A Comparative Macro-level Assessment of New Zealand's 'National Innovation System'[1]

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ABSTRACT *It has been argued that the power of the concept of a 'National Innovation System' (NIS) lies in its comparative nature. Adopting this viewpoint, we provide a comparative snapshot of New Zealand's NIS. Using macro-level indicators to measure innovation, knowledge absorption and diffusion, we compare the performance of New Zealand with that of other OECD economies. The data indicate that New Zealand continues to have a weak NIS, despite major changes to its research, science and technology sector since the late 1980s, and despite its openness to foreign direct investment. We conclude with some general policy considerations to remedy what, by international comparison, still seems to be a NIS failure in New Zealand. The paper also suggests directions for further research.*

Keywords: innovation, national systems, knowledge absorption, diffusion, New Zealand, foreign direct investment.

Introduction

There is a broad consensus in the economics profession and amongst policy makers that innovation resulting from the accumulation of knowledge plays a major role in explaining economic growth. But why is it that some countries are better able to innovate, diffuse and adapt ideas than others? This question is addressed in the non-formal literature on 'National Innovation Systems' (NISs), which argues that nation-specific factors play an important role in shaping technological change and its impact on competitiveness and economic growth.[2]

In this paper we attempt to provide a comparative snapshot of New Zealand's NIS at the macro-level. We employ commonly used indicators of innovation and diffusion of knowledge in order to compare the performance of New Zealand's NIS with that of other OECD economies, and attempt to draw some conclusions relevant to New Zealand's circumstances. NIS indicators are grouped under several headings, i.e. the potential to produce knowledge, inflows of technology and absorptive capacity, in an attempt to identify relationships between them and with respect to knowledge diffusion. Evidence of diffusion is sought by considering outcome indicators, such as high and medium technology products as a percentage of manufacturing output, exports of manufactured goods as a percentage of total exports, and economic growth.

The data are consistent with the view that a relationship exists between the potential to produce knowledge and diffusion. Despite major changes to New Zealand's research, science and technology sector since the late 1980s, New Zealand continues to be extremely weak in both areas. The paper concludes with some policy considerations to

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remedy what, by international comparison, still seems to be a NIS *failure* in New Zealand. It is hoped that it will lead to much needed in-depth research into New Zealand's NIS.

The paper is structured as follows. After first discussing the concepts of 'knowledge' and 'National Innovation System', some of the major recent studies looking at elements of New Zealand's NIS, as well as data sources, are briefly introduced. We then discuss our selection of NIS indicators and our basic results. This is followed by further discussion of the weaknesses of New Zealand's research, science and technology sector observed in a number of previous studies, and the controversial role of Foreign Direct Investment (FDI). In this context we comment on the popular comparison between New Zealand and Ireland. Recommendations to improve the general functioning of New Zealand's NIS conclude the main part of the paper.

What is a 'National Innovation System'?

Innovation is a dynamic process requiring the use of existing knowledge in order to create new knowledge. As David and Foray note, knowledge accumulation is both cumulative and integrative—the more that is invented, the greater the probability of future inventions.[3] Knowledge accumulation can be either intentional or unintentional. The former might include investment in R&D as well as training and education programmes. Lucas, for example, suggests that individuals accumulate human capital by devoting time to learning, the result being higher productivity per worker.[4] Unintentional knowledge accumulation generally occurs as a side effect of investment. Through learning by doing,[5] learning by using,[6] learning by interacting,[7] and learning by learning,[8] knowledge is gained from one's own experiences with the firm's investment and by observing the investment behaviour of others. As the stock of knowledge grows, so does human capital.

Knowledge can either be embodied or disembodied. Embodied knowledge is contained within machinery and equipment, whereas disembodied knowledge is not—examples include research papers, patents, licenses, trademarks and the like. Many analysts have noted that the absorptive capacity of an economy, which is to a large extent determined by its stock of human capital, will influence the ability of a country to take on board either embodied or disembodied knowledge.[9] Therefore, our attention turns to the issue of diffusion, that is 'the process whereby knowledge and technological expertise are spread and assimilated through the economy'.[10] While innovation on its own might greatly influence the initial level of product gains and successes, it is the diffusion of that innovation that is more likely to create economic growth and benefits to the nation.[11]

