement. Researchers who fail to display professionalism may

contribute to damaging the trust of the public in the value of research generally. Engaging with the public in a way that builds trust through professionalism and transparency will benefit the wider research community, and in turn facilitate stronger relationships with the public and greater use of shared knowledge in the public interest [10].

Given that it is in the public interest that all scientists, technologists and humanities scholars act ethically, professionally and seek to prevent harm, it would be useful to see a sixth guiding principle in the RSI strategy around social responsibility in the research community – the need to be attuned with the needs and aspirations of our communities; the need for ethical research practice; respect for the public interest above private interests of researchers, research organisations or end-users of research; and even the idea that publicly-funded research is a public good. A national research charter to set out the principles underpinning sound research practice in Aotearoa/New Zealand would be beneficial [11].

The public's trust in science is also strongly influenced by the public engagement of scientists, for which a key channel is science journalism. In an environment of immediacy and the search for attractive headlines, it is often difficult for journalists to develop the breadth and depth of understanding needed to accurately reflect the state of research evidence. This is exacerbated by turnover within the media and rapidly changing media platforms. There needs to be ongoing effort to lift the overall standard of science media reporting, facilitate media access to experts, and provide training and development for researchers and others involved in media interactions.

Excellence, Impact and Connections

The strategy proposes the use of these three concepts as guiding policies. However, focusing on just these could lead to anomalous outcomes in respect of maximising Human and Intellectual Capital. The Society would be concerned about the use of these three guiding concepts in the same way/with the same indicators in different contexts, and more particularly the use of excellence and impact sequentially in consideration of mission-led or user-led research.

For example, for research like the Marsden Fund where the key driver is researcher-driven curiosity, excellent research will be at the knowledge frontier, an academic view of excellence is appropriate, and assessment of impact and connections are of lesser importance. In contrast, for research into serious environmental issues, the potential for impact and uptake by end-users is vital, and a suitable test of excellence may include "fitness for purpose" - consideration of suitability for achieving impact and uptake. Such research might be less at the knowledge frontier, but it could well have much greater potential for Human and Intellectual Capital formation than an alternative proposal that looks academically more eloquent.

Researching and innovating towards the frontier

Do you agree that the RSI Strategy should be focused on innovation at the "frontier" (creating new knowledge) rather than behind the frontier (using existing knowledge to improve the ways we do things)?

The Society's view is that both are important and, as set out above, there are important nuances to consider. For example, as the strategy states, Aotearoa contributes a small fraction of the total global knowledge. An important

and necessary (but not sufficient) outcome from RSI activity is to build Human Capital that facilitates transfer and absorption of new global knowledge for use in New Zealand.

Further, it needs to be acknowledged that innovation invariably extends, builds on and uses existing knowledge. While one intended outcome of an RSI investment should be at the frontier, a significant portion of the investment over time may go to maintaining or adding to necessary databases and collections, maintaining high end computing, storing and managing quality of research data, making it accessible and building and maintaining relationships (connections) that may be helpful in future projects.

The RSI Strategy should, therefore, be considered a balance of creating new knowledge and the extension, maintenance, use and deployment of existing knowledge to meet our future national needs.

The balance will also depend on the characteristics of the investment. For example, the Marsden Fund is New Zealand's blue-skies research fund that is not targeted and explores the answers to questions not yet answered. These projects would expect to be at the global knowledge frontier as future applications may be speculative. On the other hand, a project with a mission to, say, map Aotearoa's biodiversity within its continental shelf would aim to provide new knowledge, some of which will be additive to existing knowledge, but also there will be a need to invest in the infrastructure to support it such as data curation and taxonomy.

Curiosity and serendipity

New Zealand commits a relatively small proportion of public funding to untargeted R&D funding, but what it does commit is important. The challenge facing those responsible for science policy is how to maintain an intellectual climate in which curiosity can flourish, and, additionally, serendipity is not supressed in pursuit of contracted research outcomes.

