Article

Science and innovation policy for New Zealand

Adam B Jaffe*
Motu Economic and Public Policy Research, PO Box 24390, Wellington 6142

Abstract

The 'Science of Science Policy' is an interdisciplinary field of scholarly study that seeks to model, measure, and evaluate the interaction of public policies (including funding) and the performance of the science and innovation system. Such study offers insights and findings that can increase the effectiveness of science and innovation policy for New Zealand.

New Zealand's rate of public investment in research is only about two-thirds, and that of business investment in research about one-third of the OECD average. Our low business R&D intensity is not unexpected given our market size, firm size, and industrial composition. Nevertheless, public policy should aim to mitigate barriers to firms' ability to undertake high-return research investments.

As we undertake only 0.2% of the world's research, most of the knowledge used in New Zealand is created elsewhere, so positioning ourselves to derive maximum benefit from others' research is likely to have high payoff. The spillover phenomenon should be considered in making decisions about public research support. A re-balancing from competition towards cooperation, and encouraging linkages between research entities and organisations with a commercial orientation will increase the likelihood of spillover benefits.

Research output could be increased relatively quickly by increasing the currently low expenditure per researcher, but any sustained increase will require more skilled scientists and engineers. Therefore public financing of research should include a monitored programme of training grants, and immigration policy settings that do not inhibit attracting skilled scientists and engineers. Attraction and retention of research 'stars' should be an explicit objective of New Zealand science policy.

A culture of innovation requires an attitude that defines success in terms of the global market, not the local market. It requires a social, economic and cultural environment that rewards risk-taking and does not see failure as a barrier to undertaking further investment. Policy makers, too, should be willing to take risks, and systematic evaluation procedures should identify the sources of failure.

**Correspondence: adam.jaffe@motu.org.nz*

The science of science policy

In 2005, Dr John H. Marburger, then Director of the US Office of Science and Technology Policy, issued a challenge for 'a new "science of science policy" that will begin to systematically address the need for better scientific theories and analytical tools for improving our understanding of the efficacy and impact of science and technology policy decisions.' (US Office of Science and Technology Policy, 2008) An interagency task force created a 'roadmap' for research, and the National Science Foundation funds a Science of Science and Innovation Policy research grant programme. While many or most of the policy initiatives of the Bush administration were abandoned or greatly modified by the incoming Obama administration, this is one that appears to have continued without disruption.

Research under this rubric falls into three broad categories:

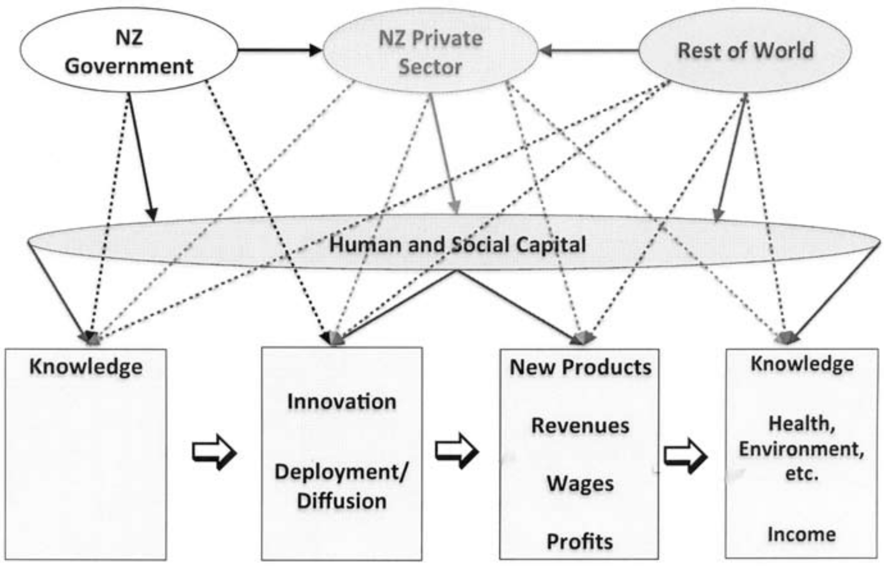
- collection of data and development of metrics and proxies;
- theoretical and empirical modelling of research and innovation processes, particularly interactions between researchers and the socio-economic system; and
- performance evaluation of specific policies and policy instruments.