It is important to see the relationship between innovation and diffusion as circular. That is, knowledge gained from the diffusion experience becomes an important input into future innovation processes. This strong interdependence suggests the need to have both processes developed within an economy in order to maximise the benefits from each. As Archibugi and Michie note, one of the greatest contributions of recent research has been to accept that innovation is not a series of isolated events shaped by 'enlightened inventors, forward looking entrepreneurs, or dynamic corporations'. Rather, it is a system that encourages the nurturing and dissemination of technological change.[12] Nations that do not exploit innovations will often fall into an underdevelopment trap. It is now widely recognised that international differences in technological competencies, resulting from differences in the volume and sectoral pattern of R&D and related activities, are important contributors to differences in trade and growth performance.[13]

From the concepts of knowledge, innovation and diffusion comes the idea of National Innovation Systems. The literature on NISs emerged during the later part of the 1980s in an attempt to understand why some countries are better than others at innovating and diffusing knowledge throughout the economy. While List is attributed as being one of the first to document the importance of innovation and diffusion for enhancing industrial development and economic growth,[14] it is Freeman who is linked with the recent introduction of the NIS concept.[15]

A NIS can be broadly defined as 'a system of structured interactions between agents who are involved in the search for innovation or economically successful technology'.[16] Metcalfe defines a NIS as 'a set of distinct institutions which jointly and individually contribute to the development and diffusion of new technology and which provides the framework within which governments form and implement policies to influence the innovation process'.[17] In Patel and Pavitt's view, a NIS encompasses 'the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change-generating activities) in a country'.[18]

While these definitions of a NIS appear comprehensive, the literature is less clear when attempting to provide detailed definitions of the elements and linkages contained within a NIS. For example, Archibugi and Michie note six crucial aspects in defining the structure and explaining the behaviour of a NIS:[19]

- *education and training*—participation rates and distribution of students by disciplines vary between countries;
- *science and technology capabilities*—for example, the percentage of GDP spent on R&D; the split of R&D expenditure between government and business;
- *industrial structure*—given that larger firms are the main agents of technological innovation, identify the split between larger and smaller firms. The level of domestic competition will also influence R&D investment outcome;
- *science and technology strengths and weaknesses*—for example, specialising in areas of leading technology vs. areas of diminishing returns. Science and technology is believed to be influenced by the size of the country, R&D intensity, market structure and international division of labour;
- *interaction and co-ordination* within innovation systems; and
- *capacity to absorb foreign knowledge*—increasing international integration will continue to influence NISs, but countries vary in their ability to take advantage of foreign knowledge.

Although there is still a lack of clarity as to what exactly constitutes the elements of and relationships contained within a NIS, the above discussion indicates that a NIS relies on effective relationships between markets, institutions and firms to enable the free movement of innovations and information between them. However, these relationships and flows will only offer the *potential* to enhance the performance of an economy. It is the ability to diffuse knowledge that really dictates how well the NIS performs. Moreover, most authors would agree that *the power of the NIS concept lies in its comparative nature*, i.e. qualitative and/or quantitative analysis should be undertaken from a perspective that compares a country's NIS with that of other countries.[20]

Outcomes of an efficient and effective NIS are wide ranging and include greater use of advanced manufacturing processes, a general increase in knowledge intensity of all sectors of the economy, increased trade in high and medium technology products, more new products being launched by firms, enhanced productivity and international competitiveness, and an increase in economic growth.

Some Recent New Zealand Studies

The aim of this paper is to contribute to the benchmarking and analysis of New Zealand's NIS. In recent years New Zealand government agencies have made some efforts to measure the country's NIS which, so far, seem to have focused on specific *elements* of the NIS, but not the NIS as a whole. We briefly introduce some of the major recent official studies.

The 'Knowledge Base' report provides an overview of New Zealand's science and technology knowledge base and the capabilities, as well as weaknesses and gaps, associated with it.[21] It has some notable shortcomings. For example, management and business sciences, the humanities and traditional Maori knowledge are not covered. In the areas covered, critical mass of research expertise is often found to be lacking, and significant gaps and weaknesses in New Zealand's knowledge base are evident in all fields. Of particular interest here is the statement that 'Research is needed into why uptake and management of technology by manufacturing industries is poor, even in areas ... where New Zealand is a world leader in research'.[22]

Walker and Edwards review much of the available information sources on the supply of 'human resources in science and technology' (HRST) in New Zealand.[23] Their main quantitative indicators are for three broad categories, i.e. the number of people in the population in each year who classify as HRST, the number of students coming through the education pipeline, and flows into and out of the HRST stocks. The study contains little analysis of the data.[24]

FORST takes a somewhat wider perspective. Using mainly data from the 1996 Census, the report 'provides a general outline of the human capital resource in New Zealand'.[25] The study of human capital is a small part of the wider study of New Zealand's 'absorptive capacity'. The absorptive capacity of a country is one aspect of its NIS. The report benchmarks the current qualifications of the New Zealand workforce, without specifically focusing on science providers.