For example, the curiosity-driven research of Professor John Boys on inductive power transfer (IPT) over a 20 year period gave the University of Auckland a patent portfolio that has produced a very substantial economic return to New Zealand. It is unlikely that this would have started in a totally application-driven research environment.

What RSI challenges are unique to New Zealand, that New Zealand is the only country likely to address?

Aotearoa/New Zealand has the opportunity to become a world leader on any subject in which we have been able to cluster resources around a research group that is making major advances in Human and Intellectual Capital creation in the field. Trying to pick such areas strategically and make them happen may not serve us well unless there is a particular reason the area is "sticky" to New Zealand or relates to a resource where this country already has an intrinsic competitive advantage. A superior approach is to have systems that quickly identify where a world leadership role is possible and then invest to grow the relevant group and provide them with suitable resources. Such an approach also needs to recognise when our advantage is gone, and be prepared to abandon those areas in favour of new emerging ones.

Key challenges unique to New Zealand include:

Protection and guardianship of the environment and our land-based activities

New Zealand has a landscape that is one of the most transformed from its natural state. Hence the minimisation of any further irreversible change, and actions to reverse those undesirable changes that are reversible is a national responsibility. Research is critical to both aspects and realistically can only be undertaken here [12].

We are also facing substantial threats to New Zealand's land-based activities due to climate change, extreme weather events, the impact of fire, invasion of pests and pathogens [13], and needing to develop more resilient ways to use our land. Included within this is developing holistic models of land-use and product diversification building on our natural resources.

New Zealand's biodiversity – a vital subset of the environment

New Zealanders live in a country remote from other land masses, with rich, diverse and unique biological ecosystems that have developed over millions of years. After splitting from other continents 80 million years ago, evolution in New Zealand has taken a unique course, resulting in plants, animals and ecosystems that are found nowhere else in the world. New Zealand is a recognised biodiversity hotspot and, as such, is of supreme interest and importance from a global perspective. New Zealand has international obligations in this area.

However, the taxonomic understanding of the New Zealand biota is undeveloped compared to other advanced economies and we know far less about our marine areas than we do our land. New Zealand should strive to have deep and comprehensive knowledge of its biota across its lands, fresh waters, and surrounding seas that: defines New Zealand's evolution, its uniqueness and cultural icons; allows New Zealand to sustainably manage and protect its natural resources and economic opportunities; enhances New Zealanders' health and wellbeing; and allows New Zealand to meet its global moral and legal obligations [2].

Agricultural greenhouse gas emissions

New Zealand also produces an unusually large portion of methane (CH_4) and nitrous oxide (N_2O) emissions due to the significant role of agriculture in our economy. This accounts for around half of our total annual GHG emissions. On-farm GHG emissions per unit of farm product (emissions intensity) have fallen consistently over the past two decades owing to increased productivity per animal or per hectare. Nonetheless, absolute agricultural emissions have grown because of an increase in total production, mainly of dairy products in response to growing global demand.

Research and investment in new agricultural mitigation technologies offer the potential for significant emission reductions in the medium to long term and is a critical leadership area for this country [1].

Health of Māori and Pacific Peoples

New Zealand has a unique population and Te Tiriti o Waitangi obligations. The health outcomes for many people who live here, and are of Polynesian ethnicity, are poor. New Zealand has responsibility for research to address the health needs of these people within New Zealand, but also to recognise our regional responsibility to Polynesian people more generally [5]. Additionally, research into the structural social and economic inequities of Aotearoa and their impacts on families, children, communities, vulnerable groups and others would be valuable.

Mātauranga Māori

The Society supports the further work envisioned in the strategy to advance Vision Mātauranga and do more work to draw on Mātauranga Māori and Rangahau in meeting the aspirations of Aotearoa/New Zealand. There is a specific responsibility to grow this unique kaupapa and associated knowledge system. For example, Māori held the only human knowledge of Aotearoa and its environment for several hundred years prior to colonial settlement. There is a need to build cross-cultural understanding in regards to the rights, interests, and values of Māori across institutions, agencies and researchers from a wide range of disciplines [14-18].

