Beyond the Farm and the Theme Park:

Can New Zealand increase its wealth via the high technology route?

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Abstract

Converting most of our forest into greenhouse gas has given us an abundance of grass and a thriving dairy industry. Yet through good fortune and some wise heads, we have, notwithstanding attempts to subdue it, sufficient residual natural environment to claim the label "clean and green". Our landscape is magnificent and helps define who we are. But this lecture will argue that we have the potential to be a great deal more besides, and that we must be if we are to build the society we want our children to thrive in. It will argue that we can enhance our prosperity through sensible investment in science. and technology, coupled with culture change. The first part is the easy bit. The second requires self-belief and a sense of purpose. David Lange once said New Zealand's destiny was to be a theme park (and Australia's, a quarry). We can surely think and act beyond that. Indeed New Zealand is such an interesting place to live precisely because we are so capable of determining our future.

What I am about to speak about today you should treat with scepticism. This, at heart, is a lecture about economics, and I am not an economist. But the discipline of economics is one I have some respect for, especially because of its own inherent scepticism. I'm a scientist, so being a sceptic comes naturally to me.

I have no expertise in economics, though it's a subject that fascinates me. Far from being "The dismal science", it is a subject about humanity, about human behaviour, and also about how we can live socially to the greatest mutual advantage. If you find that view extreme, let me suggest that you read 'The undercover economist' by Tim Harford(1), and if you are not fascinated by this subject after the first few pages, then I will be very surprised indeed.

I am also interested in economic history, and in what makes nations wealthy or poor. I believe that the keys to prosperity and wealth are effective markets, legal frameworks, property rights and an honest work ethic. But that, in itself, is not enough. If it were, then we in New Zealand would be one of the most prosperous countries in the world, since few countries can better us in our openness of markets, legal transparency, hard work and lack of corruption. Since 1984 we have been in debate about that. The economic liberals, as they like to call themselves, said that all we needed was a level playing field. With low taxes, minimal government involvement in the economy and deregulation, the markets would work their wonders and we would all prosper. But then, for over a decade, we watched ourselves slip behind countries that were frankly less pure, less economically virtuous than we were: countries like Finland or Sweden or Ireland or Israel - places where governments frankly meddled.

Like David Landes(2), who has looked at the way societies prosper or fail, I think that effective markets, legal frameworks, property rights and an honest work ethic are essential to prosperity, but they are not in themselves enough. I am interested in the New Zealand side to that story, and my lecture is about New Zealand's future prosperity. I am going to make the assumption that we would rather be wealthy than poor, although we are aware that there are measures of a nation's wellbeing that cannot be expressed in per capita income. But let me declare that I am all for a higher per capita income for New Zealand. Surplus economic capacity is what enables societies to improve life quality, should they choose to spend such capacity this way. And like many of you, I am extremely interested in the process of increasing New Zealand's economic capacity. Not surprisingly, I have no brilliantly simple solutions to offer.

Having expressed a wish to see improvement, I want to point out that our quality of life has improved in many ways, despite our relative per capita income having declined. I remember the 1950s, when we were near the top of the world in per capita income. I remember when my father called five shillings a dollar, because that is what our exchange rate was then. And yet in the 1950s men died in their fifties because of heart attacks, teenage girls disappeared for periods of nine months to stay with distant relatives, people who had travelled abroad were regarded, at least in my street, as slightly scary, food was meat and three veges, and drinking coffee was something riské and done at night in darkly lit places called coffee bars. Life was good but a bit boring, and I couldn't wait to escape New Zealand. You certainly couldn't be an international scientist or a concert pianist with New Zealand as your base.

Of course what has changed, and especially benefited New Zealand, is technological innovation driven by science, the internet and cheap air travel (being the latest to help us out). In his book[(2)], 'The wealth and poverty of nations', David Landes cites the case of Nathan Rothschild, the richest man in the world in 1836, an abscess developing on his lower back and dead at 59 years from streptococcus septicemia. No antibiotics in those days. To quote Landes : *The man who could buy anything died of a routine infection, easily cured today for anyone who could find his way to a doctor or a hospital or even a pharmacy.*

That's how Landes sees prosperity, and that makes him my type of economist.

In the New Zealand context there are several economic thinkers that I would like to acknowledge, because they have so influenced my views. David Bibby is a scientist while Andrew Cleland is an engineer. Sally Davenport is a science-business expert. And two New Zealand economic thinkers who, in my view, are both insightful and who understand how we might enhance our prosperity, are Rod Oram and David Skilling. I acknowledge them and their writings, though I take full responsibility for the views I will express.

This lecture is also then, about science and technology, and their place in our society. First and foremost the role of science is cultural. When Galileo built the first telescope he observed the moon and found it was not a perfect sphere but had mountains and craters. He observed the phases of the moon, as well as the phases of Venus, and he realised the universe was not earth-centred but that we were in orbit around the sun. And looking out to Jupiter he saw its moons, and realised that orbits took place around many different points in the universe. For that heresy, he was silenced by the church. For similar apostasy, Giodorno Bruno was burned at the stake. But despite the efforts at suppression, the enlightenment had begun, and the earth-centred universe was finished. Thomas Hooke used lenses to observe the micro world and a new plethora of living organisms was discovered, so that humanity learned that most of life was microscopic, single-celled and unfamiliar. Charles Darwin gave us an extraordinary new insight regarding the origins of life on earth, and from Ernest Rutherford's understandings of radioactive decay, we learned that our planet was not thousands of years old but 4600 million years old. From the X-ray diffraction work of Rosalind Franklin and Dorothy Hodgkin, we learned about the structure of DNA and proteins, and so the age of biological insight began, insight that enabled New Zealand geneticist Allan Wilson, to discover the links between humanity, using the method of mitochondrial DNA tracking. We now know that the average genetic difference between people of different races is insignificant compared with normal genetic diversity in any single monoethnic group. We are all part of the same human family. Racism is scientific nonsense.

Those are our philosophical insights from science. But in economic terms, science has also driven the rise in prosperity that has permitted the human population to grow.

Let me give you just a few ways in which the real wealth of nations has been immeasurably improved over the past five hundred years:

* The science of optics, the eyeglass, and, through Galileo and others, its descendents, the telescope and magnifying glass. Nothing has quite so increased human productive potential, as the ability of those beyond 40, to continue to apply their skills and contribute to their craft.

*The telegraph, radio waves, the science of electromagnetism due to Faraday and Maxwell, and modern communications. In the New Zealand case, we moved from isolation to sudden connection to the world.

*The discovery, by Fritz Haber, of how to fix nitrogen from air, enabling the synthetic manufacture or fertiliser (and high explosives).

*The discovery, by Fleming and Florey, of penicillin, the science of antibiotics and the bacterial causes of many diseases.

*The discovery of the electron by JJ Thomson, the atomic structure, by Rutherford, the laws of quantum physics, by Schroedinger and others, and thus the birth of modern electronics and the possibility of the computer age.

*The discovery, by Bardeen, Brattain and Schockley, of the transisitor.

*The development of the contraceptive pill, completely changing social relationships, empowering women, giving a new impetus to our productive potential.

Contraception has allowed us to manage fertility, so that we might see a levelling of human population on the planet. Of course we still face issues of sustainability, issues that we will need all the power of science to address. But that is a subject for another talk.