Walker and Liu provide research, science and technology benchmark indicators to show how New Zealand compares to other countries in the technological sophistication of its manufacturing sector, especially in regard to high technology sectors.[26] Their findings indicate that overall scientific and technological development activities currently make only a small contribution to the technological sophistication of manufacturing production and trade competitiveness. The New Zealand business sector invests relatively little in R&D compared to other OECD countries, even after accounting for differences in the sectoral composition of economies. The government's investment in business R&D is also very low by international comparison. On the positive side, New Zealand has very high growth rates in high- and medium-high technology trade. However, its share of OECD high technology exports has actually fallen over the period 1983–1993.[27]

Hodgson *et al.*, in a report entitled 'Technological Learning and Knowledge Application Review', adopted a qualitative approach to analyse technological learning at the micro level.[28] They provide a very detailed study of how technological learning associated with publicly funded R&D differs among the 233 user groups identified, and suggest ways in which end users' technological learning could be enhanced.

In most cases, the above mentioned studies provide much more detailed information on a particular aspect of the NIS than we do in this paper, but they do not provide an impression of the *big picture* and in many cases there is no comparison with other OECD countries. A synthesis of the separate reports in a detailed comparative analysis of the New Zealand NIS, which looks at the interactions of the constituent elements, remains to be done. It is a task beyond the scope of this paper, which, given current data constraints limiting international comparisons, aims to provide a simple snapshot of New Zealand's macro-level NIS in comparison to that of other OECD economies.

Data Sources and Methodology

We use data for 18 OECD countries. As well as reporting measures for the total group of countries, the data is split into two subgroups. The first group comprises the G7 countries, which account for most of the world's R&D spending: Canada, France, Germany, Italy, Japan, the UK and the US. The second group comprises those classified as small developed countries: Austria, Belgium, Denmark, Finland, Ireland, the Netherlands, New Zealand, Norway, Sweden and Switzerland.[29] Australia is shown separately in the tables below as a point of reference, given its economic and political importance to New Zealand, and New Zealand is shown as a separate entry as well as being grouped with other small developed countries.

The data are taken from the OECD *STAN Database*,[30] the 1988 and 1998 editions of *OECD in Figures*[31] and the *OECD Education Statistics 1985–1992*.[32] Most research and science based data reported in the 1998 edition of the *OECD Observer* is from 1996. Occasionally, some country data is even older. Therefore, the reader should assume all data to be from 1996 and refer to Appendix B for a list of exceptions. Given the lack of time series data (especially for New Zealand) static comparisons are made between countries, indicating relative positions rather than trends.

Three sets of means are calculated for each indicator: one for the total group of 18 countries and one for each of the two subgroups. In order to identify outliers, standard deviations are calculated and, where deemed appropriate, mention will be made of values that are more than one standard deviation from the mean. T-tests are also performed to establish whether means for the two subgroups are significantly different at the 5% level.

Comparative Analysis

The objective of this paper is to use indicators of innovation and diffusion in order to compare the recent performance of New Zealand's NIS with that of G7 countries and 10 other small developed OECD countries, and to attempt to draw some conclusions relevant to New Zealand's situation. The selection of NIS indicators is constrained by the requirement of comparable data for all the OECD countries included here. Where possible and appropriate, we indicate how our major macro-level indicators for particular countries have changed over the last decade.

The use of macro-level data has, of course, many shortcomings and limitations for comparative analysis. For example, Stevens criticises such data because they do not measure the general innovativeness of the economy, do not offer a convincing explanation of trends in innovation, growth and productivity, and only offer snapshots of technological performance, thereby neglecting the way in which various actors within the economy are interacting.[33]

It should be noted that the quantitative comparison of NISs is in its infancy. It is hoped that many of the more appropriate indicators referred to below that have been devised and used in individual country analyses will, in future, become available for many countries.