Some of what is known or being learned under this rubric applies to New Zealand; other aspects of the science/innovation system in New Zealand are distinctive. Modelling a point I will make more generally below, I believe New Zealand should learn what it can from others' research in this area, and then think about what research is needed to understand the consequences of our specific situation.

The New Zealand science/innovation system and the role of public policy in influencing that system are illustrated schematically in Figure 1. At this level of generality, the picture would be similar for any country, although the significance of the different influences conveyed by the arrows will differ greatly across countries. Based on research in other countries, the following general observations can be made about the elements of the science/innovation system represented in Figure 1:

Adam B Jaffe joined Motu as Director in May 2013. He is also the Fred C Hecht Professor of Economics at Brandeis University in Waltham, Massachusetts. He was previously Chair of Economics and Dean of the Faculty of Arts and Sciences at Brandeis, Associate Professor of Economics at Harvard University, and Senior Staff Economist at the President's Council of Economic Advisers under President George H W Bush. A graduate of the Massachusetts Institute of Technology and Harvard University, Dr Jaffe is the author of two books—*Patents, Citations and Innovations: A Window on the Knowledge Economy*; and *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress and What to Do About It*. Adam is also active in public policy formulation and debate, and has served on numerous panels and committees in the USA for the National Science Foundation, the National Institutes of Health, and the National Academy of Sciences. He is a Lead Author for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. He has also testified before the US Congress on patent policy reform.

Figure 1. Schematic model of the science/innovation system.



1. In general the social rate of return to investments in research is high (Adams 1990; Griliches,1992; Hall *et al.* 2009). Although the New Zealand context complicates analysis of these issues, as discussed below, this suggests that the long-run rate of economic growth in New Zealand will depend on our intensity of investment in the creation of new knowledge and new technology.
2. Knowledge and innovation are what economists call 'non-rival' and 'non-excludable' goods. Non-rival means that one agent's enjoying the benefits of the good does not prevent others from also enjoying the benefits (like clean air as opposed to porridge). Non-excludable means that it is potentially difficult to prevent others from enjoying the good. (The two attributes usually go together, but not always; an mp3 recording is non-rival but excludable.) Public goods tend to be underprovided by private markets, because they yield social benefits that are widely enjoyed, and the party that creates these benefits typically receives compensation that is only a fraction of their overall worth. Hence governments invest in science and technology for the public good, because the 'spillover' of research benefits beyond the party doing the research tends to constrict private investment.
3. The public benefits that are the ultimate goals of such investments include knowledge valued for its own sake; specific improved outcomes such as better health and cleaner environment; and increased incomes through higher profits and wages. The linkages between specific government actions and these ultimate objectives are complex and highly intermediated by forces beyond the government's control.
4. Human capital—the knowledge and skills possessed by New Zealand citizens—is vital to every stage of the processes that ultimately produce the outcomes we desire. Therefore, all government policies should be formulated with consideration of fostering the creation and maintenance of human capital.
5. While we often think of science and innovation policy as being mostly about government research support, government also influences the actions of the private sector in many ways that affect its decisions with respect to research and deployment of technology. Policy on taxes, trade, regulation, and immigration are ultimately at least as important as research support.

The New Zealand context

While economic theory tells us that the social returns to investments in knowledge and innovation are likely to be higher than the private returns, it does not follow from this that having a higher overall investment rate is always better, and it does not tell us an optimal rate of investment. There is, however, circumstantial evidence that the rate of investment in New Zealand is lower than optimal. This evidence combines the facts that: (1) the level of investment (relative to the overall size of the economy) in research in New Zealand in the last few decades has been lower than most other industrialised economies; and (2) the countries that have invested at a higher rate have generally had more rapid economic growth and generally have higher income per capita than we have.

