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Paradox and potential: trends in science policy and practice in Canada and New Zealand

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Over the last 30 years, Canada and New Zealand have redirected their science and research systems to meet changing national priorities, and in response to global trends and needs. They have shared a common effort to transform their traditionally resource-based economies. Both are committed to the creation of knowledge-based economies that can compete internationally in the face of massive globalization and the rise of the BRIC nations (Brazil, Russia, India and China). Research, and science and technology, are seen as the primary drivers towards this goal.

Canada and New Zealand developed science systems shaped by their common British heritage. In recent years, their science systems have undergone fundamental changes, yet they continue to share many evolving trends, highlighted in the ideas, methods, values and norms identified as Mode 2, in The New Production of Knowledge. *These trends, however, have been shaped by different policies and different institutional arrangements, different theoretical perspectives and different political ideologies.*

Introduction

The science and innovation systems of Canada and New Zealand have similar cultural legacies, both countries having a strong British heritage, but economies which over time have been increasingly shaped by the influence and power of global markets. The design, function and organization of their original core government science institutions, namely the National Research Council (NRC) in Canada, founded in 1916, and the former New Zealand Department of Scientific and Industrial Research (DSIR), established the same year, have their origins in the British Department of Scientific and Industrial Research. Both countries have respected university sectors that are a key element in their national systems of innovation. Both also have royal societies founded in the 1880s.

Despite these similarities, the two nations are disparate on many criteria, including the geographical proximity and influence of their closest neighbour, the structure and dynamics of their political systems, population size, resource base, climate and location. In recent decades, the two countries have shared a common effort to transform their traditionally resource-based economies. In both cases, the stated aim has been the creation of knowledge-based economies, sustainable in the face of

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massive globalization, and the rise of the BRIC (Brazil, Russia, India and China) nations. Research, and science and technology, have been identified as primary drivers towards this goal, and policies for science in both countries have been, in large part, directed at re-shaping their science and research systems to meet national priorities and in response to changing global trends and needs. To achieve these goals, however, the two countries have adopted different strategies, reflecting their individual political, cultural and social contexts.

The context of change

Gross national expenditure on research and development (R&D) in New Zealand is 1.30% of GDP (Statistics New Zealand, 2010). This compares with 1.95% for Canada, against an OECD average of 2.34% (OECD, 2010). These figures are low compared with other OECD countries. This is particularly the case for New Zealand, which on this criterion currently ranks 26/34 in the OECD (Statistics NZ, 2010; OECD, 2010); Canada ranks 15/34 (OECD, 2010). These levels of R&D expenditure have commonly been explained by the structure of their economies and their historical dependence on natural resource use. With respect to New Zealand, country-specific factors, such as distance from major markets and heavy reliance on agriculture, have been suggested (see Di Maio and Blakeley, 2004; Crawford et al., 2004). Despite efforts to address this situation, in New Zealand only 38% of R&D is business funded; 46% is government funded, and 16% is funded by universities and from other sources (Statistics New Zealand, 2010). Despite similar efforts in Canada, the relative split is 48% business, 33% government and 19% other sources (OECD, 2010). Approximately one-third of all intramural business R&D in Canada in 2009 was performed by the top 25 companies, although this number is increasing. On the other hand, since the early 1990s, there has been a significant increase in business-financed R&D performed by Canadian universities (Science Technology and Innovation Council, 2011).

Structurally, the Canadian economy is dominated by small and medium-sized businesses. It is also dominated by service industries that, in 2008, accounted for 61.5% of private sector GDP and 72.6% of private sector employment. This sector has a low intensity of R&D (Science Technology and Innovation Council, 2009). While the number of companies performing R&D continues to rise, the average R&D expenditure in constant dollars has decreased and business R&D spending is now below that in 2001. New Zealand's economic structure differs significantly from the economic structures of other OECD countries; in particular, the contribution of its agriculture, hunting, forestry and fishing sectors is much higher. Its business sector consists largely of very small companies and over a third of these are in the Auckland region. Very few of its large firms carry out significant amounts of R&D. Agriculture, broadly defined, accounts for close to 60% of the country's exports (by value) and remains a key factor in shaping R&D investment (OECD, 2007). In both countries, labour productivity is low, the workforce is aging and cost containment has tended to dominate innovation in efforts to increase competitiveness.

Despite their shared colonial heritage and similarities in key elements of their economic development, Canada and New Zealand differ fundamentally in their constitutional arrangements. These have had a major impact on the redesign of their R&D systems and efforts to use science and technology to meet national goals. In both countries, however, the consequence has been a profound transformation in the production of knowledge that exemplifies many of the trends identified as Mode 2 in *The New Production of Knowledge* (Gibbons *et al*., 1994), including institutional arrangements, changes in the context of application, and quality controls.

The Canadian STI system

In Canada, the federal government has a constitutional responsibility for economic development and plays a key role as research funder, performer and facilitator in the national system of innovation. This role, however, is confounded by the division of power and responsibility between the federal government and the provinces that dates back to the British North America Act of 1867. The federal government has, *inter alia*, authority over macro-economic policy, foreign policy, banking and defence; the provinces have control of natural resources, property laws and education. Shared jurisdictions include social welfare, health care, agriculture and immigration.

The paradoxes and contradictions that characterize Canada as a nation are evident in the history of its discourse on science, technology and innovation (STI). Repeated themes are the investment in highly qualified and skilled personnel, yet Canada's difficulty in creating and sustaining profitable world class companies; the high level of private sector tax credits for research and development, yet the low level of R&D investment by the private sector and the paucity of firm-based innovation (Innovation Canada, 2011); the quality of academic research, yet the low level of commercialization of university research and the need for better linkages among the government, academic and private sectors (Expert Panel on Commercialization, 2006). These same themes are repeated in New Zealand.