Domestic Knowledge Inputs: The Potential to Produce Knowledge

Typical input measures include the proportion of GDP spent on R&D and the number of scientists engaged in R&D.[34] Other measures of knowledge accumulation might include spending on training and development.[35] In addition, a strong industrial base might indicate the potential for, or occurrence of, targeted R&D—given that the industrial sector is often more interested in producing commercially valuable R&D than the government sector.[36] We were able to identify the following indicators:

- gross domestic expenditure on R&D (GERD) as a percentage of GDP;[37]
- government expenditure on R&D as a percentage of GDP;
- the percentage of GERD financed by industry;
- the number of researchers per 10,000 workers in the labour force;
- the contribution made by the industrial sector to GDP (as opposed to the agricultural and services sectors).

Table 1 presents comparative indicators for the potential to produce knowledge. On average, gross expenditure on R&D as a percentage of GDP is 2.03%. New Zealand scores the *lowest* figure with only 0.98% of GDP being devoted to R&D. Interestingly, since 1986, this figure for New Zealand has hardly altered while it has nearly doubled in Australia (up 0.49 points). Of course, industry structure affects the overall R&D intensity of an economy. However, Walker and Liu note that even if differences in industry structure are taken into account, the overall level of business investment in R&D as a percentage of total sales revenue in New Zealand would still be only about a quarter of the level in other OECD countries.[38]

Table 1. The potential to produce knowledge

	GERD as % of GDP	**Government expenditure on R&D as % of GDP**	**% of GERD financed by industry**	**Researchers per 10,000 labour force**	**Industry contribution to GDP (%)**
All 18 countries	2.03	0.73	53.9	57	31.3
G7	2.14	0.77	54.2	62	33.6
Small countries	1.99	0.71	54.4	54	33.0
Australia	1.62	0.62	46.3	64	27.1
New Zealand	0.98	0.49	33.7	35	25.1

Governments spend on average 0.73% of GDP on R&D and there is little difference between G7 and small countries. However, the percentage for New Zealand is small, as was already indicated by Walker and Lui's findings. On average, 53.9% of GERD is financed by industry with little difference between G7 and small countries. Once again, New Zealand scores the *lowest* figure. Ireland (and Switzerland) rank highest among the small countries with 67.4% each. New Zealand has shown the most substantial increase—up by almost 15 points or a 75% increase over the past 10 years—but it is still placed at the bottom of the list.

Countries had on average 57 researchers per 10,000 workers (62 for G7 countries and 54 for small countries). New Zealand's score of 35 places it in the bottom group—slightly ahead of Italy (33) and Austria (34). Since 1986, New Zealand has only slightly increased the number of researchers per capita while Ireland, for example, has doubled its number of researchers (up from 28 to 58). Australia also had a marked increase (from 40 to 64). Industry's contribution to GDP is fairly similar for both G7 and small countries. Ireland is noted as an outlier in that its score of 40.2% places it more than one standard deviation greater than the mean for small countries; New Zealand is also an outlier (25.1%), but at the lower end of the distribution (slightly ahead of Denmark which had a score of 24.3%).

International Knowledge Inputs: Inflows of Technology

Data is readily available for some proxy variables that indicate the potential for international knowledge flows: Foreign Direct Investment (FDI), imports of manufactured goods and the ratio of payments to receipts for overseas technology. It is important to note that a country needs a balance between domestic and foreign R&D. Without a strong domestic knowledge-producing sector, a country runs the risk of creating a knowledge gap, making it less able to fully exploit foreign innovations.[39] The following indicators are used here:

- technology payments divided by technology receipts;
- FDI inflows as a percentage of GDP;
- imports of manufactured products as a percentage of total imports.

On average, small countries pay more than twice as much for foreign technology compared to what they receive for domestic technology (see Table 2). For G7 countries, payments and receipts are more or less balanced, indicating stronger domestic R&D activities in these countries. In contrast, the ratio for New Zealand indicates low payments for technical know-how, even relative to a low level of receipts for technical know-how.

Table 2. Inflows of technology

	Technology payments/ receipts	FDI inflows (% of GDP)	Imports of manufactured goods as % of total imports
All 18 countries	1.57	1.57	78.1
G7	0.93	0.95	74.7
Small countries	2.16	2.01	79.8
Australia	1.93	1.55	84.5
New Zealand	0.40	4.21	84.5

On average, FDI inflows account for 1.57% of GDP. There is a significant difference (at $\alpha = 0.05$) between G7 countries and small countries. Of the 18 countries examined, New Zealand has the *highest* proportion of FDI to GDP. New Zealand has become a lot more open to FDI inflows, with the FDI/GDP ratio rising from 1.36% in 1986. Along with FDI, another source of embodied technology is the importation of manufactured products. The average for the sample of 18 countries is 78.1%. New Zealand is an outlier with a high figure of 84.5% (second only to Switzerland with 87.7%). New Zealand imports the majority of its capital goods, indicating a large *potential* pool of embodied R&D spillovers.