Table 1 provides some illustrative statistics regarding the science and innovation enterprise in New Zealand. Column 1 shows total research expenditure as a percentage of GDP. New Zealand spends about 1% of GDP, which is about one-half the OECD average and slightly more than one-fourth the percentage for the highest spending countries. Interestingly, Column 2 shows that employment of people in research in New Zealand seems much higher than one would expect based on the expenditure numbers. The fraction of the workforce engaged in research in New Zealand is, in fact, about 40% above the OECD average and almost two-thirds that of the countries with the highest research employment share. Note that New Zealand's GDP per capita is slightly below the OECD average, and its fraction of the workforce employed is higher than the OECD average, so our position in terms of research expenditure per employed person is even lower than indicated by the research/GDP ratio. Arithmetically, there are three possible factors that could reconcile a relatively high research workforce share and a relatively low research expenditure share: (1) the definition of 'researcher' in New Zealand is broader than that used in other countries; (2) the wage of researchers in New Zealand, relative to other New Zealand workers, is lower than the wage of researchers in other countries relative to their other workers; or (3) non-wage expenditures (equipment and supplies) per researcher are lower in New Zealand than elsewhere.

I do not know if there is anything to the possibility of differences in definition. Casual observation indicates that research wages are lower in New Zealand than in other countries, but

Table 1. Resource investment indicators.

	(1)	(2)	(3)	(4)	(5)	(6)
	Total Research Expenditure as Percent of GDP: 1999; 2009[1]	Researchers as Percent of Total Employment, 2009[2]	Public Research Expenditure as Percent of GDP: 2007[3]; 2010	Business Research Expenditure as Percent of GDP: 1999; 2009[1]	Important[4] patents per Capita, 2007-09	Trademarks Abroad per Capita, 2007-09
New Zealand	.98; 1.17	1.08	.51; .55	.29; .50	11	48
Other Countries Similar to NZ	Russia 1.0; 1.24 Hungary .67; 1.15	Denmark 1.23 Sweden 1.05	Russia .33; .56 Australia .45; .53	South Africa .39; .54 Turkey .18; .34	Italy 12 Iceland 11	Sweden 49 Ireland 44
OECD Average	2.16; 2.33	.76	.72; .75	1.49; 1.62	38	28
Highest	Israel 3.52; 4.28 Finland 3.17; 3.96	Israel 1.71 Finland 1.67	U.S.A. .99; 1.18 Finland .92; 1.10	Israel 2.49; 3.42 Finland 2.16; 2.83	Switzerland 115 Japan 107	Luxembourg 283 Switzerland 221

Notes:
1. 2007 for New Zealand and 2008 for OECD Average
2. 2007 for New Zealand and OECD Average
3. 2008 for New Zealand and OECD Average
4. "Important" patents are defined for this purpose as those that were granted in the U.S., the European Union and Japan.

Source: OECD, Science, Technology and Industry Scoreboard 2011, Main Science and Technology Indicators Database; http://dx.doi.org/10.1787/888932486070; http://dx.doi.org/10.1787/888932485899; http://dx.doi.org/10.1787/888932485386; http://dx.doi.org/10.1787/888932486659

wages in general are lower in New Zealand than in other countries; reconciling the expenditure and personnel data require that the wages of researchers are more depressed compared to other countries than are wages in general. One indication of what is going on is that about 75% of the tabulated researchers in New Zealand are employed in government or higher education, with the other 25% in the private sector. (This breakdown is not visible in Table 1, but is contained in the cited OECD data.) As can be seen by comparing Columns 4 and 1 of Table 1, on an expenditure basis, business accounts for about 43% of research. Thus expenditure per researcher is considerably higher in the private sector than in government and higher education. Assuming that the definition of researcher is consistent across these sectors, this suggests that research expenditure per researcher in the publicly-funded sector in New Zealand is truly low by international standards. Although the data do not separate wages and other expenditures, it is likely that both categories are relatively low.

Public investment in research

Column 3 of Table 1 shows the only indicator that is directly under the control of public policy, the rate of public investment in research. New Zealand's public investment rate is only about two-thirds the OECD average and one-half the rate of the highest-intensity investors (USA and Finland). As indicated above, the low level of public investment is manifested primarily as a low level of expenditure per researcher, rather than as a low number of people engaged in publicly funded research.