In Canada, there have been Royal Commissions, major reviews and declared innovation strategies at both federal and provincial levels (see, for example, National Advisory Board on Science and Technology, 1995; Council of Canadian Academies, 2006; Expert Panel on Commercialization, 2006; Ministère du Développement Economique, de l'Innovation et de l'Exportation, 2006; Industry Canada, 2007; Innovation Canada, 2011), all of which generated much debate and contention. Change, however, has generally been slow and incremental. The focus of the 2007 federal S&T strategy (Industry Canada, 2007, 2009) on entrepreneurial advantage, knowledge advantage and people advantage still remains the dominant STI policy framework. In 2008, four R&D theme areas were identified by the federal government as priorities for public investment – environment, natural resources and energy, health and life sciences, and information and communications technologies. Since then, the digital economy has emerged as an additional thrust.

Canada has a business innovation problem. To date, however, the majority of policy and programme developments have been on the R&D supply side. The majority of federal instruments and investments in STI since the mid-1990s involve the three federal granting agencies or research councils, the Canadian Institutes for Health Research (CIHR), the Natural Sciences and Engineering Research Council (NSERC), and the Social Sciences and Humanities Research Council (SSHRC), as well as two foundations – the Canadian Foundation for Innovation (CFI) and Genome Canada (GC). Prior to the disestablishment of the Medical Research Council in 2000 and its replacement with the current CIHR, research funding was allocated in the relatively neat and simple format of three disciplinary-oriented research councils. CIHR's research is oriented towards application, not discipline, creating a much more complex landscape. All three research councils and associated foundations explicitly foster the translation and transfer of research findings to end users, and are directed at mid- to long-term socio-economic benefits.

The period from 1997 to the present represents a major and purposeful federal reinvestment in the universities designed to enhance Canadian research capacity and to catalyze private sector innovation through R&D 'push'. Three additional agencies for funding academic and hospital research also introduced new dynamics: the Canada Foundation for Innovation (CFI), established in 1997; the Canadian Health Services Research Foundation (CHSRF), also established in 1997; and Genome Canada (GC), established in 2000. The CFI, which has had a particularly large impact on the Canadian research landscape, funds research infrastructure needs, including large regional and national research resources and facilities; CHSRF fosters research and its application to support efficient and effective health services; GC has developed and implemented a national strategy for large-scale genomics and proteomics, positioning Canada centrally on the world S&T stage in this area of endeavour.

The three core funding agencies (research councils) operate at arm's-length from government. They provide funds through competitive review processes for the direct costs of research and research training, and cover all areas of academic R&D activity, from fundamental to applied research, including inter-sectoral partnerships, knowledge translation/mobilization, international collaboration and research training. New federal initiatives in the last decade have particularly focused on: (a) attracting and retaining world-class talent through well-funded competitive programmes of support for research chairs, graduate students and postdoctoral fellows; and (b) the transfer of the outcomes of research to end users. These actions have both enhanced the research environment and heightened the level of competition among institutions for the prestige associated with a number of the newer large awards. They also contribute in large part to the current, complex, overlapping nature of Canada's STI landscape.

Three additional substantive challenges of this new landscape are also receiving attention, albeit not as yet addressed: (a) the perceived failure of the federal government effectively to align capital (CFI), personnel (Canada research chairs, Canada excellence research chairs) and operating grants, leading to an expansion of infrastructure and positions unsupported by operating grants; (b) insufficient funding for the indirect costs of research, especially for research intensive universities; and (c) a need to streamline and coordinate national policies and practices among the various funding agencies and among academe, government and the private sector.

There are now calls from government and end users for increased collaboration and joint action to increase efficiency and economic benefits in an era of fiscal constraint, with increased private sector innovation being the prime objective. The academic R&D system is recognized as a dominant element in the national system of innovation; meanwhile, government laboratories face continued belt tightening and reductions in capacity as the policy focus has shifted increasingly to academic research.

Since the mid-1990s, government R&D has been downsized and more focused on departmental missions. With increasing strength and diversity in academic research, the focus within government science has been on shorter-term, mission-specific activities and support for business. In particular, the National Research Council's research institutes have tried to align their research with private sector interests. This has been promoted through contract R&D and the transfer of technology through industrial alliances, as well as through the support of start-up firms and the creation of spin-off companies. This has been reinforced by a recent federally-appointed expert panel (Innovation Canada, 2011), which declared that efforts to date have been insufficient, and made the recommendation to:

> Transform the institutes of the National Research Council (NRC) into a constellation of large-scale sectoral collaborative R&D centres involving business, the university sector and the provinces, while transferring NRC public policy-related research activity to the appropriate federal agencies.

Such a massive reorganization could not take place without perturbation in all sectors of the R&D landscape; it remains to be seen how the Canadian government will respond.

While the mix of indirect and direct measures to support business R&D in Canada has remained heavily skewed to the indirect (through tax incentives), the same expert panel has called for an adjustment in the balance between indirect and direct business R&D incentives, as well as process simplification, to foster the growth of small and medium-sized enterprises. These and other recommendations in its report are illustrative of the increasing dominance of innovation in the Canadian STI discourse.

The New Zealand STI system

Changes in the redesign of New Zealand's STI system have frequently been radical, even abrupt. This is made possible because, as a small unitary state, New Zealand has few checks and balances in its political system. The nature of these changes can only be understood within the context of the broader restructuring of the New Zealand economy and its public sector, which started in 1984 (Cartner and Bollinger, 1997).