Absorptive capacity

Once technology is available, its usefulness is maximised if the economy is able to absorb and diffuse those technologies, ultimately adding to the stock of knowledge and thereby enhancing the opportunities for future innovations. Human capital, particularly within the R&D sector but also in general, is considered an important factor in the absorption of knowledge and the extent to which knowledge spills over. The following indicators are use here:[40]

- university graduates as a percentage of the total population;
- science graduates (i.e. maths, engineering and natural sciences graduates) as a percentage of university graduates.

On average, 0.35% of the population graduated from university in one year (Table 3). There is a significant difference (at $\alpha = 0.05$) between G7 (0.43%) and small countries (0.28%). New Zealand is a high outlier compared with other small countries and Australia is a high outlier compared with the total sample of 18 countries. When only science graduates are considered, the result becomes more telling with New Zealand moving from a strong position in terms of the number of university graduates per capita to the *lowest* of the 18 countries in terms of science graduates. Since 1986, the share of science graduates in New Zealand has declined from 22.9% of all graduates to the current level of 14.5%. Australia has followed a similar trend. The data are consistent with the findings of more formal empirical studies that suggest that both countries are relatively poor at absorbing foreign knowledge.[41]

Table 3. Absorptive capacity

	University graduates as % of population	Science graduates as % of university graduates
All 18 countries	0.35	23.4
G7	0.43[a]	21.3
Small countries	0.28	24.9
Australia	0.60	18.5
New Zealand	0.41	14.5

Note: [a] Excludes Japan and France.

Evidence of Diffusion Taking Place

If diffusion is taking place, one looks beyond linear outputs of a NIS, such as patents, to outcomes. Outcomes include greater use of advanced manufacturing processes, greater use of information technology in the service sector, the proportion of the workforce employed in high technology industries, an increase in social and private rates of return as a consequence of investing in R&D,[42] an increase in the proportion of new products in sales[43] and a greater proportion of high technology products in manufacturing or foreign trade.[44]

Thus, methods to map both the flow and consequences of innovations need to be adopted. At the simplest level, surveys of firms can be undertaken to identify, for example, adoption rates of new technologies.[45] The OECD also suggests conducting literature-based surveys, i.e. identifying reports of new products or processes published in magazines and journals.[46] A more complex study might be to conduct cluster analyses to trace the interactions between actors of an industry or sector within a NIS.[47] There is also a large literature, which uses input–output matrices to identify the extent of knowledge spillovers and diffusion within an economy.[48] Further evidence of innovation and diffusion taking place might be obtained by looking at outcomes such as international competitiveness and economic growth rates.[49]

Given data limitations, only the following indicators are used here:

- the percentage of production accounted for by high and medium technology products (see Appendix A);
- exports of manufactured goods as a percentage of total exports;
- growth of manufactured exports (average annual 1986–1996 growth rate); and
- economic growth (average annual 1985–1995 GDP growth rate).

On average, more than 43% of all manufacturing output in the 18 countries is of high and medium technology products. The figure is 50.8% for G7 countries and 37.4% for small countries (see Table 4). New Zealand has the *lowest* percentage (24.8%). Considering the proportion of exports that comprise manufactured goods, we find the average share to be above 75%, rising to 83.9% for G7 countries and falling to 71.1% for small countries. New Zealand is a low outlier (34.1%), slightly ahead of Norway (29.9%) and behind Australia (51.9%). New Zealand experienced 11.8% growth in manufactured exports over a 10 year period, slightly greater than the mean of 11.0% for the sample of 18 countries (Australia's manufactured exports grew by 22.7% over the same period). There is less variation in the sample in relation to economic growth. However, New Zealand's growth rate has been below the average for all 18 countries, as well as below the average for small countries, and well below Australia's growth rate.