Today I want to stake out my position as a humanist, and one who believes that it is not best to leave nature alone, or that "nature knows best", but instead that it is best to harness science and technology so that humans may prosper, while living in harmony with nature. Those who seek to return to some mythical, Arcadian, pre-industrial past, better reckon on reducing the world's population to 100 million, and then, to be prepared for a brutal and probably precarious existence. Unless we relish the thought of some sort of "rapture" or "Armageddon" where the unbelievers will be struck down, the unbelievers I guess needing to be 98% of humanity, we humans probably have no choice except a future based on science and technology.

Let me turn to New Zealand. If you go to the Rangitikei district of the North Island you can do a tour of stately homes of the Rangitikei. Most were built in the late 1890s or early 1900s when New Zealand changed from being a poor economy, to one in which prosperity rose rapidly and newly wealthy families developed delusions of grandeur. That change was brought about by the science of thermodynamics, and the development of the refrigerator. Refrigerated shipping lifted New Zealand from subsistence trade, to trade advantage and relative wealth. I spoke to a group of MPs recently about this. Not one of them knew the name of the ship that carried New Zealand's first refrigerated cargo. When I was a schoolboy we all knew the name of the S.S. Dunedin.

Agriculture became New Zealand's source of and its wealth generation. I have made a few ribald remarks in my abstract about our use of forests (Figure 1). We all know how our use of land has been a springboard for our present prosperity. I don't really think we need make apologies for that. In fact, if you take Jared Diamond's perspective[3] about the importance of a biodiversity buffer of indigenous forest (he reckons about one third is ideal) then we are looking very balanced at present, and I don't think there is any serious suggestion that we should cut down more of our native forest. Of course we may not have quite the moral high ground in telling developing countries that they shouldn't cut down their rainforests, but that is a matter for politics.

So, not only did we have new land in pasture, but our science innovation gave us world-class agriculture, so that by the time I was born, New Zealand had one of the highest per capita incomes in the world. And more than that, we have become a big international player in agriculture. For amusement, the University of Sheffield[4] has given us 'World Mapper' in which we can see how we perform in different terms, for example, net dairy exports, net electronics exports and tourism. We really are a "superpower" in dairy.

But something is not quite right in our economy. Even though our absolute prosperity increases as we all share the fruits of international science and technology discoveries, we see that our per capita income has relentlessly slipped behind countries we used to better (Figure 2). We see that our prosperity requires us to work harder, for less, in order to try to keep pace with the rest of the developed world. You might say, "Who needs the rat race? We have a good quality of life here and we don't need to ape Europe and the United States, and we don't need to be as prosperous as the Australians." If so, you would have a point, yet let me put two things to you.

First, we see that our roads are, by first-world standards, poor, and that people die unnecessarily. We have a congested Auckland, and we don't know how to afford to build Transmission Gully in Wellington. Not so serious? Well let me try another tack. We can't afford the medicines we think we need. Worse, we see that our Australian cousins can, and we are outraged. So suddenly we see that our prosperity isn't quite good enough for us, and that it doesn't meet our expectations. But, you might say, we just have to take our chances with health. At least we have a good quality of life in New Zealand, in terms of the basics, the things that really matter. Actually, I'm not so sure that is true when you look at our housing, the quality of the living environment that causes old people to die in winter and kids to get colds and infection. Our national housing stock, when it comes to insulation and interior warmth, is poor, substandard given our cool and damp climate.

But, even if you are prosperous and think that you can avoid all these problems, there is a second reason why you might be worried. Our children go to London or Sydney or New York, and frankly, they quite like the lifestyle there, and the high salaries, and they have plenty of Kiwi mates on hand. What is the size of our diaspora? 500 000? One million? Indeed, there are plenty of people with brains and talent who want to exchange places with our kids. There are plenty of countries on the planet less prosperous than ours. But when our grandchildren are growing up on the other side of the world, when we have to Skype to read a bedtime story when we would rather hold the grandchild and read the book in person, we feel a pang of grief. Our prosperity gap, and especially our prosperity gap with the English-speaking world, causes us a loss of children and grandchildren. Prosperity matters to families. And while we are dealing with OECD rankings(5), in quality of life measures such as imprisonment rates and life expectancy, we have a rather spotty story. As for infant mortality, it is nothing short of shameful. Are these social factors related to prosperity? I don't know for certain, but I can't see how a declining per capita GDP ranking can help.

So what's the problem? Let's go back to some of those historical indicators. First, look at this data from 'The Economist' magazine(6). We export commodities, and at the moment we think that's a pretty good thing to do. But look at the long-term trend for commodities (Figure 3). It has its local peaks when times are good, but the overall trend is relentlessly down. To hammer home that point, David Bibby, who I mentioned earlier, produced an interesting graph (Figure 4) a few years ago showing the ratio of meat exports to pharmaceutical exports, the number of sheep carcasses needed to buy a quantity of aspirin or some chemotherapy treatment, if you like. This ratio shows that we have deteriorated in advantage by a factor of 4 in the past 30 years. I decided to update it a bit, and so I have added the last seven years. Well, at least matters have stabilised for the moment, but they have merely stabilised when we have enjoyed a commodity boom. What's more, we work more hours for less output that the countries we like to compare ourselves with (Figure 5).

Now let's home in on the Aussies. In the abstract to this lecture, I quoted David Lange, who said that New Zealand's destiny was to be a theme park while Australia's was to be a quarry. What a clever man, and so very entertaining. And aren't those Australians lucky! All they have to do, when they are feeling poor, is to dig another hole and sell the contents to China. Or at least, that's how our myth goes.

But the fact remains that we have a GDP per capita shortfall vis-a-vis Australia, and for the last year, it represented around 29 billion US dollars. In other words, that's how much more we have to produce in order to match Australia's per capita GDP. And the problem for us is that we are just 0.2% of the world's economy. Our local market is very small, and much of what we want to buy will be made offshore. What that means is that our extra productive capacity will need to be directed to exports. Everything we want to buy offshore, whether pharmaceuticals or i-Pods, we can only do if people elsewhere in the world want to exchange their dollars, euros or renminbi for our goods, or for our land or our dollars. We can, for a while, sell them our dollars on the basis of high local interest rates, but eventually they will repatriate their earnings, and probably their principal. We can sell them our land or our businesses, but one day we will run out of things to sell. Crunch time always comes and the consequence of that is a weaker New Zealand dollar value, and us working even harder to buy even less from offshore. Is that what has happened? Hence, in the 1950s, my father referred to five shillings as one dollar and he meant one US dollar. For those of you who are too young to know what five New Zealand shillings was, think 50 cents. 50 New Zealand cents was worth one US dollar, in the 1950s. Our currency is now less valuable by a factor of 3. So yes, if we don't export enough, we get relentlessly poorer, relatively speaking.

So where might we earn another 29 billion US per year in foreign exchange? The relative export dollar fractions as indicated by the latest Department of Statistics data (Figure 6), show that Tourism is now number one, with manufacturing close behind. Dairying continues to be a great New Zealand success story. 29 billion US per year extra means multiplying our dairy industry by 4 or 5, our Tourism by 3 or 4. Let's look first at Dairy. Fonterra is a great success but it has its limits to growth and it faces potential risks, including environmental impact, methane contribution to greenhouse gas (Figure 7), and international perceptions regarding "food miles". Tourism is extremely successful but it has its limits as well. Indeed, we may have already reached the limits to "eco-tourism" in some areas.