The Society's view is that the draft RSI strategy is currently positioned towards incorporating Mātauranga and Māori participation within the existing RS&I structures, rather than acknowledging Mātauranga Māori as a valid knowledge system in its own right with specific characteristics and needs. The Society encourages engagement with a wide range of Māori stakeholders seeking their assistance to reposition what is in the draft strategy and consider the specific needs and approaches of Māori communities

Our key challenge – Connectivity

Do you agree that a key challenge for the RSI system is enabling stronger connections?

Connections are vitally important in two major ways – our researchers connecting to other researchers (both locally and internationally), and researchers connecting to end-users. Connections are an enabler rather than an end in themselves. High quality infrastructure including national and international inter-connectivity is important given our dispersed economic and research geography. New Zealand probably needs to spend more than most other countries to support the necessary international connectivity of our research organisations.

The Society's view is that New Zealand can (and does) compete internationally in many areas of science, making fundamental discoveries and innovations that advance knowledge and its application in a global sense [19]. Exposure of this work at an international level is a driving force for our best scientists. Participating in international scientific collaborations is an essential part of world-class research, and international investment in New Zealand hi-tech companies also often depends on the international reputation of scientists in our universities and CRIs.

A key driver of researcher to end-user connection is the one-way transfer of people – an ex-researcher who is the "client" may prove a key success factor for connections that actually derive benefit. Further, such transfers shift both valuable Human and Intellectual Capital value to the end-user community.

Improving the connection between researchers and communities is vital for ensuring ongoing trust in science and technology [20]. The strategy also needs to reflect the specific approaches of Māori and Pacific communities which include, for example, more emphasis on involvement in the establishment phase of research and a whanau-based approach to delivering it and recognising excellence and impact.

The government could also usefully consider further initiatives (or scale up existing initiatives) to: (i) incentivise research organisations to provide research services to firms by subsidising such interaction (this builds Human Capital in both places); (ii) complement the new R&D tax credit with project-based grants to firms to bring in human capital that won't be captured by the overall tax incentive; and (iii) provide incentives to better align PhDs

with industry and other end-user needs, and the flow of talented graduates into firms and other end-user environments.

Guiding Policy – Excellence

Do you agree with the definition of excellence presented here as the best thing possible in its context?

Research of high Intellectual Capital value, that is also highly applicable, will be exceptionally strong in impact and connection. Hence we recommend a much more nuanced view of excellence. There needs to be a context-relevant definition of excellence that is fit-for-purpose for each type of research. Our preferred approach of testing excellence is through the likely extent to which Human and Intellectual Capital value can be created and applied in the relevant contexts.

Thus, whilst the characteristics of excellence identified are important, care needs to be taken in using them. Excellence is context dependent and really only stands independent of context in investigator-led research with peer review where the quality of an idea and method are the main measures. For mission-led and user-led research, in which fitness for purpose is highly important, global context is less relevant.

For investigator-led research, there is a strong academic understanding of, and international proxies for, excellence. However, the application of these proxies to mission-led or user-led research would often be less appropriate. For infrastructure, excellence is ensuring we have world-best practice in data management, use of technology and accessibility, while meeting New Zealand's specific needs for protecting its environment and people.

People

In some contexts, excellence means publishing in high profile international journals and prestigious (largely US-based) university presses. For non-Anglo colleagues it also means publishing in English. Research excellence is increasingly assessed through proxies such as PBRF grades, h-index of individual researchers, citation scores, journal impact factors and other such metrics. Many researchers feel they have been incentivised to perform this version of research excellence through labour market dynamics and promotions processes. They argue that to succeed in these terms means moving up the research hierarchy by strategically publishing and focusing narrowly on the research component of their roles, to the detriment of teaching in our universities and wider forms of organisational citizenship essential to making our research ecosystem work.