Table 4. Evidence of diffusion taking place

	High and medium tech. manufacturing as % of total[a]	**Exports of manufactured goods as % of total exports**	**Average annual growth of manufactured goods exports 1986–1996**	**Average annual growth rate of GDP (in %) 1985–1995**
All 18 countries	43.2	75.0	11.0	2.32
G7	50.8	83.9	9.6	2.31
Small countries	37.4	71.1	10.7	2.25
Australia	38.1	51.9	22.7	3.00
New Zealand	24.8	34.1	11.8	1.70

Note: [a] Excludes Ireland and Switzerland.

New Zealand's National Innovation System *Failure*?

New Zealand has the poorest record of all 18 countries in our sample as far as its potential to produce knowledge is concerned. However, one should assume that there are plenty of opportunities for knowledge to flow into New Zealand given its high level of FDI inflows, strong imports of manufactured goods and the balance in favour of technology payments over receipts. In addition, New Zealand does have a relatively high number of university graduates. However, it has the lowest number of science graduates of the 18 countries in the sample indicating a limited potential for adapting and improving upon ideas flowing in from abroad. And, when considering evidence that diffusion has taken place, New Zealand ranks among the lowest of the 18 countries sampled.

Before attempting to draw conclusions from this evidence, it is appropriate to briefly reflect on New Zealand's history in R&D, its current status and policy initiatives. Bollard *et al.* discuss some findings of the Probine report which identified characteristics of New Zealand's environment that might influence the R&D profile of the country.[50] The characteristics are: the small size of New Zealand's production by world standards; the difficulty of evaluating products and markets due to isolation; problems presented by competing diversified land-based industries; the small scale of most manufacturing firms; the difficulty of appraising overseas technologies; the problem of balancing applied and basic research work; the limited number of scientists and the inability to specialise.

In addition, Winsley and Hammond note that most scientific research undertaken within New Zealand was completed by government departments such as the Department of Scientific and Industrial Research (DSIR), the Ministry of Agriculture and Fisheries (MAF) and the Ministry of Forestry. There were no real attempts made to develop science priorities and the research sector had a limited external view of the research being undertaken. Further, the pre-1989 science system lacked philosophical and strategic coherence, there was no independent co-ordinator of the science and technology function, no clear policy on the role of science in public life, sciences were funded on the basis of inputs rather than outputs, and the private sector generated a very low level of research.[51]

Crocombe *et al.* highlight other factors that have helped shape New Zealand's R&D efforts: exporters have demonstrated a limited commitment to R&D; commodity exports have traditionally been sold on the basis of price rather than product differentiation; and R&D budgets are often cut in order to maximise short term profits. They also note the low proportion of technically qualified general managers (30%) compared with the European Union (80%) and Japan (around 67%). Consistent with this finding was the fact that only around 30% of New Zealand firms had an R&D policy and even fewer had an R&D budget.[52]

There was a need to change New Zealand's research, science and technology landscape. Three new pieces of legislation acted as catalysts for change: The State Owned Enterprises Act (1988), the State Sector Act (1988) and the Public Finance Act (1989).[53] As a consequence, New Zealand's science and technology sector underwent major reforms between 1989 and 1992 with the dismantling of the DSIR and the establishment of three key bodies responsible for administering public research: The Ministry of Research, Science and Technology (MORST) which provides policy advice; the Foundation for Research, Science and Technology (FORST) which predominantly provides funding for research via the Public Good Science Fund (PGSF); and nine CRIs which are government owned research institutes. Obviously, there are other research providers such as universities, private sector based research associations, trusts, private companies and individuals—all of which can apply to the PGSF for funding.[54]

However, despite the radical changes to New Zealand's research, science and technology sector, Winsley *et al.* have identified current weaknesses, particularly in the private sector. These weaknesses include: a continually low level of investment in R&D; low employment of technologists; limited ability to either apply results of publicly funded research or to evaluate opportunities presented in research; lack of skills to manage technological innovations; limited stimulation for innovation, given New Zealand's small industrial sector, and limited domestic competition; and the confinement of research to narrow niches that do not attract the attention of international competitors.[55]

Perhaps many of these weaknesses provide explanations for the indicative results of our quantitative analysis. However, it cannot be expected that the data used in our analysis show the impact of the recent changes in New Zealand's science and technology system. Moreover, there is now also a stated political commitment to increase public R&D expenditure as a proportion of GDP, and to encourage more private R&D. It remains to be seen whether these and related measures will survive short-run policy reactions to economic fluctuations, and whether, if they were actually implemented, they would be able to remedy what, by international comparison, seems to be a National Innovation System *failure*. It is fair to say that if, as Winsley and Hammond claim,[56] the policy changes of the last decade have established a NIS in New Zealand which is unique amongst OECD countries, it still has to prove itself.