By the early 1980s, New Zealand was in rapid economic decline, evidenced by increasing public debt and poor economic performance. Its ranking on GDP *per capita* among 28 OECD countries had fallen in a decade from ninth to eighteenth (New Zealand Parliament, 2001). The election of a new Labour government in 1984 resulted in the exposure of its hitherto sheltered economic environment to global market forces. An equally radical and widespread reform of the public sector was also begun. Although there had been long-standing debates within DSIR to redeploy science and technology to support and encourage economic growth, 1984 proved a watershed. A number of reviews and reports dating back to at least the mid-1970s (see, for example, NRAC Planning Advisory Group, 1975; Palmer and Miller, 1984; *Science and Technology for Development*, 1985; Miller and Mosley, 1985; Ministerial Working Party on Science and Technology, 1986; Bollard, 1986) contributed to the discussion. In the post-1984 environment, debate centred on the appropriate balance of public good (tax-payer based) funding *versus* industry-funded R&D investment, the extent to which market forces should be used to determine R&D needs, and the role of government in encouraging industry to develop a better pattern of R&D investment. The priority given to other areas of government reform, however, delayed the restructuring of the science system until 1988–89, although its gestation extends back over at least the previous 10 years. Significantly, these changes were implemented with broad, cross-party, political support.

Prior to this point, public research was directly funded by the government through budget allocations. Research agendas and priorities were determined largely by individual researchers and the institutions themselves. The main recipient of this funding was the DSIR, which undertook research across almost all areas of science, but research was also funded by individual government departments, such as the Ministry of Agriculture and Fisheries, the Ministry of Forestry and the Meteorological Office (Palmer, 1994). A social science research fund committee distributed grants, primarily to the universities, for research in sociology, psychology, anthropology and education. In addition, the universities received block grant research funding.

In 1990, a new Ministry for Research, Science and Technology (MoRST) and the Foundation for Research, Science and Technology (FRST) were established. MoRST was mandated to provide policy advice and executive support to the minister, while FRST was designed to support research using a contestable research fund (Palmer, 1994). A Health Research Council was also created in 1990 with a mandate to fund public health research. This replaced the pre-existing Medical Research Council.

In 1992, the DSIR was dissolved, as were the research arms of all government departments. Together these were re-structured and re-established as 10 Crown research institutes (CRIs). The creation of the CRIs was probably the most fundamental change to the pre-existing science system. Each CRI was based around either a productive sector or a grouping of natural resources, giving each a clear purpose or problem focus, and a clear end-user base (MoRST, 1993). To some extent, DSIR groups had been multidisciplinary, but people worked as individuals or in very small teams. The new model required larger, stronger, multidisciplinary teams. The CRIs were structured as limited companies run on a business model. Boards of directors were appointed by the government (as the shareholders) and, while recognizing their contribution to the public good, they were also expected to generate a cash income. Significantly, managers were hired who copied the methods of business and this was to be a major source of discontent. A loss in traditional institutional allegiance, changes in employment conditions, and the challenge to traditional disciplinary identities sparked vigorous opposition from many researchers and research managers, particularly within the Department of Scientific and Industrial Research (1991). Surveys of scientists in 1996 and 2008 identified continued concern over issues such as unstable research funding, red tape and bureaucratic management, and the role of government in setting research agendas. Overall, dissatisfaction remained highest among CRI scientists (Sommer, 2010). This is explained by the replacement of their autonomy and interest in creating national benefit by requirements to give allegiance to companies and to work in the interest of those companies.

Fundamental changes also occurred in the organization and management of research funding. The public good science fund (PGSF) had its first round in 1990–91. Managed by FRST, the PGSF consolidated research funding previously allocated to the DSIR, or held and allocated by individual government departments. The universities became fully eligible to apply to the PGSF (and subject to the government's research priorities) in 1994–95, after agreeing to transfer to the PGSF the estimated proportion of funding they had committed to public good research. The PGSF was open to bids from not only the CRIs and universities, but also the private sector. Overseas applicants were also eligible for support.

From the first, research priorities were signalled by specified national objectives and the available funds were aligned to support these needs. (These priorities were largely those previously used by DSIR.) Initially, bids had to emphasize the public good and avoid direct relevance to identifiable end users. Two or three years later, this approach had shifted and bids were then required to include provision of support from potential end users. This could include evidence of co-funding or some form of material support. Researchers were also required to identify how they planned to transfer their findings to potential users. Initially, research priorities were guided by 40 output classes in line with the former DSIR model (by 1995, this had been reduced to 17). This commitment to prioritization was reinforced by the inherent financial constraints faced by a country with a small population and consequently low tax base. Priorities have been repeatedly modified. The net result, however, was always the necessary collaboration of different disciplinary groups (including the social sciences) to address areas of national priority. While these changes substantially increased the pool of funding available to university researchers, they were also the focus of substantial opposition by academic staff, many of whom viewed them as a challenge to academic freedom and requiring changes in behaviour and practice more in line with a business model.

The radical changes made to the New Zealand science system in the early 1990s were part of a deliberate attempt to separate policy advice, purchasing and service provision. Inherent in this was a shift in the production of knowledge that highlights many of the characteristics of Mode 2. Government science was radically restructured with a strong problem focus requiring large, multidisciplinary teams. Funding was redirected better to address national priorities and social accountability. The pooling of funding and its availability to all members of the research community provided a basis for the evolution of new collaborations and new institutional arrangements. The existence of, and challenges inherent in, intra-organizational collaboration were largely ignored. The much greater involvement of user groups in priority setting and as members of funding panels also challenged researchers to meet a wider range of performance measures than the reliance on academic publications that had previously dominated. Elements of these changes are evident in Canada. New Zealand's size and constitutional framework, however, allowed a much more dramatic shift in the organization of science than is evident in Canada, or elsewhere. Subsequently, new components have been added to the original structural purity of the New Zealand science system, and, as in Canada, the STI environment has involved increasing layers of complexity.