Highly individualised and competitive features of the research landscape may be both biased and dated. Research colleagues in CRIs, independent research organisations, the private sector and iwi organisations will already be attuned to a much more porous and heterogeneous research landscape.

The Society draws attention to the growth of new research relationships with industry, government and cultural institutions. We should be particularly aware of such relationships in Aotearoa New Zealand given the importance and influence of kaupapa Māori in shaping knowledge formations and research practices in this country [21]. Excellence proxies used by MBIE need to reflect this diversity. For example, for Māori (and Pacific) researchers:

- While research (rangahau) is important and has the potential to take Māori to the world, research begins with the aspirations of local communities, and Māori researchers are measured by the expectations and accountabilities put on them by their communities to make a difference.
- The research ecosystem is also very important in indigenous research, and has moved from a focus on individual research stars towards research teams, team leaders and collaborations.

Partnership

There are changing conceptions of research excellence emerging in an engaged, interdisciplinary and cross-sectoral world. A more holistic adoption of research excellence requires different skill sets to those we have traditionally preferred. Established relationships, inter-personal skills, and significant amounts of emotional labour are used to negotiate, not just with research partners, but with the rapidly changing expectations of funders and host organisations who now see research collaboration as a means of delivering on wider ambitions. If we need researchers capable of doing this kind of work then we will need to think differently about doctoral training, appointments processes, and academic professional development.

This new environment has implications for our funding arrangements. We know from Māori researchers and community organisations the importance of research partners being named as full co-investigators rather than simply as sub-contractors. This means such partners can be brought in at the beginning of the research process, and they are recognised as full contributors to the research process. To deliver more fully on these ambitions for collaborative research, there may need to be increased use of two-stage funding models that allow for the explicit funding of relationship building; and partnerships in which non-traditional research organisations have control over their own proportion of the funding [21].

New Zealand Journals

The Society also notes that New Zealand journals play an important role in publishing excellent research that is relevant to New Zealand, and that excellence in research is not determined by the journal it is published in. The Society is already concerned that there is an expectation of publication in international journals where possible and has submitted these concerns to the PBRF review. Focussing too strongly on international journals, especially in mission-lead research with particular relevance to New Zealand, could threaten the viability of the New Zealand-based journals and remove an important part of the publications infrastructure.

How can we achieve diversity within our research workforce?

What are the current barriers preventing a diverse range of talent from thriving in the RSI system?

The Society agrees that there needs to be improved representation of under-represented groups but wishes to ensure that such changes are evidence-based. Goals include more women in high level roles, and more Māori and Pacific people at all levels. There is a need for further analysis, but it is well-known that female researchers are over-represented in temporary employment early in careers, and progress to senior roles disproportionately slowly.

The low participation of Māori and Pacific people is deeper seated. The likelihood of a student even starting a higher degree is low. The reasons behind this are likely outside the scope of the RS&I strategy. The strategy

needs to reflect and support the needs and approaches of Māori and Pacific researchers. For example, are processes for research-grant applications perceived by Māori and Pacific researchers as supportive of the way Māori and Pacific researchers think and act?

Guiding Policy – Impact

How can we improve the way we measure the impact of research?

The Society would be uncomfortable if attempts to assess impact go beyond a very broad-brush approach. Rather, we believe that a well-performing system is characterised by:

- Demonstrable and valuable contributions to the body of knowledge,
- Demonstrable increases in tacit knowledge and know-how, with those skills contributing widely beyond the research sector,
- End-users progressively providing the resources to further develop products, processes or services using new knowledge and the skills transferred from the research sector.

Whilst much attention is paid to finding examples of when Intellectual Capital value is found to have impact, there is also the need to acknowledge Human Capital for its impact, both outside and inside the research community. For example, where the private sector has a high level of literacy of the research and development process it will seek research input in its search for solutions. Such literacy is seen in the number of the high technology companies in the New Zealand manufacturing and professional services sectors. Their use of the research sector does not align with the linear results-chain model set out in the draft strategy.