I doubt that it would be feasible to Fonterra's production let alone increase it by a factor of 4, and I doubt whether we would want to triple the number of tourists visiting New Zealand each year, from 2.5 million to 7.5 million. Milford Sound already has 10,000 visitors per week, and if you walk the Tongariro Crossing on a fine day you will share the track with 500 people. Of course we could just have more of the higher-paying visitors, the sort of people, for example, who will pay 8,000 dollars to shoot a deer in an enclosure. But is that really how we see ourselves as a nation? Is that what it means to be a New Zealander, servicing that trade?

I want to suggest another model for New Zealand export business, and one that has few downsides. To start with, here's an analysis of some international businesses, in terms of two particular metrics. I have tried to look at how much different sorts of businesses earn, both in terms of revenue per employee and in terms of profit per employee. Figure 8 shows a list of companies, many in what I would call the "science/technology" sector, and some, for comparison in retailing or food. I am not arguing that either revenue per employee or profit per employee is necessarily that helpful an indicator of wealth generation, but it is interesting. Of course, one needs to look at the assets of a company to get the full picture. What did it cost to build the asset base to allow that industry to function? In the case of high-tech companies, the asset base is mostly brains and knowledge, whereas for an energy company, it may be large-scale construction along with some brains, or fewer brains, depending on the particular company.

But looking at largely brain-based business, it does seem, overall, that high-technology companies come out quite well. Indeed there are several companies, in the US especially, where $1 million US revenue per employee is not uncommon. Of course large revenue will be most interesting, from a wealth generation perspective, when it arises from the lowest raw materials input value, or supplier product input value (and least capital asset base). In this regard, Samsung, which makes its own chips and consumer electronic products, could be close to that ideal. The point is that Samsung produces about three quarters of New Zealand's GDP with 123,000 employees. That's a sobering thought.

Let's make some New Zealand comparisons of revenue and profits per employee. It's not as easy to get this data (Hoovers[7] don't analyse many NZ companies), but based on NZX data, CCMAU data, and company reports, I could glean the following. At the high end is Meridian Energy. For 2006/7 it was US$ 3.7 million per employee. This seems high but it overlooks the company's enormous asset base of $5 339 million, assets from which they gain a 20% rate of return, which is, of course, not too bad. Amongst the New Zealand top performers, it seems that Auckland Airport also makes a large amount per employee, but they too have assets, and there is a cost to capital. And of course, they do have a very fine airport and, what may seem to the airlines who pay them, a nice business arrangement. There is no doubt that Auckland Airport greatly contributes to New Zealand's wealth, and most certainly to its shareholders.

So what are our high-tech stars? These are the companies whose assets are the brains of their team. No dams, no windmills, no runways and airbridges, but just talented people who create employment for other talented people, who might have some computers, some machine tools, some circuit manufacturing capability and some plastics moulding equipment. We have a handful of such companies in the 100 to 200 million dollars per year of revenue category. These include Rakon with GPS on a Chip, Fisher and Paykel Healthcare with hospital technology, Tait Electronics with radio communications equipment, and Gallaghers with security equipment and electric fencing. None of them beats Fonterra in terms of revenue per employee, but let's consider for a moment their big advantage. Rakon, Fisher and Paykel Healthcare, Navman, Gallaghers, Alphatech, Vega Industries: all these high-tech firms, whether 10 or 100 million per annum, need no new resources to start except brains and market understanding. Unlike Fonterra (or Meridian), they need practically no land. They incur no significant costs of transport across the world, because their products are worth tens of thousands of dollars per kilogram, or better still, weightless. They emit neither significant greenhouse gases nor do they dump nitrates in our lakes. The Resource Management Act is no bother to them at all, and, if their products are really valuable, they are perfectly happy with a high New Zealand dollar value. And you put these businesses in perfectly attractive buildings, without smokestacks or waste dumps. In short, they are environmentally and socially benign.

So, if we are to generate significantly more wealth in our economy without new land impacts or environmental impacts, a path worth carving out is "high technology". High tech is characterised by[(6)] "products that embody relatively intensive research and development (R&D) inputs, either directly at the final manufacturing stage or through the intermediate components used in their production." One British definition includes "processes which could be carried out in a residential area without detriment to amenity.".

The high-technology sector is often perceived as having greatest financial risk, yet greatest potential for future growth. It is an international phenomenon, assisted by internet communications.

There are many innovative New Zealand companies, such as Icebreaker and 42 below, who are doing a brilliant job building export-led business. But my particular focus is on those companies where exceptionally high scientific or technological knowledge is central to the business model. Our star performers, Rakon, Navman, Fisher and Paykel and Tait Electronics, build on a platform of physical sciences and engineering capability, and they have shown that knowledge-rich physical technology platforms can be as competitive from New Zealand as from anywhere else.

Clearly New Zealand would benefit if many more such "knowledge businesses" were to form, but what can we do to seed that process? The reason that each of these companies started, the nucleus of each subsequent growth, is not widely understood, although in several cases, pathways to success have been examined[(9)]. Anecdotal evidence suggests the role of inspired individual entrepreneurs, few of whom came from a formal, research-based scientific background, but all of whom have extensively employed high-level R&D capability. To quote[10] from one CEO in the Davenport *et al* study, head of a company employing 160 design engineers in the largest electronics R&D facility in Australasia,

In those days (30 years ago), a radio was designed by one person and it took hundreds of people to manufacture it. Nowadays, you almost need no-one to manufacture it, but it takes hundreds of people to design it.. ...so right now we are looking at what we have to do to give highly creative engineering people and software people an environment.... which enables them to be creative.....we have done a lot of work on a career path for technical people.

I don't think that it is sufficient for us to merely create a macro-economic environment conducive to business, and especially export business, and to then hope for seed nuclei to form. My interest is in multiplying the seeding process and seeing the first steps to market assisted. One obvious place to look for such seeds is in the large body of publicly funded scientific research, especially in those areas of science where commercial opportunities abound. Our prior success stories suggest that physical sciences may be our best hope.

I am speaking here of spin-out companies. A spin-out is *a company formed through the transfer of technology from an R&D company, which is completely independent of the parent (R&D) company, and involves the transfer of human capital*. Given that the receptor capacity of New Zealand is weak (*ie* there are not suitable pre-existing vehicles for commercialisation), the spin-off strategy is, in many cases, the only viable option for the parent IP owner[11]. Examples of such recent spin-offs are: Southern Photonics Ltd (optical pulse analysers) from the University of Auckland, WhisperTech (Stirling cycle engines) from the University of Canterbury, magritek (magnetic resonance technology) from VUW and Massey University, Australo (nanomanipulation of DNA) which has grown out of prior University of Otago research, and Photonic Innovated Ltd (laser detection of gases) also from the University of Otago research but is now independent of the university. And in the biotechnology sector, we have Proacta, a US company commercialising University of Auckland cancer drug IP, and Protemix, a University of Auckland spin-out company developing drugs to treat diabetic heart failure. Both show considerable promise, but a significant income stream has yet to be generated. Therein lies an interesting issue.