Evolution and change

Over the last 20–30 years, shifts in political agendas, inter-agency battles for power, and changing perceptions of national needs have generated further policy initiatives and institutional changes to the STI framework in Canada and New Zealand. Such changes and shifts continue today, driven by an increased political acceptance of the link between research and innovation, and increased demand for some means to boost productivity and economic growth.

Canada

Until the late 1970s, research funding allocated by the three core research councils [NSERC, CIHR (then MRC) and SSHRC] remained largely responsive to the quality of the applications received and independent of strategic national priorities. The councils were then (1977) allocated special funding to support research in areas of national need. Subsequent initiatives introduced an overlay on the researcher-directed model, but at most involved only broadly targeted themes. This did, however, result in the involvement of potential research users in the review process. In the 1980s, these somewhat limited initiatives were greeted with very mixed reactions. Researchers in engineering applauded, health researchers considered them largely as business as usual, and those in the natural and physical sciences, the social sciences and humanities either embraced or pilloried the new initiatives – a pattern of responses again largely paralleled in New Zealand.

Since these early initiatives, there have been major changes in the programmes of the three research councils, although overall they still retain a strong central core of funding provided in response to researcher-generated applications. Today, close to 40% of the research funding from NSERC is aligned to targeted or designated theme areas, or carried out in partnership with a user group (i.e. in innovation or Mode 2 category). An example of the latter is the collaborative research and development (CRD) grants programme that supports well-defined projects undertaken by university researchers with an industry partner who is required to contribute 50% of project costs. The idea to innovation (I2I) programme also supports activities leading to technology transfer to new or established companies.

The SSHRC now invests some 30% of its research funding in partnership grants (formerly strategic areas and community–university research alliances, CURA). Many such initiatives require an equal intellectual partnership between researchers and community organizations. An additional 5% is dedicated to knowledge mobilization and dissemination. The level of research funding directed to strategic areas through the CIHR appears to be around 40%. Furthermore, the advisory boards to the CIHR institutes include users, lay people and health charity partners. In all these examples, such shifts in the allocation of funding have significantly impacted on thinking within the research community. They have raised awareness of the social context within which research occurs, and have generated much questioning and debate about the evaluation criteria applied to measure research outputs.

Initiated in 1988 to foster partnerships between academia, industry, government and not-for-profit organizations to enhance economic and social benefits from research, the networks of centres of excellence (NCE) programme has had a particularly strong impact on the research landscape. The programme has become internationally recognized for innovative networking and as one of the prime vehicles for technology transfer for commercial benefit (including new products, services and processes, spin-off companies and the enhanced viability of existing firms). On this score, it appears to perform better than federal laboratories. The programme has three defining attributes: multidisciplinarity; inter-institutional and international networking; and a focus on real world problems. It supports research training in an applied, multidisciplinary context and fosters interactions of trainees with end users. Overall, private sector linkages and training benefits have been strong. However, the networks created do not embrace significant components from the social sciences and humanities and are not necessarily superior vehicles for promoting impacts on public policy, regulation and changes to practice. Perhaps these are the Canadian analogy to the New Zealand CRIs.

The addition of business-led NCEs (B-NCEs) and centres of excellence in commercialization and research (CECRs) to the suite of NCE activities has extended the reconfiguration of science funding towards the private side of the public/private divide. These recent initiatives are designed to catalyze more knowledge-based innovation in the private sector, incorporating a hybrid philosophy of R&D push and pull; it is, however, premature to assess their effectiveness as they are still in the early stages of implementation.

The CFI and Genome Canada have come to play a key role in shaping the research environment. CFI support for academic research infrastructure requires applications at an institutional level and integration of the initiative within the institutional strategic research plan. All applications must address the socio-economic benefits for Canada. This has resulted in a bottom-up alignment of infrastructure investment aligned with federal priorities and it is expected that this will be strengthened in future rounds. Genome Canada has effectively allowed the biology community to 'think differently' and 'think big'. This has resulted in the creation of six regional genome centres across the country. In addition, GC initiatives incorporate considerations of ethical, environmental, economic, legal and social challenges as a means of improving the prospects of the research having a practical benefit. Forward directions involve more focus on the translation of discoveries into new applications, targeting key sectors of strategic and economic benefit to Canada.

These changes have shifted resources in favour of university-based research. There has also been a relative and absolute decline in the importance of government science managed through federal science departments and the NRC. As described previously, the role of the NRC is likely to undergo further change as it becomes more focused on business and more clearly differentiated from academic-based research initiatives. This reallocation of resources and linking of new funding to issues and priorities set by research users and national priorities has fundamentally changed the research environment. The universities have been forced to accept a broader sense of social responsibility (and accountability). Government laboratories have also gone through similar changes. All have had to restructure to incorporate much more interdisciplinary research, and continue to wrestle with the need for new measures of quality control.