Likewise, where central and local government have a high level of literacy of the research and development process they will seek research to inform policy development and manage social and environmental issues in the public interest. Such literacy is seen for example in the government appointing science advisers and employing researchers.

Another example of the potential diversity of impact is in the UK Research Excellence Framework (REF) assessment process. Here the excellence of 'impact' is assessed through narrative case studies and underpinning evidence. Impact case study writers, journalists, film-makers, bloggers, public engagement experts all have roles to play in ensuring the research had impact, and that this impact can be evidenced as 'excellent'. Impact assessment needs to be broad brush, not at a project or even programme level, but more at an agglomerated level [21].

By overly focussing on seeking to demonstrate attributable impact it is possible that the system can be inadvertently dis-incentivised away from Human Capital value development.

ORCID, once fully implemented, will provide a useful evidence base for impact on the body of knowledge. Information from ORCID will allow our research system to understand the impact of funding programmes by tracking the outputs of the research funded [22].

Actions – Making New Zealand a Magnet for Talent

How can we better nurture and grow emerging researchers within New Zealand and offer stable career pathways to retain young talent in New Zealand?

The research community is part of an international labour market – for researchers to be attracted and retained then the working conditions and rewards need to be sufficiently attractive. We commend the application of labour market analysis to the issues of research talent.

The goal of attracting and retaining talent is worthy. It should also be while acknowledged that time spent in international contexts develops connections which aid knowledge transfer back into the country. It is also important to note the role of specialisation in an increasingly knowledge-led world and our small contribution to the global knowledge base. New Zealand cannot supply all our own specialists and should expect to "import" some Human Capital from overseas to support RSI here. Ensuring immigration and other relevant settings are optimised to attract this talent is important. If analysis of immigration data shows we have a net export of inexperienced researchers and a net inflow of experienced researchers with great track records, we would then be a proven "magnet for talent".

The Society's greater concern is our view that institutional drivers are creating a mismatch between the knowledge and skills acquired through postgraduate tertiary education in this country and the skills needed in employment. The technical aptitude and, in particular, transferable practical skills that employers are looking for in job applicants appear to be lacking [23]. This suggests the need for change in the nature of doctorates and masters towards programmes where the research is conducted more often in end-user communities, with the likelihood the researcher will immediately flow on into worthwhile and stimulating employment there. We need top talent as much in the end-user communities as the research laboratories. Top talent in end-user communities goes a long way to improve connectivity, as stated earlier.

There may also be a need to ensure that price signals in the research labour market are appropriate, for example that stipends offered in high-demand disciplines are realistic to attract top talent.

Other factors include the impact of research funding mechanisms on career stability (lest top people walk to more secure employment environments). It is doubtful that many, if any, researchers would want to undertake temporary employment – most do it as a means to getting to more secure employment, and use it as a way to enhance their CVs to gain that permanent employment. Is our research system holding people in temporary or insecure roles for unduly long times?

In addition, despite the common refrain that the New Zealand science system is 'fully costed', PhD students fulfil a systemically-important role in the science system because they are subsidised via Vote Education outside the fully costed RS&I model. This may have negative implications for the students (in terms of remuneration below salary level), but it also reduces the supply of Post-Doctoral opportunities, as senior researchers are incentivised to use PhD student labour over fully costed Post-Doctoral labour.

Actions – Connecting Research and Innovation

What elements will initiatives to strengthen connections between participants in the RSI system and users of innovation need in order to be successful

Successful connections occur when there is something the parties perceive to be of value that unites them in joint endeavour. The level of spend from an end-user community with a research organisation also tells much about the strength of connections. The performance by CRIs and independent research organisations in obtaining such income is strong.

Some other connections are already strong. For example, New Zealand already does well at researcher-to-researcher level on our publications both nationally and internationally. Marsden funded university research is very international [24].