New Zealand's Growth and Innovation Framework has targeted Biotechnology and ICT as the best areas for R&D investment. I think that ICT is indeed an area of high technology where we can get to market quickly and where we have shown that we can be successful. But Biotechnology is one of the most difficult areas in which to get products to market, the most difficult to generate income streams. We are not particularly effective at turning science intellectual property into business, especially in the biotechnology area. By contrast we seem to be very good at doing it in what I call the physical platform technology.

I think, given our capability in physical sciences and engineering, that we could generate many more start-ups of the Rakon/Navman variety, and if a fraction of them succeed we may do far better than via the biotechnology route favoured by government. One of our main funding instruments for building a platform for high technology spin-out has been the New Economy Research Fund (NERF). The MoRST-commissioned report on this fund, undertaken by US firm ABt Associates(13), suggests that New Zealand disproportionately invests in biotechnology (Figure 9, 10), yet the outcomes, in science, intellectual property and business activity, have been significantly poorer than those for physical sciences and engineering.

The research and commercialisation effects of people like Bill Denny of Proacta or Garth Cooper of Protemix, are heroic, and we should continue to support such high quality biotechnology research. If we succeed, the payoffs could be very good indeed. But the fact is that New Zealand's research investment profile is anomalous by comparison with most of the countries with which we compare ourselves. My own impression, and all I read from Ministry papers suggests this, is that a decision has been taken that we should emphasise biotechnology because we are good at farming. In my view we should invest in platforms where we have capability and talent, and being the small country that we are, we would be most unwise to plan in advance where these capabilities and talents are likely to arise. The list of output area allocations in this year's NERF bidding round (Figure 11), prior to calling applications, shows just how we are trying to micro-manage our research. No public servant has the prescience needed to make such pre-selected allocations. It would not be difficult to change the way we manage these instruments. We certainly need more investment in physical sciences and engineering, but we need it to be allocated to people with good ideas and enterprising intent, rather than bundled up in prepackaged boxes. It may be that we have talents in biotechnology, but we certainly have great potential for wealth generation in physical technologies. We should remember that Rutherford and MacDiarmid did their Nobel prize-winning work in physical sciences (abroad, of course). And we should note that the overwhelming majority of New Zealand's successful technology startups are in physical technologies.

I am not advocating spending less on Biotech research. But I am suggesting that we shouldn't apply blinkers, that we do have a track record of producing great businesses out of physical sciences and engineering, and we have the potential to do a great deal more.

But most importantly, we should realise that we probably won't get results on the cheap. We invest less per capita in R&D than the OECD average[12] (figure 12), and our industry research investment rate is extremely poor. Further, we invest a great deal less per capita in crucial future-focused areas such as nanotechnology (figure 13). Despite that, our per capita rate of science publication is high, on a par with the best in the world. But where we perform badly is in the generation of intellectual property per capita. Here we rank with some of the worst performers. Why is that? Perhaps in part it reflects the nature of business in New Zealand, and in particular the low technology character of much of our manufacturing. But I also believe that it is because of the lack of an enterprise culture amongst our scientists. It would be interesting to have information for New Zealand patent rates broken down by institution type. In some CRIs, boards and management are loath to share benefits of IP with research staff. By contrast, in the universities, fewer excuses for poor performance exist. Staff are entitled to one third share of benefits.

Indeed at least one report suggests that our commercialisation rate from university research exceeds the United States average, but we should remember that many US universities are weak in research, and that they are more than compensated for by the spectacular success of institutions of the commercialisation calibre of Stanford, Caltech or MIT.

Frankly, New Zealand science needs to do a whole lot better. That is where Centres of Research Excellence can contribute. One of the things we have tried to do in the MacDiarmid Institute is to try to create a culture of entrepreneurship among our graduate students, to share with them the experiences of their fellow graduates who have gone into business, and to bring them seminars from world-leading technology entrepreneurs. Amongst this group we have outstanding human research capability, in physical sciences and engineering. Our challenge is to turn that capability into a manufacturing industry, to get people to "make things that the market wants". We have to fire up our young scientists so that they see starting their own business, or joining a start-up team, as the most exciting prospect for working in New Zealand.

Part of our culture change will be to encourage a marriage of physical sciences and engineering. Ultimately, when we come to make products to sell to the world, we will need the skills of the engineers and designers. And New Zealand performs badly in this regard. We have a disjoint between engineering and physical science that borders on hostility in places. This is ridiculous. We have far too few students enrolling in engineering courses in our universities (Figure 14), and far too few taking the necessary maths and physics at high school. But the solution, I believe, lies in the hands of the present science and engineering generation. When we create the exciting high-paying jobs in the New Zealand high-technology sector, smart kids will cotton on fast.

I want to tell you a personal story about my quite recent journey from science into entrepreneurship. It grew out of geophysics research funded under a global climate change output of the Foundation for Research, Science and Technology (FRST). It had a myriad of causes, many of which were to do with physicists and electronics engineers working together in an Antarctic adventure. It was encouraged by the FRST twisting our arms in the direction of enterprise. It took off because we had a brilliant and unconventional young entrepreneur with a PhD in magnetic resonance who could act as CEO. It grew out of the principle that technology and science are intertwined. I can't be certain that magritek will make it, but it is performing, with revenue of nearly one million per annum, six employees, and a minimal asset base.

So how do we boost the high technology sector in New Zealand? First and foremost we should do the easy things. We should discard the myth that because we are good at farming, our best high-technology future lies necessarily in biotechnology. In fact our best high-technology future will lie where our skills, our talents and our enterprise are apparent. Biotechnology may be one area where talent exists. However, the obstacles to successful commercialisation in physical sciences and technology platforms are apparently lower, and the country clearly has capacity in this area. The FRST needs to disengage the process of encouraging wealth generation from the process of maintaining CRI stability (allocations in boxes). The NERF fund in particular needs to be freed up to all-comers, with funds being allocated where the science, engineering and enterprise capability is exhibited, and not in pre-labelled packages invented by FRST officials. We should be prepared to be surprised, to find talent in unexpected places and in unexpected science platforms.

Second, we need an injection of new public funding in research. We cannot expect to reach the technology-based economic performance of countries we aspire to equal when we invest in R&D at a much lower rate, lower in business investment and lower in government investment. We have it in our power to do something about the latter. But new money should be invested wisely. I am not convinced that Vote R S and T is the best vehicle for that investment, unless the FRST is able to allow open and free competition from across the research sector, thus allowing New Zealand's research capability to be fully unleashed. In my view, physical sciences and technologies languish under the Foundation's stewardship. At the moment much of New Zealand's nanotechnology research is funded via Vote Education. Whatever route is chosen, such additional funding will need to avoid prescriptiveness, except for demanding ingenuity, intelligence, enterprise and commercialisation intent.

More funding and more effective investment instruments are relatively easy to achieve. What is much harder to achieve is a culture in which scientific and technological enterprise is valued, where business seeks to innovate, where scientists regard business as a valid outlet for their talents, and where children aspire to be scientists, technologists and engineers. We need our universities and institutes to champion world-class New Zealand science research where only the best will do, attracting the world's best to New Zealand, and enabling New Zealanders to be world-class scientists working in New Zealand. We need to build a science platform that is internationally connected, wealth generating and a focal point for society, hopefully raising the status of science in the New Zealand context. And most importantly perhaps, educating a new generation of scientists who are excellent, entrepreneurial, communicative and socially aware, a generation seeking lifetime contributions to New Zealand.