Analysis of New Zealand's public research investment by sector over the last four decades indicates no effect of public research expenditure in a given sector on productivity in that sector (Johnson *et al.* 2007). At the macro level, however, evidence from other OECD countries indicates significant long-run economic benefit from public investment in research (Adams 1990; Guellec & Van Pottelsberghe de la Potterie 2001; Wu *et al.* 2007). Calls for an increase in public research investment in New Zealand have been heard for many years, and repeated recently (Ministerial Working Party on Science and Technology 1986; Gluckman 2011; Hendy & Callaghan 2013). I will return to this issue below.

Private investment in research

With respect to business investment in research (Column 4), New Zealand's rate is about one-third the OECD average and one-fifth that of the highest intensity countries (Israel and Finland). Column 5 gives numbers for patents per capita. A country's patenting rate is determined to a large extent by its industrial composition (because patents are used more in some industries than others) and by its research investment. New Zealand patents per capita were about one-fourth the OECD average, and one-tenth that of the top countries (Switzerland and Japan, reflecting the importance of pharmaceuticals to the former and electronics to the latter, two high-patent-intensity industries). Thus these two indicators tell a similar story of significant relative under-investment in business-related research in New Zealand.

The last column of Table 1 presents data on trademarks, and provides an intriguing hint that New Zealand is more innovative when research and technology are not involved. Trademarks (like patents) vary enormously in their meaning and significance, so aggregate trademarks per capita should be taken with a grain of salt. However, it is interesting that on this measure New Zealand is significantly above the OECD average. This suggests, perhaps, that if the research and technology base could be strengthened, New Zealand businesses might well have the capabilities to exploit any increased commercial opportunities that emerge.

In other countries, R&D intensity is higher in larger firms than in small firms, and is higher in some industries than in others. New Zealand's firm size distribution is much more skewed towards small firms than other countries', and a higher-than-average fraction of our GDP is in sectors that typically exhibit low R&D intensity (primary industries and tourism). In addition, to the extent that firms give a significant weight in their investment planning decisions to potential returns in their home market, New Zealand's small size as a country would also reduce firm's incentives to invest in R&D. Statistically, one can estimate the average relationships across countries between R&D intensity and firm size, industrial shares, and home market size, and then use those estimates to calculate what New Zealand's business R&D would look like if those world-average relationships held in New Zealand. The result is that the observed R&D and patent intensities in New Zealand are at or slightly above what would be predicted by these worldwide relationships (Crawford *et al.* 2007). In other words, our low business R&D intensity is not surprising given our market size, firm size, and industrial composition.

From a policy perspective, the fact that New Zealand's low private R&D intensity is consistent with its industrial structure is useful but not dispositive. To the extent that these factors deter private R&D investment because the returns to such investment are relatively low, then public policy designed to increase private research expenditure might also have a low rate of return. That is, though we expect the social rate of return to exceed the private rate of return because of spillovers, if the private rate of return is relatively low in a given situation, it is potentially problematic to count on large spillovers to make public investment in that area worthwhile. On the other hand, to the extent that the industrial structure is associated with low R&D intensity because of barriers to firms' ability to undertake high-return research investments, then public policy aimed at mitigating those barriers could have a high return. If, for example, firms in New Zealand and other small countries do not invest in R&D because information on how to participate in international technology markets is difficult to acquire, then public investment in information provision (a local public good) could be highly productive. I will return below to how we could improve our understanding of the extent of barriers to New Zealand private research investment, and thereby inform public policy as to options that might exist to increase it productively.

Observations and speculative recommendations

The greatest analytical challenge for the science of science and innovation in New Zealand is to understand how our small size, remote location, and unusual industrial structure affect the relevance of lessons learned elsewhere. In the final section, I will suggest some empirical research that could clarify some aspects of this challenge. In the meantime, I make some tentative observations based on my understanding of the factors underlying the science and innovation system.

Knowledge creation

While the evidence is only circumstantial, I believe it is compelling that New Zealand's long-run wellbeing would be improved by a higher rate of investment in research and innovation. I will address the level of business research investment further below, but public and private research are economic complements (in the long run), so I will add my voice to the others that have called for an increase in public research investment.