Universities gain the bulk of their research income from non-commercial sources so if there is a need for stronger connections it may be a higher need in that sector than in CRIs. However, end-user connection is not their core role, which is instead research-lead teaching. An under-utilised route for developing connections is where research students undertake their research located in an end-user community, rather than a research organisation laboratory. That draws supervisors and the student into regular contact with end-users, and if successful leads to enduring connections.

At a strategic or organisational level, our historical reliance on competition (to drive excellence) creates a tension with cooperation between entities. A belief that success requires collaboration supports multi-party bids However, once funding is gained, sub-contractors often report they are used as a convenience and disadvantaged in practice. This is particularly the case for many Māori researchers. Further, programmes such as the National Science Challenges suffer a significant overhead cost of maintaining the cooperative multi-party approach.
It would be helpful to develop better understanding of how other countries have found an appropriate balance between the benefits of competition for funding, whilst allowing the necessary flexibility needed to enable enduring connections to develop and bear fruit.

Are there any themes that we need to take into consideration?

Government policy research

The Society proposes that as part of the strategy, the government considers establishing a new fund focussed on supporting the aspiration in the strategy for innovation in public services. This would make use of recent developments in the use of government data through the IDI, and allow a more joined up approach to research-informed policy advice. This would also helpfully complement the Science Advisor Forum chaired by the Prime Minister's Chief Science Advisor.

Actions – Start-up

Are there any other initiatives needed to support start-ups?

A reality for start-ups in New Zealand is that they cannot develop scale in the local market. Hence they need significant capital investment far ahead of revenue generation. They will generally be industrial marketers rather than consumer marketers, will generally operate in narrow niches which are too small to interest large multi-national companies, and they will often be the globally dominant supplier in the niche. To succeed they need high risk but very patient capital. They also need help in market development and supply chain logistics.

A successful start-up will have high initial Intellectual Capital value. Hopefully, with the right decisions, and with the availability of capital and expertise in disciplines it does not initially hold itself, it will deliver a product to market with high levels of embodied knowledge. The challenge is to do this quickly enough to avoid the loss of value by the appearance of a competitor.

The past 20 years have seen slow but steady growth in the angel and venture investor community, but always the need to find high-risk Financial Capital that will go the journey for the long term return from global penetration.

The Society encourages ongoing and greater support, for example through incubators, Pre-seed funding, the commercialisation networks (which are an important connecting initiative), and venture capital initiatives. However, soft start-ups (i.e. those formed inside existing entities or between existing entities) can deliver better outcomes because many start-ups do not stay in New Zealand, instead heading overseas well before they are cash positive.

Actions – Building Firm Foundations

What additional research and innovation infrastructure is necessary to achieve the goals of this strategy? What elements will initiatives in this area need to be successful?

The Society supports "firm foundations" as a critical part of the RSI strategy. Just as in the general economy there is significant investment in infrastructure as a means to improve economic efficiency (e.g. speeding up circulation of goods and services), there is a similar need and justification for research infrastructure. It is justified as an essential enabler, but also by the increased efficiency it brings across the system compared to local supply which may lead to duplication or competition.

Infrastructure includes both equipment (such as high speed computer facilities and networks) and the data that provides much of the evidence base for the research system (e.g. understanding our biodiversity.)

It also includes many elements of "softer" infrastructure. For example, New Zealand's national taxonomic collections (which are distinct to Aotearoa) and taxonomic expertise are vital to our economy and society. Biological collections, taxonomic research, and the associated databases and biodiversity information systems provide the scientific baseline that underpins the management of New Zealand's unique biodiversity and living

economic resources, including both native and introduced species. They ensure ecological science is reproducible and enable New Zealand to meet its legislative and international obligations [2].