We need to build active links with the Kiwi diaspora, along the lines of the important work carried out by Stephen Tindall and the KEA network. New Zealand has an opportunity to recruit new migrants and returning Kiwis of exceptional enterprise and scientific/technological talent, in a world that looks increasingly tense and unstable. To be successful we need to be viewed internationally as more than a 'Farm and Theme-park'. A major cultural shift towards greater emphasis on science and technology may thereby generate new high technology enterprises through such a multiplier effect. Perhaps even more important is the degree to which we can create urban environments in which people of talent and enterprise will want to live. Arno Penzias[13], Nobel Laureate and, until 1998, CEO of Lucent Technologies (Bell Laboratories), has expressed the view that successful technology business clusters tend to form in the vicinities of excellent universities where the living environment is conducive to graduates wanting to continue to live in the vicinity, the San Francisco Bay area, Boston and the Rayleigh-Durham triangle being examples. If we are to attract the best scientific and technological entrepreneurs to base their business enterprise here, if we are to attract talented expatriate

Kiwis home, and retain the best of our own, then we not only need a vibrant science and technology culture, but great urban environments and a stimulating intellectual climate.

We need to acknowledge the heroes of New Zealand's high-technology sector: Neville Jordan, Peter Maire, Gary Paykel, Rod Drury, Ken Stevens, Russell Smith and Angus Tait amongst others. They have done in business what Peter Jackson and Richard Taylor have done in the film industry. The kids know about Weta and the Jackson studios. But they don't know the stories of the remarkable individuals who began our high technology sector.

We need to remember that small countries can do astonishing things. Finland with a population of four million produces Nokia cellphones. Sweden, with a population of nine million makes Saab fighter jets, Volvo motorcars and Erikson cellphones. It manufactures pharmaceuticals and, in Ikea, sells kitset furniture to the world. One single family, the Wallenbergs, donate 200 million New Zealand dollars a year, mostly to science research. That's five times our Marsden Fund. Sweden runs the Nobel Prizes, they decide who get the top prizes in science for the world. That's pretty impressive.

Swedes aren't any better educated than us. They aren't more ambitious than us. It's just that they expect to innovate with science, while we see ourselves differently. Look at how we overachieve in sport, and compare that with how we underachieve in creating large sustainable businesses (Figure 15). Australians are as anomalously good at sport as we are, but they do better in the business arena as well.

It doesn't have to be that way. We have the capacity to do a whole lot better. We have the brains, the education system, the inventiveness. But we do need to resist our occasional little-mindedness, our parochialism, our tendency to divide amongst ourselves, our tendency to be suspicious of each other. We have business suspicious of government, engineering suspicious of science, Wellington resenting Auckland, Auckland University pretending the other universities don't exist, CRIs jealously protecting research grants from universities, the Ministry of Research, Science and Technology disjointed from the Ministry of Education, the Foundation for Research Science and Technology disconnected from the Tertiary Education Commission. We just can't afford it, we in this wonderful, but small country, with our population no bigger than Manchester of Philadelpia, but no smaller than Finland, where people seem a whole lot better at working together. My plea is that we believe in ourselves and work hard to discover the business models that work for us. My plea is for New Zealand-incorporated perspective, where we build links with our talented diaspora and all the other fellow travellers who love this country in the great big Global Village out there.

I started by praising economists. Now that's a huge start for a scientist in overcoming little-mindedness. I cannot be certain that we can lift our per capita GDP performance via the route I am suggesting. But I think it's worth a serious try. Further, by enhancing the role in New Zealand society both of science and, more importantly, of the values of science, we better prepare ourselves for a future where science and technology will play an increasing role in all our lives. Science is (or should be) about honesty, persistence, striving for excellence, scepticism, and seeking consistency with what we know. I suspect that some or all of those values lie at the heart of most effective economies.

Let me finish by quoting Landes again(1).

Rich economies must defend themselves (ease but not eliminate the pain) by remaining on the cutting edge of research, moving into new and growing branches, learning from others, finding the right niches, by cultivating and using ability and knowledge. Much will depend on their spirit of enterprise, their sense of identity and commitment to the common weal, their self-esteem, their ability to transmit these assets across the generations.

We live in the dessert age. We want things to be sweet; too many of us have to work to live and live to be happy. But that doesn't promote high productivity. You want high productivity? Then you should learn to live to work and get happiness as a by-product.

The people who live to work are a small and fortunate elite, but an elite open to newcomers, self-selected, the kind of people who accentuate the positive. In this world, the optimists have it, not because they are always right, but because they are positive. Even when wrong, they are positive, and that is the way of achievement, correction, improvement, success. Educated, eyes-open optimism pays; pessimism can only offer the consolation of being right.

The one lesson that emerges is the need to keep trying. No miracles, no perfection, no millennium, no apocalypse. We must cultivate a sceptical faith, avoid dogma, listen and watch well, try to clarify and define ends, the better to choose means.