Because of the public-good nature of knowledge and innovation, their creation in the Rest of World is of value to New Zealand. Further, as we undertake approximately 0.2% of the world's research, it will always be the case that most of the knowledge used in New Zealand is created elsewhere. Unfortunately the 'spillover' of research benefits is mediated by physical/social/organisational/cultural distance, so our remote location puts us at a disadvantage in enjoying the benefits of worldwide research. Nonetheless, given our size, positioning ourselves to derive maximum benefit from others' research is likely to have high payoff. This is not to suggest that we eschew doing research ourselves and try to free-ride on others' investments. Indeed, both casual observation and empirical research suggest that our ability to absorb the benefits of research done elsewhere depends upon having people engaged in active research themselves (Cohen & Levinthal 1989). Rather, it suggests that our choices regarding research areas, institutional structures, modes of government support, and other policy decisions should be taken with an eye to always getting maximum benefit from the larger investments being made elsewhere.

In any public funding programme, there is a tradeoff between competition and cooperation. Competition among research entities for public support is desirable to encourage excellence and to assist public decisionmakers in identifying the most promising candidates for support. Cooperation is desirable because research is subject to economies of both scale and scope, meaning that larger and more diverse research teams are more productive than smaller and more specialised ones (Jones 2009). While I cannot identify the optimal balance between these, New Zealand's small size certainly argues for much greater weight on cooperation than would be optimal in a larger country.

In public debate about government support of science, practising scientists sometimes bristle at the introduction of economic considerations into decisionmaking. Science should be valued for its own sake. However, science's intrinsic value is not a logical reason to ignore other possible benefits to society of public science investments. Recognising that investment in science has multiple objectives suggests that these investments will be most successful overall when all of the objectives are considered. This means that the spillover phenomenon and the resulting potential economic benefits of research should be taken into account in all aspects of science policy, including decisions about what kind of research entities to support, and the encouragement of linkages between research entities and firms or organisations with a commercial orientation. This observation also reinforces the point of the previous paragraph, because having a rich network of cooperation among diverse entities in the science/innovation system will increase the likelihood of spillover benefits (in addition to probably increasing the effectiveness of the research itself).

Finally, I would add a word of caution to the suggestion that public investment in research should be increased in New Zealand. Fundamentally, the rate of real investment in new knowledge is constrained by the availability of the specialised inputs to the research process itself, primarily appropriately trained scientists and engineers, but also specialised research equipment. This means that there is a limit to how rapidly the research enterprise can be effectively expanded, even if a large amount of money is made available. In economists' jargon, there are 'adjustment costs' in the research process, which make large changes in the rate of research investment inefficient (Goolsbee 1998). The doubling of funding for the National Institutes of Health (NIH), which was undertaken in the late 1990s, had very unfortunate consequences for the health research system in the USA: the response to doubling the budget was, understandably, to train more scientists, expand existing laboratories and build new ones, but when severe budget restraints came into play in 2003, this, coupled with inflation, caused the effective research budget to fall every year since, dramatically reducing the number of successful NIH research grants (Jaffe 2007).

The relevance of this consideration to New Zealand is made somewhat unclear by the appearance that we already have a relatively large research workforce, but one with a low rate of expenditure per researcher. It is possible that increasing expenditure per researcher could increase research effectiveness relatively quickly without generating significant adjustment costs. It is likely, however, that low expenditure on both wages and equipment have inhibited our ability to attract and retain the best researchers, so that a sustained increase in research output will require the attraction and/or development of additional high-quality scientists and engineers. That process requires time. Therefore, a gradual sustained increase in funding is likely to be more effective than a 'crash' programme to increase public research funding dramatically over a few years.

Building human capital

If it is true that any sustained increased in New Zealand research output will require an increase in the availability of skilled scientists and engineers, this suggests that explicit incorporation of training objectives should be part of public financing of research. This has been an important component of the generally successful (despite the problems associated with the rapid doubling last decade) public investment in health research in the USA (Cockburn *et al*. 2011). This could involve explict use of training grants as distinct from research grants, and should involve use of metrics related to trainee success in evaluation of grant programmes.

Given New Zealand's small size and historical relative under-investment in research, optimal growth of the research enterprise almost surely would involve an influx of scientists and engineers from overseas. This requires immigration policy settings that do not inhibit such flows.