New Zealand

Predicated on the belief that RS&T were amenable to principles of contestability, the structures and relationships established in the early 1990s included an implicit assumption that market signals would lead to further change as needs evolved. The PGSF, designed to generate research to meet these needs, left a gap in funding for basic, blue sky research. This was addressed in 1992, with the establishment of the Marsden fund. Initially managed by FRST, control was subsequently (1995–96) transferred to the Royal Society of New Zealand. Marsden funding, however, has remained at only 10–15% of that available from the PGSF (replaced in 2000 by a set of output expenses), and is typically severely over-subscribed with an average success rate of just over 10%. Today, the major source of funding for basic research is the performance-based research fund.

Change might have been anticipated in the CRIs. Indeed, the CRI established for social research proved unviable and was disestablished after only two years. At various times, other CRIs have struggled to remain financially viable; however, none has been allowed to go out of business and only one merger has occurred. Equally, some universities have struggled financially, but none has closed. In 2008, an interesting proposal to merge AgResearch and Lincoln University was subsequently dropped. Within each CRI, however, different areas of research have expanded or decreased as research funding has grown or declined. This was bluntly demonstrated in 2010, when AgResearch responded to a vote by sheep farmers to drop their research levy by cutting 36 scientific staff associated with the biology of wool (although this cut in funding was quickly cushioned by additional funding from FRST). Over the last 20 years, redundancies of university researchers have occurred in response to financial constraints. Recurrent redundancies of scientists have occurred within the CRIs despite funding provision for research not explicitly driven by external priorities (originally representing 10% of the PGSF funding awarded to each CRI, but changed in about 2005 when a new capability fund was introduced, based on total funding received from government). This was originally designed to guard against 'purchaser failure', but did not result in the successful retention of scientists. This raised concern over long-term, national research capability, and was used in support of more stable funding.

For their part, individual universities have varied widely in their success in accessing PGSF funds, but overall faced little substantive competition from the CRIs. At the same time, they received increased funding from Health Research and the Marsden fund. This, together with more funding from PGSF, has pushed New Zealand universities towards a significantly larger national research role, while requiring them to develop a greater applied focus. Reinforcing this has been an increase in university researchers providing contract research services for industry. Sometimes this has encouraged collaboration with CRIs, building on their links with specific industries: more often it has brought universities into direct competition with CRIs.

In 2007, a review of New Zealand's innovation policy (OECD, 2007) suggested that the STI system was overly competitive, and argued for more stable funding to retain human resources, ensure the build-up of core knowledge, and avoid a distortion of research activities. These findings were undoubtedly influenced by input from MoRST. Problems had been recognized some years before (see MoRST, 2005) and there had already been a series of moves signalling a retreat from the competitive model. The negotiated extension of existing research contracts, efforts to establish centres of research excellence and outcome-based investments (OBIs), as well as the creation of a natural hazards research platform, all included an assurance of long-term funding. These new policy initiatives, did not, however, lessen any commitment to interdisciplinary research. Rather, they further consolidated this trend and extended moves towards greater networks and collaboration among researchers in different institutions (and overseas) and closer alignment of research and national priorities. Arguably, these policies also more explicitly identified national priority areas. Their linked provision of long-term funding allowed a means to build and retain research capability in these key areas.

In 2010 the most significant shifts in the New Zealand science system since the reforms of the early 1990s began. The government first announced a decision to merge MoRST and FRST in a new Ministry of Science and Innovation (MSI) (Key, 2010), and then, in response to a report from the Crown Research Institute Task Force (2010), announced a decrease in competitive funding with the allocation of long-term, stable funding to the CRIs. This was vigorously opposed by the universities, at least some of whom had done well from the competitive model. The task force rejected any need to reduce the number of CRIs, at least in the short term. It highlighted (to a large extent, simply by repeating the earlier statements of purpose of the 1990s) the need to clarify the core purpose of the CRIs and to develop stronger, long-term partnerships with New Zealand businesses. It further identified technology transfer as one of their core responsibilities. These changes were argued as part of a move to cut compliance costs, promote greater cooperation across the STI system and to help the CRIs address issues of national economic growth and sustainable natural resource use. These changes did not, however, address the commercial model on which the CRIs are based, and which many observers view as the core problem. Rather, these changes appear to reflect a growing pragmatism in the shaping of New Zealand's STI policy and the unpalatable political consequences generated when the competitive model is rigorously applied to the research system. The recommendations of the task force have been accepted by the government and are being implemented.

The shifts and turns in the policy environment since the early 1990s have had a substantial impact on the STI environment. An overall increase in research activity in the universities was further strengthened in 2004–2007 by the introduction of the performance-based research fund (PBRF) (Performance-based Research Fund Working Group, 2002). Designed to encourage and reward excellent research and to fund universities on their performance, the PBRF changed the universities' previous reliance on student numbers as their primary funding criterion (Ministry of Education, 2009; Smart, 2009). The first quality evaluation was completed in 2003, a second partial round occurred in 2006, and the next full round will take place in 2012. Each round requires the evaluation and grading of individual researchers. The subsequent funding allocation to a university is based on three elements: 60% on the quality of its researchers; 25% on research degree completions; and 15% on the level of external research income. In effect, the PBRF reinforces the Mode 2 format of knowledge production by confirming the importance of traditional measures of research performance and research quality (i.e. academic publications). This further differentiates researchers in universities from those in the CRIs, whose performance to date has been and remains more broadly couched in terms of social accountability and contributions to the commercial imperatives of organizations.

Importantly, STI arrangements in New Zealand continue to support a major role for government-funded science (if within a new and evolving institutional structure) and an increased role for research within the university system. New Zealand's eight CRIs now account for one-quarter of the country's total research provision, the eight universities account for closer to 40% (Crown Research Institute Task Force, 2010), although there is wide variation among the different universities and among the CRIs. It remains uncertain how these arrangements will evolve or how the probable increase in internal competition within CRIs will be addressed.