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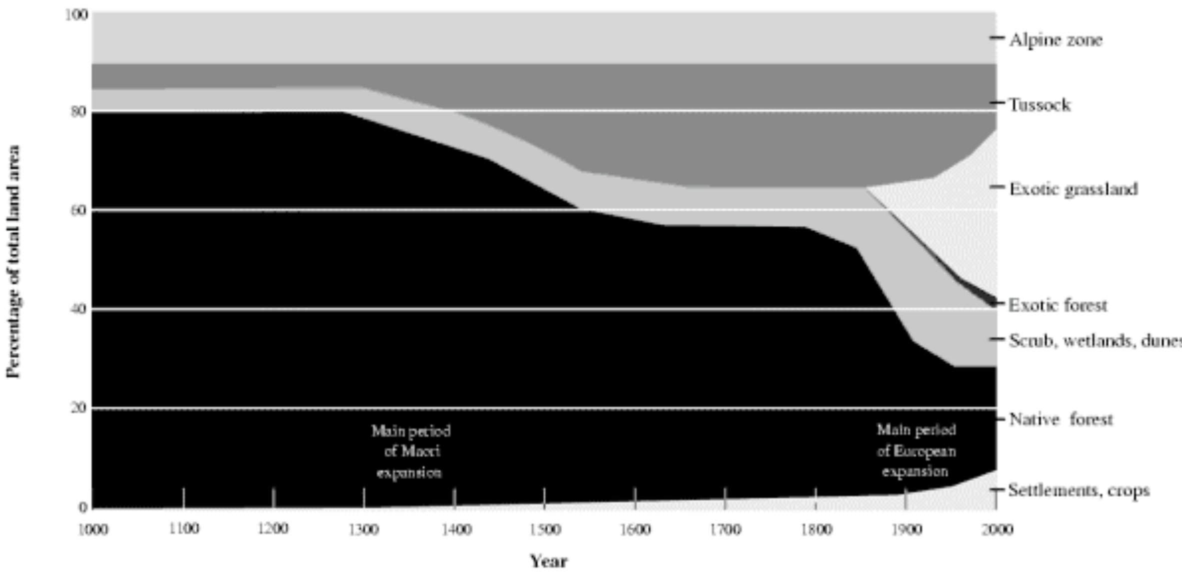
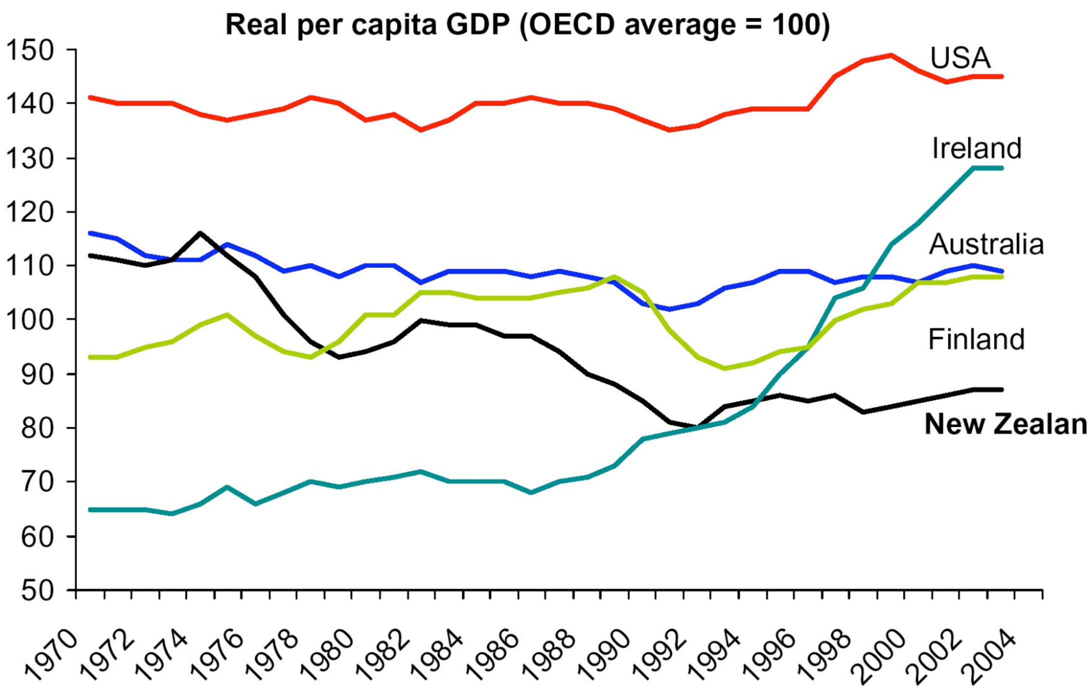
Figure 8.3

The recent history of New Zealand’s land cover[1].



[1] Vegetation areas and timing of changes are approximations only

Figure 1 (http://www.mfe.govt.nz/publications/ser/ser1997)



Source: OECD.

Figure 2: Per capita GDP 1970 to 2005

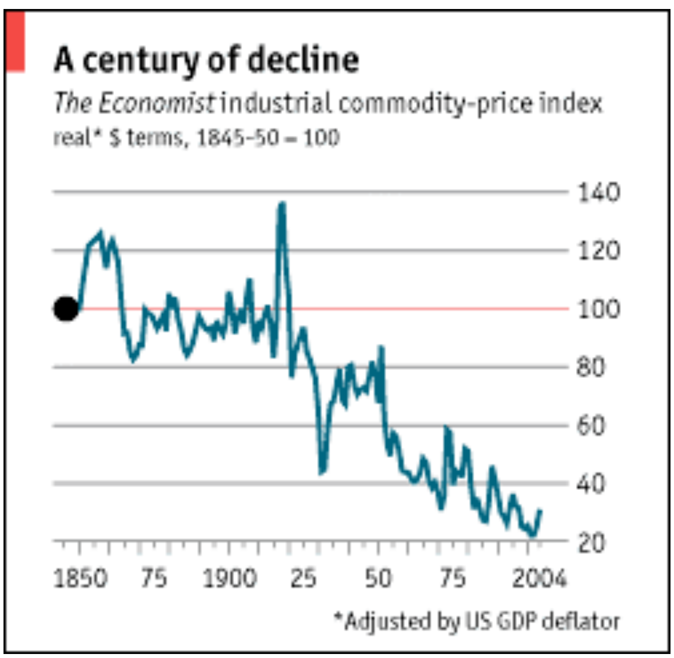


Figure 3

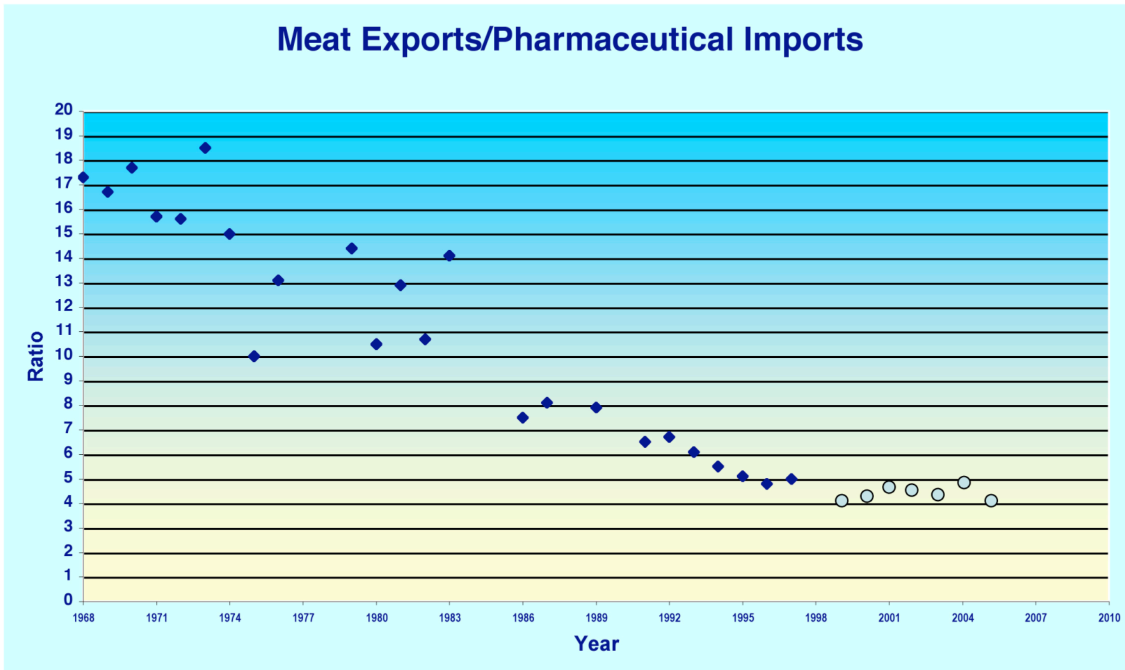
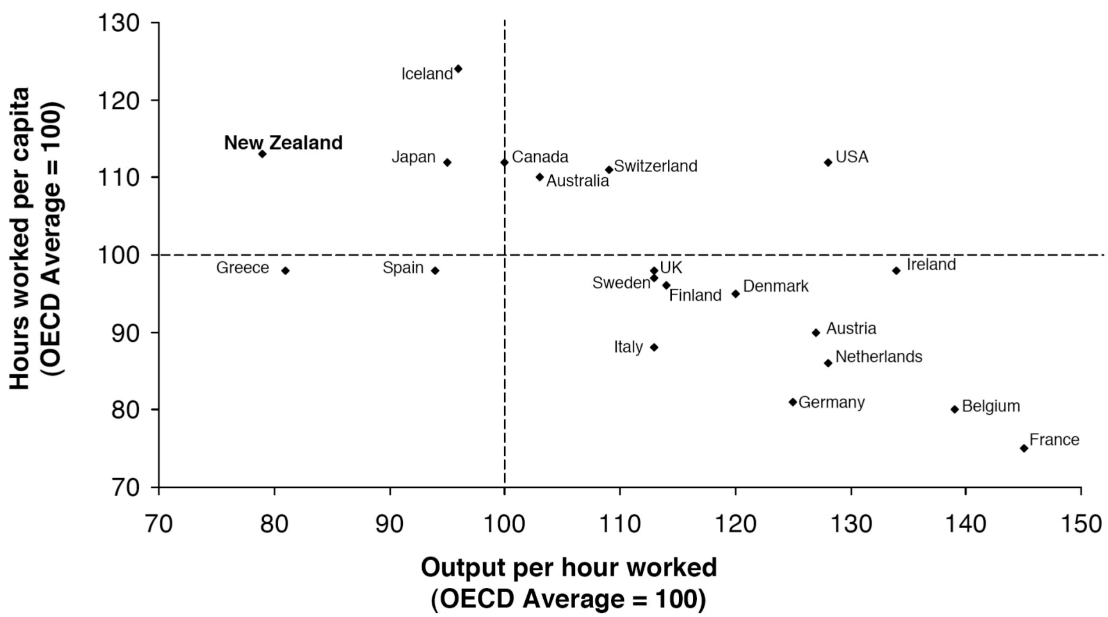