We conclude that our quantitative analysis supports (but does not prove) the view that a country needs to have a strong domestic R&D sector, including a strong industrial sector undertaking in-house R&D, in order to prosper in a knowledge and innovation intensive world economy. A strong domestic R&D sector enables a country to absorb international knowledge flowing across its borders, thereby reducing the risk of a knowledge gap appearing or widening.

Future research should focus on developing more sophisticated internationally comparable NIS indicators in order to take a more in-depth look at the profile of innovation, knowledge absorption and diffusion occurring within a diverse cross-section of countries and to develop a greater understanding of those processes. Also, New Zealand research is needed to identify both the dominant clusters that exist within the economy and how innovation flows within those clusters.[57]

Foreign Direct Investment

FDI inflows clearly provide a conduit through which knowledge can flow, but not all FDI is equal in this respect. This is highlighted by a comparison of New Zealand and Ireland. The case of Ireland, with its spectacular inflows of FDI into high-tech export-oriented sectors and strong economic growth in recent years, is attracting a lot of attention in New Zealand.[58] Like Ireland, New Zealand has opened up its economy to FDI inflows. For Ireland, this happened in the 1950s with the abolition of the *Control of Manufacturers Act*, which had prohibited foreign ownership and the introduction of subsidies and incentives to encourage foreign investment.[59] For New Zealand, the stability and business confidence generated by its major economic reforms since 1984 has meant that it became an attractive location for overseas investors. Economic reforms also allowed New Zealand firms, for the first time, to invest abroad.[60] However, the key difference between the two countries is that most investment in Ireland was into sectors where Ireland did *not* have an existing comparative advantage. FDI tended to result in the building of entirely new state-of-the-art factories on greenfield sites, which produced mainly for export.[61]

By contrast, FDI into New Zealand pre-1984 was directed to sectors where New Zealand *already* had a comparative advantage (such as agriculture, hunting, fishing and forestry) and was predominantly used to support import-substituting manufacturing. Therefore, the investment was particularly inward-oriented and inhibited technological development.[62] Since 1984, New Zealand firms have become more internationally competitive, FDI has been directed into non-traditional sectors, notably telecommunications and banking, and FDI has supported some export growth. But, FDI into New Zealand is seldom of the greenfield variety; most FDI inflows have been brownfield, i.e. taking over and modernising existing plants. Also, while New Zealand does not have a completely 'hands-off' industry policy, Ireland's industry policy has been much more pro-active, especially in regard to investment incentives.

The different characteristics of the FDI inflows into Ireland and New Zealand provide an explanation as to why the link between inflows of technology and evidence of absorption and diffusion taking place is weaker in New Zealand than in Ireland. It might also explain why Irish students are attracted to science education. Put simply, there are more job opportunities in science-related fields in Ireland than there are in New Zealand. It also suggests that the New Zealand government should have a closer look at whether its FDI policies are as growth promoting as they could be.

Recommendations

New Zealand has put in place a structure for fostering, prioritising and supporting science, research and development through the development of MORST, FORST and the CRIs, along with universities. The priorities are heavily biased towards sectors where New Zealand already has a competitive advantage. So, what should New Zealand do to improve the functioning of its NIS? We offer some general policy recommendations and suggestions.

First, New Zealand needs to emphasise improving education and developing human capital. While there seems to be a need for more science graduates, it is debated in New Zealand whether such graduates should be technicians or scientists and engineers. In our view both levels of training should be encouraged. Technicians are able to translate science and technology findings into usable forms for industry while scientists and engineers can push the frontiers of knowledge and develop innovations that ultimately provide New Zealand firms with some kind of competitive advantage in the international marketplace.

This leads to the second recommendation, that is, to develop applied research while continuing with basic research. FORST favours research that is directly applicable to industry, rather than basic research undertaken for the sake of research itself. This view presents two concerns for New Zealand. First, since so few firms engage in R&D, the opportunities for directed research are limited; and second, emphasising directed research over basic research can remove opportunities to renew and reconfigure ideas.[63] As Laursen notes, 'basic research at the national level is ... economically important because it provides research training, state-of-the-art development and use of research techniques and instrumentation, and access to high-quality international networks'.[64] While there is no doubt that New Zealand needs to continually invest in human capital and undertake research, the emphases suggested by FORST toward developing technical skills and undertaking applied research may not be beneficial to New Zealand in the longer term.