Changing dynamics within Canada and New Zealand's STI systems

In both countries, there is an increasing acceptance of research and innovation as the major driver of employment and growth. This perspective has been reinforced by the recent global economic and fiscal crisis. There is consequently continued debate and some puzzlement in both countries at the failure to produce the level of innovation anticipated and desired. This is promoting on-going attempts to re-set the STI system and remove any impediments to innovation and economic growth. These attempts provide further insight into many of the key features identified in *The New Production of Knowledge* (Gibbons *et al.*, 1994), their consequences for institutions and disciplines, and the practices and policies of research.

Reflexivity, transdisciplinarity, policies and practices

In both Canada and New Zealand, a preoccupation with the commercialization of research and technology transfer parallels that in other OECD nations. It is a particularly active issue in both Canada and New Zealand, however, because of the persistent, relative weakness of private sector innovation. At a federal level, Canada has for, the most part, chosen to shape its STI system by creating a positive fiscal environment for private sector innovation without extensive direct intervention. This is under challenge (Innovation Canada, 2011). Canada has established a strong system of tax incentives, but significantly less in the way of direct support for business innovation. In 2010, \$C3.5 billion or 55% of federal expenditures in support of business R&D was devoted to the scientific research and experimental tax credit programme. The next largest programme – the industrial research assistance programme – focuses on small and medium-sized enterprises and does provide direct, non-repayable support for business R&D. With an annual budget of \$C0.24 billion, it is heavily over-subscribed. New Zealand has put a stronger emphasis on direct intervention through a range of programmes that subsidize R&D and innovation by businesses and industry groups. At the same time, a range of different structural arrangements, funding models and policies has been introduced to better align research with business needs and to capture and commercialize research findings.

The importance of universities in the research system of both countries has resulted in national policies for innovation designed to influence their research agendas. This has, at the same time, entailed attempts to commercialize research findings better. In New Zealand, this was already evident in the changes made to research funding under the PGSF in the early 1990s, and the award of research funding conditional on the demonstrated support of user groups. Evidence of a strategy for technology transfer to user groups is now an established component of research bids. Universities, driven in part at least by financial need, have been encouraged actively to seek more external research funding. The introduction of the PBRF has also resulted in the universities gaining control and responsibility for the allocation of an expanded internal pool of research funds. There has also been an increase in engagement by university staff in contract research for industry and other user groups. Commercial research activities are now a significant source of funding within the New Zealand research system.

In Canada, a similar shift is evident in the increased proportion of funding from the research councils aligned with federal priority areas. Canada's university chairs of excellence (established in 2008) are also aligned with national priorities and require demonstrated end-user engagement. Other programmes, including the NCEs that bring together researchers and partners from the academic, private, public and not-for-profit sectors, carry an explicit expectation of business partnerships, knowledge transfer mechanisms and the generation of economic returns. New Zealand's centres of research excellence (CoREs), established in 2001, have a similar design and objectives. Meanwhile, the government of Canada has signed an agreement with the universities collectively to double the amount of research conducted and increase the commercialization of research results.

In 2007, the Networks of Centres of Excellence International Advisory Committee (2007) described the Canadian NCE programme as having 'transformed the way research is done in universities'. This equally describes the impact of the changes to research funding in New Zealand. Indeed, in this respect New Zealand might be considered as ‘further along the track’. For much of the 1990s at least, little funding was available to researchers that was not linked to national strategic objectives. Since then, both the Marsden fund and PBRF have shifted the balance, particularly for the university sector. Over time, however, new policy initiatives have refined national objectives and more explicitly directed research to foster innovation and address corporate needs. Government research funding to support both Canada’s NRC and New Zealand’s CRIs is increasingly tightly tied to business needs. While this is so, for many years the CRIs have got less than half their funding from government research sources.

Universities have proven adept at working within this new environment. In both Canada and New Zealand, they have developed closer relationships with the private sector, ranging from collaborative research and consulting to the generation of spin-off companies. At graduate level, there is evidence of increased co-supervision with non-university staff, the use of shared research facilities, and the placement of graduate students in non-university settings to complete their research.

These changes have catapulted universities into an era of professional research management. Offices providing research services have expanded and become central to facilitating, planning and the construction of proposals, and in helping obtain funds. They are increasingly important in ensuring that funding agreements are subject to effective governance and management. In addition, new corporate style organizations have been established to manage contract research, including the encouragement of spin-off companies and licensing of rights to intellectual property.

This new research environment has impacted on academic appointments. The Canada research chairs (CRC) programme provided support for 2000 research professorships, designed to attract and retain accomplished and promising minds in universities across the country. Although the programme has no explicit thematic focus, universities are expected to have strategic research plans in place and to align these appointments with their research priorities. New Zealand has no equivalent programme. The creation of Rutherford discovery fellowships in 2010 and the increasing establishment of research chairs at individual universities provide a similar thrust. However, only one Rutherford fellowship has been awarded. Perhaps more importantly, there is increasing interest in the appointment of academic staff (at all levels) with a proven interest and capacity to work with user groups and access research funds. There is a comparable commitment to expand graduate research numbers and retain the best researchers. These moves are backed by a wide range of programmes and initiatives in both countries, established at both a national level and within individual universities (Davenport, 2004).