Figure 4: (Courtesy David Bibby,with post 1998 added by author from Statistics Dept data.)



Source: Groningen Growth and Development Centre and the Conference Board, Total Economy Database, August 2005. 6

Figure 5: (from NZ Institute).

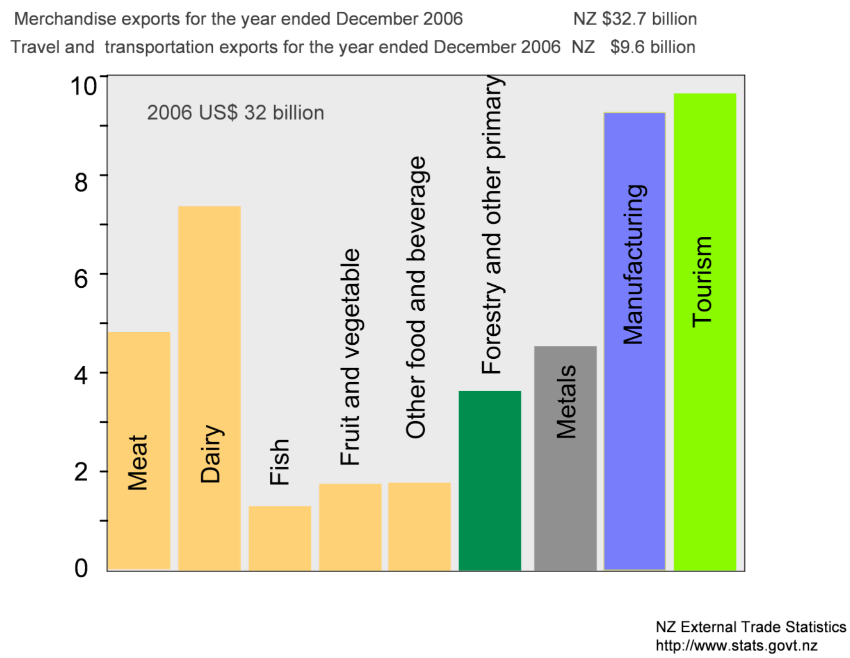


Figure 6: NZ exports by sector 2006 ($NZ billions)

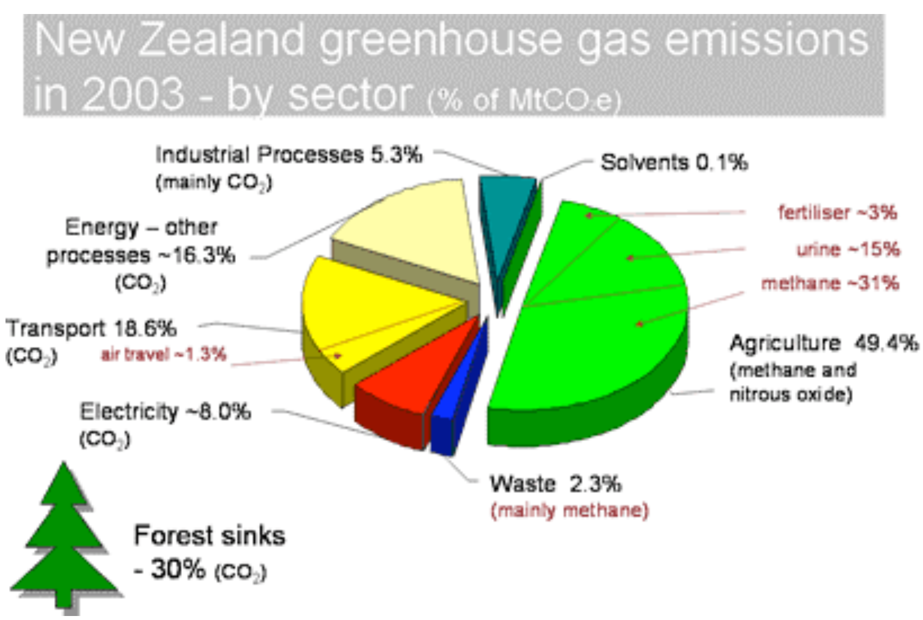
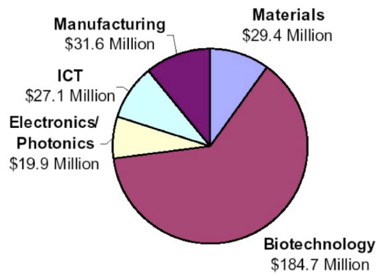


Figure 7 (http://www.mfe.govt.nz/issues/climate/industry-feb06/presentation.html)