Third, public and private research partnerships should be encouraged. Commenting on the past 25 years of innovation studies, Pavitt notes that 'technologically dynamic firms depend heavily on the close proximity of publicly funded academic research and related training'.[65] In addition, firms should have easier access to ideas and assistance with adapting those ideas via consultancy, benchmarking and diagnostics.[66] FORST, through its subsidiary Technology New Zealand, has already put in place a programme to provide firms with a FORST approved consultant who will conduct technological evaluations and benchmarking studies and provide advice.

Fourth, New Zealand's private sector should be made more aware of the gains that can be made from R&D, not just at the level of the firm but for the economy as a whole. Perhaps this might require a more pro-active role from FORST in promoting both the benefits of research, science and technology and the services offered by FORST, and then assisting firms to develop and implement R&D strategies, even if this simply means linking in with public research institutions. In addition, FORST needs to encourage firms to see R&D as a dynamic process rather than a myopic process; that is, to see R&D for the intangible outcomes it also produces—such as irreversible learning and processes that enable future R&D. Therefore, firms should be discouraged from viewing investment in R&D as a conventional investment requiring a well defined market demand and a strong discount for risk and time.[67]

Fifth, analysts of the New Zealand economy are divided over the question of whether the country should mainly focus on upgrading its existing competitive advantages in natural resource based production, or whether a more radical re-orientation towards new competitive advantages is necessary in order to halt New Zealand's slide down the OECD league table. The latter view is increasingly being endorsed, influenced by the example of Ireland's success story.[68] An earlier example is the 'Porter report'[69] whose recommendations seem to have been largely ignored by policy makers. However, what contribution a nation's science system can make to affect its technology system in order to bring about such a redirection is not clear. The view, currently propagated by the government, that the science system has to be reoriented to more directly affect technology and growth seems far too simplistic.[70] Moreover, it can be argued that basing science funding on foresight exercises, as is currently being done in New Zealand, might be misguided. In short, distinctions between blue-sky and more immediately economically useful research are largely spurious, and academic research should not be made the scapegoat for shortcomings in other parts of the NIS.[71] This highlights the urgent need for further studies of the New Zealand NIS and a critical assessment of current government policies in regard to science and technology, industrial strategy, education and training.

Appendix A: Definition of High, Medium and Low Technology Industries

Industries are grouped on the basis of their R&D intensity in the OECD area as a whole, defined as the ratio of business enterprise R&D to production.[72]

- *High technology*: aerospace (ISIC 3845); computers and office equipment (ISIC 3825); communications equipment and semiconductors (ISIC 3832); electrical machinery (ISIC 383–3832); pharmaceuticals (ISIC 3522); scientific instruments (ISIC 385).
- *Medium technology*: chemicals, excluding drugs (ISIC 351,352 – 3522); rubber and plastic products (ISIC 355,356); non-ferrous metals (ISIC 372); non-electrical machinery (ISIC 382 – 3825); motor vehicles (ISIC 3843); other transport equipment (ISIC 3842,3844,3849), other manufacturing (ISIC 3841).
- *Low technology*: food, beverages, tobacco (ISIC 31); textiles, apparel and leather (ISIC 32); wood products (ISIC 33); paper and printing (ISIC 34); petroleum refining (ISIC 353,354); non-metallic mineral products (ISIC 36); iron and steel (ISIC 371); metal products (ISIC 381); shipbuilding (ISIC 3841).

Appendix B: Data Used in the Analysis That Is Not For 1996

1. Government expenditure on R&D: Australia (1994); Switzerland and the USA (1992).
2. GERD as a percentage of GDP and financed by industry: Australia (1994), Switzerland (1992).
3. Researchers: Australia and Italy (1994); Austria, Canada, Germany, Switzerland and the USA (1993).
4. Technology payments and receipts: Australia and the USA (1994); Sweden (1993) and France, the Netherlands, Norway (1992).
5. Researchers: Austria (1993); Belgium (1991); Canada (1993); Finland (1993); Germany (1993); Ireland (1993); New Zealand (1993); Norway (1993); Sweden (1993); Switzerland (1992); the USA (1993).
6. All education figures—1992.
7. Manufacturing: New Zealand (1995, therefore the growth rate is for 1985–1995).

Notes and References

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