Finally, research overseas suggests that location of research 'stars' – individuals in the extreme upper tail of the publication impact distribution – has a disproportionate effect on success of the research enterprise more generally (Darby *et al.* 1999; Azoulay *et al*. 2012). Thus, attraction and retention of stars should be considered as an explicit objective of New Zealand science policy. This could be another argument for being careful abour heavy reliance on competition in awarding grants; stars are likely to be successful in competitions but they prefer not to spend large amounts of time on proposals. It also may be an argument for identifying a small number of areas in which New Zealand, despite its small size, will seek to be a world leader, because stars will always want to operate at the frontier of world research.

Encouraging business research and innovation

It is likely that a significant increase in business research investment and innovation would increase the long-run prosperity of New Zealanders. However, it is important to be clear that, from a public policy perspective, business R&D expenditure is a means to that end, not an end in itself. In order to foster achievment of the ultimate goal of greater prosperity, government policy has to reduce barriers to private R&D investment, so that firms can and will undertake high-return investments. As discussed below, more research is needed to understand the nature of these barriers, but again I will make some tentative observations.

In general, public research investments foster private investments. The mechanisms for this effect are complex, however, and it should not be expected that public research investments in particular sectors will spur research or innovation in that particular sector. Indeed, as mentioned above, there is no evidence that public research investments in particular sectors in New Zealand have been associated with improvements in productivity in those sectors. Innovation is highly path-dependent, so it is likely that many of the most important commercial innovations will come from the sectors that are already large in New Zealand, but this is not a reason to favour those sectors in the allocation of public research support. Conversely, an increase in business innovation should be seen as requiring the creation or growth of particular high-technology sectors. Public investments should be made to support public objectives, while being agnostic as to which particular sectors may capture commercial innovation benefits.

There are two empirical regularities from the rest of the world that are likely to hold in New Zealand: large firms and firms focused on export markets are key to the innovation system. Large firms are important in part because they can undertake research investments at a scale that many small firms cannot, but also because they tend to be the training ground for entrepreneurs and the spawning ground for successful new startups. Ironically, having successful large firms seems to be important for generating successful small firms. Thus public policy should make sure not to create barriers to large firms. Since growing our own large firms will be difficult, we should be as open as possible to investment by multinational enterprises in New Zealand. Even if that investment is not in high-technology or high-value operations, increasing the presence of such firms here could have long-run benefits.

An export orientation is key to innovation, because the New Zealand market is too small to justify the kind of investment that is frequently necessary for significant innovation. How this should effect public policy is complex. Programmes that provide information on aspects of global markets such as import qualification or intellectual property rules might be productive. Policy choices that encourage New Zealand firms to look inward should be viewed with caution. In this regard, I worry about the decision not to grant software patents in New Zealand. While this makes it easier to introduce new software products here, it inherently encourages development of those products for the local market rather than for the global market, because in the global market other countries' software patents will have to be avoided. Hence the long-run effect of this change on information technology innovation in New Zealand is unclear.

Most fundamentally, innovation depends on a set of attitudes that are at least as important as the magnitude of research investment. It requires a social, economic and cultural system that rewards risk-taking. This means that both financial and non-financial rewards should be seen to be associated with commercial success. It also means that, while there are financial costs associated with failure, they not be paralysing, and failure should not be seen as a stigma or a barrier to undertaking the next investment. As noted, a culture of innovation also requires an attitude that defines success in terms of the global market, not in terms of the local market.

Finally, despite the image of the visionary entrepreneur cooking up a big idea in the garage, most significant innovations arise because of interactions between and among different people with ideas or knowledge about different pieces of what ultimately becomes a successful innovation. This means that an innovative society is a highly interactive one, in which people from different kinds of organisations (e.g. universities and firms) are in routine contact with each other. Public policy does not determine culture or social structures, but it does influence them, for example by the way it rewards competition versus cooperation and by the rules it imposes on public and private institutions (Little 2011).