Changes in the research environment are part of efforts to link knowledge creation and innovation to national ambitions for economic growth, social development and national protection (Samarasekera, 2009), but in both Canada and New Zealand, there is acceptance that the nature of science is itself changing. Issues of economic, social and environmental importance are increasingly intertwined, and this is forcing researchers to deal with new levels of complexity and whole systems in ways that challenge the hitherto dominant reductionist paradigm. Technological and other advances which allow the use and manipulation of large databases and the application of complex models are all contributing to making multidisciplinary teams an increasingly standard part of the research process (Gluckman, 2010).

The multidisciplinary team as a characteristic of the modern research environment is both a driver and consequence of structural and policy changes in the STI system. The need for such teams has resulted in an erosion of traditional disciplinary boundaries. It has also prompted many universities to establish centres and institutes to promote research in thematic areas that cross traditional discipline lines. Within Canadian and New Zealand universities there have also been many mergers of traditional disciplinary units. Integrated schools of biology and of the environmental sciences are two examples, but there are others in the arts and humanities (for example, the merging of European languages and linguistics) and there are well-established examples in the professional schools. While some such mergers have struggled or failed, there has also been an overall growth and expansion of programmes and courses in new thematic areas, and of non-traditional courses as part of core programmes.

The increased proportion of research funding tied to national and business objectives has required multidisciplinary research bids. It has also required an increased diversity of representation on review panels, and challenged researchers to communicate better beyond the boundaries of any one disciplinary group. The emphasis on user needs, innovation and technology transfer has, in turn, encouraged the greater integration of the social and bio-physical sciences. This has been, and still is, a challenging evolution. There has been difficulty (or reluctance) to build social science into the design and format of research bids. There has equally been a reluctance within the social sciences and humanities to rethink their research approach to embrace interactions with other disciplinary perspectives. As a result, the social and human component frequently remains a 'tag-on' to multidisciplinary bio-physical research bids. Efforts to broaden review panels have often resulted in the inclusion of only one social scientist as part of an overwhelmingly bio-physical team. This does not tackle the problem. Nonetheless, some progress has been made. Many research programmes now explicitly recognize the need for a social component and there is a heightened awareness of the need to strengthen the representation of the social sciences in the evaluation of research proposals. In New Zealand, for example, designated research funding for climate change (managed by the Ministry of Agriculture and Fisheries) and natural hazards (including that provided by the Natural Hazards Platform and by the Earthquakes Commission) include an explicit social component. In Canada, initiatives by Genome Canada have explicitly required full integration of the social and human dimensions. Similarly, many of the priority research questions and economic opportunities relating to the digital economy are now recognized as being founded in the social sciences, humanities and fine arts.

As well as changes within universities and the CRIs, broader changes in the research environment have resulted in the establishment of new institutions and research arrangements. The commitment inherent in New Zealand's PGSF to accept the best research bids from whatever source, generated research in the earth sciences, for example, not only from the CRIs and universities, but also from independent researchers and consultancies (Foundation for Research, Science and Technology, 1995). For the most part, however, the bulk of government research funding still goes to researchers in the universities and the CRIs. Even more significant have been the repercussions of other policy changes.

The NCEs and many of the larger CFI-funded initiatives provide dramatic examples of how the research environment has changed in Canada. Each of these initiatives has created 'transaction spaces' for the ongoing interaction of researchers from various sectors, and in many cases various disciplines. The fact that NCEs are not formally entities of the institution, but associated indirectly with it has caused considerable tension, but forged new ground, integrating government and industry into the fabric of collaboration, and generating novel approaches to the governance and management of research. Researchers and policy makers play an active role in the networks.

Research facilities also foster inter-sectoral and multidisciplinary relationships. The Canada Foundation for Innovation (CFI) has enabled the creation of large national facilities, such as the Canadian Light Source and the refit of the Arctic research vessel Amundsen, established research platforms, such as Compute Canada (providing high performance computing facilities across the country), supported the establishment of research data centres (providing access to a multiplicity of Statistics Canada micro-datasets), and catalyzed creation of a consortium negotiating site licences for research libraries. Hundreds of regional and local infrastructure facilities have also been set up. By providing funding to build innovative research spaces, as well as encouraging the sharing of facilities, CFI has spawned common-use facilities located in areas easily accessible to a diversity of users. Multidisciplinary, shared use and strategic alignment with institutional priorities are key features of the CFI model. The impact has been profound. Institutions have become much more strategic in their decisions on priority investment areas (as institutional funding is a key requirement) and in aligning hiring, capital construction and infrastructure investments with these priorities.

These two Canadian examples have their counterparts in New Zealand's centres of excellence and in the natural hazards research platform, which bring together researchers from different disciplines and a diversity of institutions in common purpose. Other examples include the new research infrastructure platforms, such as eScience and NZ Genomics, designed to promote national collaboration among scientists across universities and CRIs. Ongoing changes in the organization and management of the CRIs are also designed to facilitate collaboration among different research institutions, business and government. All these examples, whether in New Zealand or Canada, challenge established management structures and practices for university and government science, and are likely to require further changes and new management skills.

Against these broader changes in the research environment, the reward systems for individual research have proven more difficult to adapt. Canada and New Zealand continue to struggle with the problem of how to provide credit for knowledge and/or technology transferred to a user, or for changes in the operation of a community group resulting from research insights. In New Zealand in particular, there is an alignment of most research funding to strategic national objectives and the needs of user groups. The requirement to demonstrate outputs and outcomes beyond articles in peer-reviewed journals has been an integral component in the evaluation of both research bids and research achievement for two decades. There are now increasing demands for researchers to demonstrate positive outcomes in user groups.