Justifiable infrastructure requires a long-term commitment and stable investment to work effectively. The annual cost of providing enabling infrastructure is a relatively small fraction of the benefits. For example, an effective biological collections infrastructure is critical in the defence of the economy, environment and society against pests, diseases, and weeds which currently cost New Zealand $2.45 billion annually, and in ensuring market access for New Zealand's $1.5 billion seafood exports [2].

New Zealand has historically under-rated the importance of research infrastructure and this is reflected in an infrastructure deficit. The strategy needs to recognise this and propose investment at more realistic rates, as occurs in other countries such as Australia.

Other comments relevant to the questions

The Society supports regulatory change and standards settings where appropriate, to enable and maximise impact from research (e.g. emissions, freshwater quality, pollution, plastics recycling) and to assist the move towards a circular economy over time.

The Society would like to see government investment made on a real rather than nominal basis so that the purchasing power of existing investments is at least maintained over time once investment is in place.

Public sector innovation challenges

Public innovation often has to balance confidentiality with transparency an openness when partnering with the private sector and there is an expectation of openness and availability of quality assured data and data infrastructure. The costs of the latter appear to be under-valued over the long run. The private sector does not have these issues as they are mostly at the development end of innovation and don't see their role to support national infrastructure.

Further information

This paper has been developed for the Council of the Royal Society Te Apārangi. For further information, please contact info@royalsociety.org.nz or go to the Royal Society of New Zealand web page: http://www.royalsociety.org.nz/expert-advice/

Appendix 1: Rationale for investment to support economic development

The strategy should better acknowledge the relative roles of private sector R&D. and the public sector for research supporting economic development. Nationally, about 80% of economically-driven R&D is undertaken in the private sector and about 20% in the public sector. (e.g. 2018 Stats NZ data).

The primary sector has some specific characteristics. Whereas in manufacturing small businesses fund their own R&D, there is a long history of the Government gifting much R&D to the primary sector, rather than levying those sectors at a level they can fund their own, as most other businesses do. The strategy needs to be clear that due to our agricultural economy and the traditional organisation and expectations of that sector, Government is carrying more of the economic research burden than the norm in other economies.

Beyond the farm gate, in our style of economy, where firms cooperate with each other in R&D it is normally through clustering of dis-similar firms (e.g. part of a value chain) which offer complementary products and services, rather than firms with similar products. Firms that compete against each other in the marketplace will tend to only work together on certain types of issues – like those assisting market access or improving sustainability. Further, firms that succeed in going global from a small domestic base are normally industrial marketers (rather than consumer marketers), offer narrow niche products for which the global market is too small to interest multi-nationals, and have low capital requirements for manufacturing or scale-up.

Existing companies run their own R&D in-house to maintain control. Where they draw on the public sector it is to seek assistance with issues they cannot resolve in-house, or to access new skills. This is the dominant model for economically important R&D. The much smaller component of total business-related R&D is the "science push" component from the public sector. Some of this goes to existing companies to morph them towards a higher technology future, but much goes into start-ups.

Additionally, the strategy should acknowledge the relative absence of multi-nationals from our economy, and the implications of this. Multi-nationals regularly scan the public sector for new Intellectual Capital, seek to grab it, and exploit it. With the absence of multi-nationals, New Zealand can expect to have lower patenting activity as successful patenting requires the large resources that typically only very large companies can bring to bear. Not having multi-nationals also reduces one of the easier routes for the science push component from the public sector.

The route of Human and Intellectual Capital creation in the public sector research organisations and transferring to the private sector is important, but the majority process for intellectual capital is its creation in the private sector itself. The role of Government is to provide incentives (e.g. the tax incentive), the right types of Human Capital as new entrants to the private sector and, more importantly, to incentivise researchers to have the desire to move to the private sector. Part of Callaghan Innovation's role could to be to provide a conduit for developing Human Capital and transferring those that carry it into the private sector.

In summary, the role of government in Aotearoa for stimulating economic activity has a large component of incentivising existing companies and creating human capital for them. Two other components are research for the development of the primary sector, and research that leads to science push to existing companies and/or start-ups.

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