Innovation in innovation policy

Science and innovation policy should model the culture of innovation desired for the science/innovation system. It should be willing to take risks, and willing to fail. This means trying different modes of policy intervention in a systematic manner, based on explicit consideration of mechanisms likely to be associated with specific policy goals. This should be done with the expectation that some of these efforts will fail, but that failure will be informative and allow more effective policy to be undertaken in the future. This stance only makes sense if systematic programme evaluation is built into all science and innovation support programmes from the very beginning. Such explicit incorporation of evaluation into initial programme design will facilitate *ex post* evaluation of such programmes that can isolate the 'treatment effect,' i.e. the extent to which the policy intervention resulted in improved policy outcomes relative to the counterfactual or but-for world that would have occurred without the policy intervention (Jaffe 2002).

Failure is a key aspect of a culture of innovation, but failure is difficult for bureacracies, be they public or private. I am not naïve about the difficulty of cultivating a constructive attitude toward failure in an electoral environment. Ideally, systematic evaluation can help by distinguishing different kinds of failure. Since research and innovation are highly uncertain processes, failure of one or a few investments should be distinguished from systemic failure; such distinction is facilitated if evaluation is systematic so that individual failures are always seen in the context of a portfolio of successes and failures, and failure of a particular policy instrument can be distinguished from failure due to incompetence. Again, that distinction is made most easily if evaluation is systematic, so that failed policy instruments can be replaced by others demonstrated to be effective.

It is important to note in this context that a culture of experimentation is not the same as instability in policy management and delivery. I understand that the Parliamentary system is different from the statutory government structure in the USA, but it is nonetheless shocking that the key groups responsible for science and technology policy in New Zealand have been reorganised twice in a few years. This is both wasteful of public resources, as a significant fraction of public servant effort is dissipated in adjusting to new structures, and also inimical to evaluation, since it is difficult to identify stable policies to evaluate. Whatever the merits of the current structure, it is to be hoped that it will now be allowed to operate in this form for a long enough period of time so that its strengths and weaknesses can be measured.

Topics for research

The science of science policy (SciSciP) can lead to better outcomes for New Zealand, but this will require better understanding of the workings of the New Zealand science/innovation system. Issues that could likely be illuminated by further research include:

What are the determinants of research, innovation and performance at the firm level? New Zealand has good data on individual firms in the Longitudinal Business Data (LBD) maintained by Statistics New Zealand. Econometric analysis of the characteristics that distinguish those firms that do invest in research, and of the relationships between such investment and innovation and firm performance, could shed light on the ways in which business R&D could be increased with high returns.

Is there potential for greater cooperation and collaboration, both among firms and between firms and government or non-profit entities? Study of the performance of existing coopeative and collaborative mechanisms, and identification of apparent gaps in this structure, could be useful for determining if there are barriers to successful cooperation.

Why do multinational enterprises invest or not in New Zealand? It is obviously a small market, but are other factors involved?

What is the relative effectiveness of different modes of public research support? As noted above, public research support programmes should all be part of a systematic evaluation programme.

What are the most important factors affecting migration of skilled workers into and out of New Zealand? All other policy efforts will be for nought if high-quality researchers do not choose to work in New Zealand. To some extent, we can assume they will be drawn in by other policies that increase research investment, but understanding the factors that matter could make the overall policy more effective.

Conclusion

Sir Peter Gluckman has recently issued a call for more systematic reliance on evidence in the formulation of public policy in New Zealand (Office of the Prime Minister's Science Advisory Committee 2013). One would hope that science and innovation policy would be the policy arena in which participants are most attuned to the importance of systematic evidence in support of policy formulation. There are, indeed, findings from the SciSciP that could make New Zealand policy more effective, though we need to be clear on the limitations of evidence in policy choices. First, much of the evidence has been developed elsewhere; more research is needed to understand how the general findings apply to New Zealand. Second, because science/innovation policy has multiple objectives, and those objectives (knowledge for its own sake, better health, cleaner environment, higher incomes, etc.) are largely incommensurable, policy choices must in the end be made based on values, though ideally informed by evidence. We should also be clear that there are no magic bullets. New Zealand's size and remoteness are real handicaps that we can work to minimise but we cannot eliminate, so science and innovation here will remain difficult regardless of policy settings.