There is considerable disagreement about the value that should be placed on such outcomes and how they might be measured without the customary peer validation associated with journal publication. In many respects, the programmes of the research councils in Canada and FRST in New Zealand, and of other funding agencies, have evolved more rapidly than their own merit review systems, and more rapidly than the culture and practices of academia. For the most part, funders continue to advocate a balanced approach and an appropriate mix of outputs in the form of both peer-reviewed publications and other contributions, while university promotion systems have remained tied to conventional peer-reviewed outputs. Recent changes to the university funding formula in New Zealand appear to encourage this approach. Research funders demand greater balance, while new researchers are cautioned to demonstrate individual contributions through traditional performance criteria (Mode 1 type research) to establish themselves, prior to any foray into Mode 2 activities. The debate continues. Changes in the mandates of the CRIs in New Zealand, for example, seem likely to push a need to demonstrate performance into new territory. The CRIs are being challenged through MSI to develop and address key performance indicators that go well beyond traditional measures.[1] In this latter case, these indicators apply to organizations as a whole, while the PBRF (as applied to the universities) focuses primarily on individual performance.

The research councils in Canada and FRST in New Zealand lag behind the changes in the research environment when it comes to the evaluation of research funding applications. While they have long had mechanisms to support research that crosses disciplinary lines as well as evaluation by reviewers from multiple disciplines and different fields, complaints by applicants of inadequate treatment are not uncommon. Here again, there is a scale issue. Peer review implies a focus on individuals and a traditional view of quality. Entirely different views are required for larger scale and more outcome-related work. NSERC is currently redesigning its peer-review system for 'responsive research' to tackle a number of issues, among them its capacity to deal with interdisciplinary and multidisciplinary research (some 30% of its applicants identify themselves as active in areas that cross two or more sub-fields). In response, NSERC is introducing a 'conference model', where reviewers meet in different combinations to provide appropriate evaluation. In New Zealand, there is unofficial acknowledgement of the continued challenge to incorporate properly both Maori perspectives and social science needs in the review process. Undoubtedly the most difficult integration is between the social sciences and humanities and the natural and biomedical sciences. The CIHR is wrestling with two distinct sub-cultures within its now broadened health remit, working to bridge the cultures with revised criteria and new approaches to training reviewers.

Conclusions

Changes in the terminology used in government documents on science policy in the last 20 years illustrate the dynamics of science and research as documented in this paper, and the increasing dominance of business and economic goals in the official discourse on science policy. This is most explicitly expressed in the shift in discussion from science and technology policy to science, technology and innovation. While this shift is evident in both Canada and New Zealand, the discourse has been most fully extended in New Zealand, with research contracts replacing research grants, stakeholders replacing potential research users, and, of course, outputs replacing published journal articles and other forms of reported results.

At times almost numbing in their impact, the changes in terminology around science and research policy have contributed to a fundamental shift in thinking within the science community, in the structure and management of institutional arrangements, and in the determination and measurement of success in scientific research. Changes in terminology have not occurred in isolation, but have been accompanied by, at times, radical shifts in research structures at a national level, as exemplified in New Zealand by the disestablishment of scientific activities concentrated in specific government departments and the creation of new business-oriented, if largely government-controlled, CRIs. In Canada, challenged as it is by four and a half time zones and huge distances, networking and collaboration, whether formal or informal, is now an increasingly important way of life within the research community, triggered by the NCEs and encouraged by most funding programmes. Partnerships with the private sector are commonplace. These initiatives have had a cascade effect. Individual research centres have responded with further structural adjustments. In this, the universities and their establishment of new interdisciplinary research units, interdisciplinary teaching programmes and new commercial arms provide apt examples.

The result of such changes may be described as part of a new contract for science, and reflective of a shift in the nature of research priorities and in government (and taxpayer) expectations of research. These priorities are increasingly defined in terms which demand a multidisciplinary team response, while expectations are increasingly framed in terms of economic or commercial returns. This has undoubtedly been further accelerated in recent years by the global financial crisis, and highlighted within science policy by increasing moves both in Canada and New Zealand to tie research investment and funding more explicitly to initiatives and proposals aligned to business needs and national economic objectives. For individual research scientists, the result has been an increased requirement to build links with business and other groups, and moves to measure performance in terms of funding generated and indicators of technology transfer (e.g. patent licences and spin-off companies) rather than conventional peer-reviewed journal articles.

These changes have not occurred without resistance from at least some sectors of the research community in both Canada and New Zealand, and in each case there have been winners and losers in the struggle to access resources and compete. Breaking down disciplinary allegiance in favour of multidisciplinary teams has proved difficult and often unpopular. In particular, evidence of the development and adoption of new transdisciplinary programmes is slight. Often interdisciplinary funding to address multifaceted strategic issues remains a framework for researchers to advance their own individual research and career objectives along traditional disciplinary lines. This is further encouraged where tenure and promotion systems have still to catch up.

Over time there have been repeated policy shifts and a realignment of research funding in keeping with political agendas and perceived needs. However, in both Canada and New Zealand, the net result is a profound shift that confirms support of the ideas presented in *The New Production of Knowledge* (Gibbons *et al*., 1994). This has occurred under two very different political and ideological regimes. To this extent, it seems reasonable to argue that the new dynamics of science and research in Canada and New Zealand, at least, are less a product of a particular political agenda than a response to the changing nature of science and broad societal needs. All this is not to deny the multifarious political and economic forces which continue to play themselves out within the science policy arena. Policy shifts continue to reflect inconsistencies and contradictions that may be inherent in a democratic society. These, at least in the short term, may divert from the overall direction of change, but in the longer term seem unlikely to subvert it.

Note

1. See http://www.msi.govt.nz/cris/toolkit/section3/genericindicators.

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