Finally, though this is a challenge for elected officials, we need to acknowledge that no science or innovation policy initiative will have immediate benefits. Better policy in this arena will benefit future generations of New Zealanders, to some extent at the expense of today's citizens whose expenditure on other things will be reduced to make room for greater research investment. However, New Zealand has taken far-sighted decisions in the past, and can do so again.

References

Adams, J.D. 1990. Fundamental stocks of knowledge and productivity growth. *Journal of Political Economy 98(3)*: 673–702.

Azoulay, P.; Graff Zivin, J.S.; Sampat, B.N. 2012. Evidence from professional transitions for the superstars. In Lerner, J.; Stern, S. (eds) *The Rate and Direction of Inventive Activity Revisited*. Chicago, University of Chicago Press.

Cockburn, I.; Stern, S.; Zausner, J. 2011. Finding the endless frontier: Lessons from the life sciences innovation system for energy R&D. In Henderson, R.; Newell, R. (eds) *Accelerating Energy Innovation: Insights from Multiple Sectors.* Chicago, University of Chicago Press.

Cohen, W.M.; Levinthal, D.A. 1989. Innovation and learning: The two faces of R&D. *Economic Journal 99(397)*: 569–596.

Crawford, R.; Fabling, R.; Grimes, A.; Bonner, N. 2007. National R&D and patenting: Is New Zealand an outlier? *New Zealand Economic Papers 41(1)*: 69–90.

Darby, M.R.; Liu, Q.; Zucker, L.G. 1999. Stakes and stars: The effect of intellectual human capital on the level and variability of high-tech firms' market values. *National Bureau of Economic Research Working Paper No. 7201*.

Gluckman, P.D. 2011. The wider roles of science and innovation. *New Zealand Science Review 68(1)*: 49–51.

Goolsbee, A. 1998. Does government R&D policy mainly benefit scientists and engineers? *American Economic Review 88(2)*: 298–302.

Griliches, Z. 1992. The search for R&D spillovers. Scandinavian Journal of Economics 94: 29–47.

Guellec, D.; Van Pottelsberghe de la Potterie, B. 2001. R&D and productivity growth: Panel data analysis of 16 OECD countries. *OECD Economic Studies 33*: 103–126.

Hall, B.H.; Mairesse, J.; Mohnen, P. 2009. Measuring the returns to R&D. *National Bureau of Economic Research Working Paper No. 15622.*

Hendy, S.; Callaghan, P. 2013. *Get Off the Grass: Kickstarting New Zealand's Innovation Economy*. Auckland, Auckland University Press.

Jaffe, A.B. 2002. Building programme evaluation into the design of public research-support programmes. *Oxford Review of Economic Policy 18(1)*: 22–34.

Jaffe, A.B. 2007. Double research funding? Be careful. *The Scientist 3*: 34. http://www.the-scientist.com/?articles.view/articleNo/25181/title/Double-research-funding--Be-careful/

Johnson, R.; Razzak, W.A.; Stillman, S. 2007. Has New Zealand benefited from its investments in research & development? *Applied Economics 39*: 2425–2440.

Jones, B.F. 2009. The burden of knowledge and the 'death of the renaissance man': is innovation getting harder? *Review of Economic Studies 76(1)*: 283–317.

Little, S. 2011. Role of innovation in economic growth in a New Zealand context. *New Zealand Science Review 68(1)*: 8–11.

Ministerial Working Party on Science and Technology 1986. *Key to Prosperity, Science & Technology: Report of the Ministerial Working Party*. Wellington, Government Printer.

Office of the Prime Minister's Science Advisory Committee 2013. The Role of Evidence in Policy Formation and Implementation. http://www.pmcsa.org.nz/wp-content/uploads/The-role-of-evidence-in-policy-formation-and-implementation-report.pdf

US Office of Science and Technology Policy 2008. The Science of Science Policy: A Federal Research Roadmap. http://scienceofsciencepolicy.net/sites/all/themes/sosp_theme3/userfiles/SoSP_Roadmap.pdf

Wu, Y.; Popp, D.; Bretschneider, S. 2007. The Effects of Innovation Policies on Business R&D: A Cross-National Empricial Study. *Economics of Innovation and New Technology 16(4)*: 237–253.