Company	Type	Sales per annum 2005 (US mill)	Net per annum 2005 (US mill)	Empls	Revnue /empl per annum (NZ$)	Net /empl (NZ$)
Apple	computer	$13,931	$1,335	16,820	$1,335,871	$128,016
Microsoft	software	$44,282	$12,599	61,000	$1,170,862	$333,131
Genentech	Biotechnology	$6,633	$1,279	9,500	$1,126,214	$217,148
Nokia	cellphones	$40,495	$4,242	58,874	$1,109,395	$116,213
Samsung	consumer electronics	$78,250	$10,300	123,000	$1,026,095	$135,064
Hewlett Packard	computers, electronic instrum	$90,866	$2,513	150,000	$977,054	$27,020
Garmin	Global positioning systems	$558	$242	986	$912,779	$395,865
Pfizer	pharma	$51,298	$8,085	106,000	$780,554	$123,022
Sony Corp	Consumer electronics and entmn	$63,541	$1,050	158,500	$646,596	$10,685
Varian semiconductor	semiconductor instruments	$601	$72	1,518	$638,042	$76,501
Intel	semiconductor devices	$38,826	$8,664	99,900	$626,853	$139,882
Varian medical	Medical imaging	$1,383	$207	3,600	$619,444	$92,742
Astrazeneca	pharma	$23,950	$3,884	64,900	$595,209	$96,526
Boeing	Aviation, military	$54,845	$2,572	153,000	$578,168	$27,114
Raytheon	Military, communications	$21,894	$871	80,000	$441,411	$17,560
Northrop Grumman	Military, aviation	$30,721	$1,400	123,600	$400,890	$18,269
Agilent	Electronics test equipment	$5,139	$327	21,000	$394,700	$25,115
Sigma-Aldrich	Fine Chemicals	$1,666	$258	6,849	$392,334	$60,758
Tektronix	Electronics test equipment	$1,039	$92	4,334	$386,665	$34,238
Walmart	Discount department store	$315,654	$11,231	1,800,000	$282,844	$10,064
McDonalds	Fast food chain	$20,460	$2,602	447,000	$73,826	$9,389
Nike	Sportswear	$14,955	$1,392	28,000	$861,457	$80,184
Meridian	Energy (large assets)	$1,025	$263	480	$3,370,833	$883,333
Auckland airport Ltd	assets+clipping the ticket	$180	$64	280	$1,037,143	$367,857
Fletcher building	construction	$3,422	$370	11,000	$501,818	$54,182
Fonterra	Dairy products	$8,060	$151	38,000	$342,105	$24,400
F and P Health Care	Medical technologies	$180	$59	1,250	$232,000	$75,840
Rakon	GPS devices	$49	$5	450	$174,000	$17,067
68 Electronics companies		$496		4,600	$173,913	
Tourism	(Min Tourism data)	$10,788		176,000	$98,864	

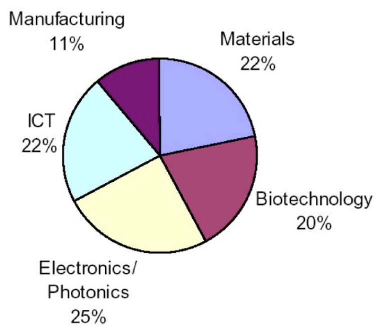
Figure 8: (data from Hoovers, NZX, NZ Company Reports, MED data)

Investment to Date by Research Area



Source: Abt Associates classification based on survey response and project description and FRST contract information.

Research Area Distribution of the U.S. Advanced Technology Program



Source: ATP Economic Assessment Office.[32] Percentages represent investment to date.

Figure 9a

Publication Breakdown by Research Area

Research Area	Cumulative Publications	Average Publications per Project	Publications per million dollars
ICT (N=14)	202	16.8	9.8
Manufacturing (N=6)	79	13.2	5.7
Biotechnology (N=51)	547	10.7	3.9
Electronics/Photonics (N=10)	101	10.1	6.1
Advanced Materials/Chemistry (N=14)	124	8.9	7.1

Source: Abt Associates survey data. 93 respondents.

International Involvement by Research Area

Research Area	Avg % of international researchers per project	Avg % of international students per project
Biotechnology (N=51)	5%	7%
Advanced Materials/Chemistry (N=15)	9%	8%
ICT (N=14)	13%	15%
Electronics/Photonics (N=10)	9%	12%
Manufacturing (N=7)	1%	17%
Cumulative Average	**7%**	**10%**

Source: Abt Associates survey data. 97 respondents.

IP Return by Research Area

	Money Invested to date	IP Count	IP per million dollars
Advanced Materials/Chemistry	$19,783,987	78	3.9
Electronics/Photonics	$16,536,174	46	2.8
ICT	$22,969,500	53	2.3
Manufacturing	$31,679,650	51	1.6
Biotechnology	$139,934,495	164	1.2

Source: Abt Associates survey data and NERF contract information. 97 respondents.

Figure 9b

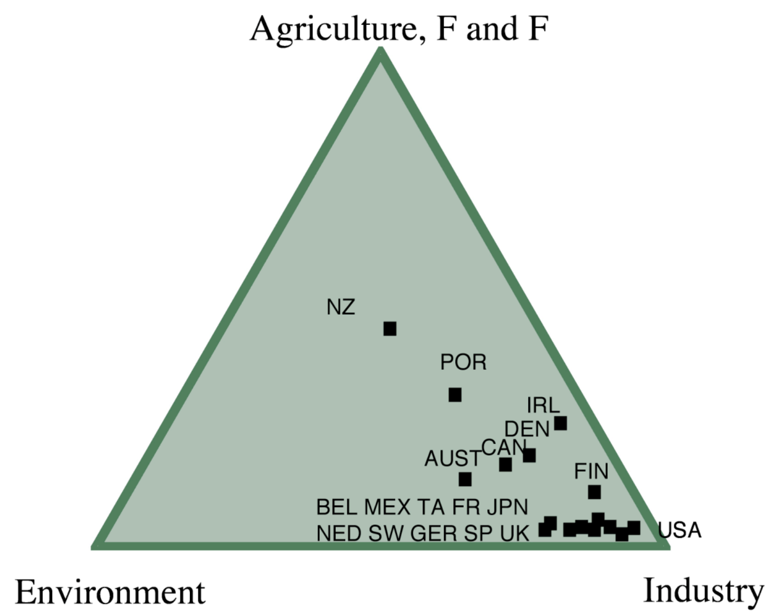


Figure 10: New Zealand’s R and D investment profile (from David Bibby, IRL, 1998)

Portfolio cluster	Portfolio	Total funds in portfolio available for contest and negotiation ($m p.a.)[1]	Target outcome	Theme	Investment band for theme in 2006/07 ($M p.a.)	Portfolio total for 2006/07 ($M p.a.)	Portfolio cluster total for 2006/07 ($M p.a.)
Primary Production and Sustainability	PQA	31.7	PQA1	1.1 Animal diseases	No investment this process		21.1
				1.2 Animal welfare			
				1.3 Plant pests and diseases	2.1 ± 0.6	18.8	
				1.4 Food safety			
				1.5 Traceability			
				1.6 Technical barriers			
			PQA2	2.1 Productivity	7.9 ± 2.0		
				2.2 Quality	8.8 ± 2.0		
	SPS	27.1	SPS1	1.1 International agreements	1.8±0.5	2.3	
				1.2 Indices			
				1.3 Tools and systems			
			SPS2	2.1 Pre/at-border biosecurity	0.5±0.5		
				2.2 Existing pests			
New Materials, Technologies and Services	MAN	19.3	MAN1	Improved productivity and international competitiveness of New Zealand manufacturing sector		2.7	20.0
	SER	2.1	SER1	1.1 Tourism	1.0 ± 0.2	2.4	
				1.2 Creative industries	0.4 ± 0.2		
				1.3 ICT	1.0 ± 0.2		
	NPT	21.4	NPT1	1.1 ICT	6.3 ± 1.4	7.6	
				1.2 New materials	1.3 ± 0.4		
	FHT	23.6	FHT1	Opportunities arising from research in understanding humans		7.3	

Figure 11: NERF prescriptiveness-2006 portfolio descriptions
(http://www.frst.govt.nz)

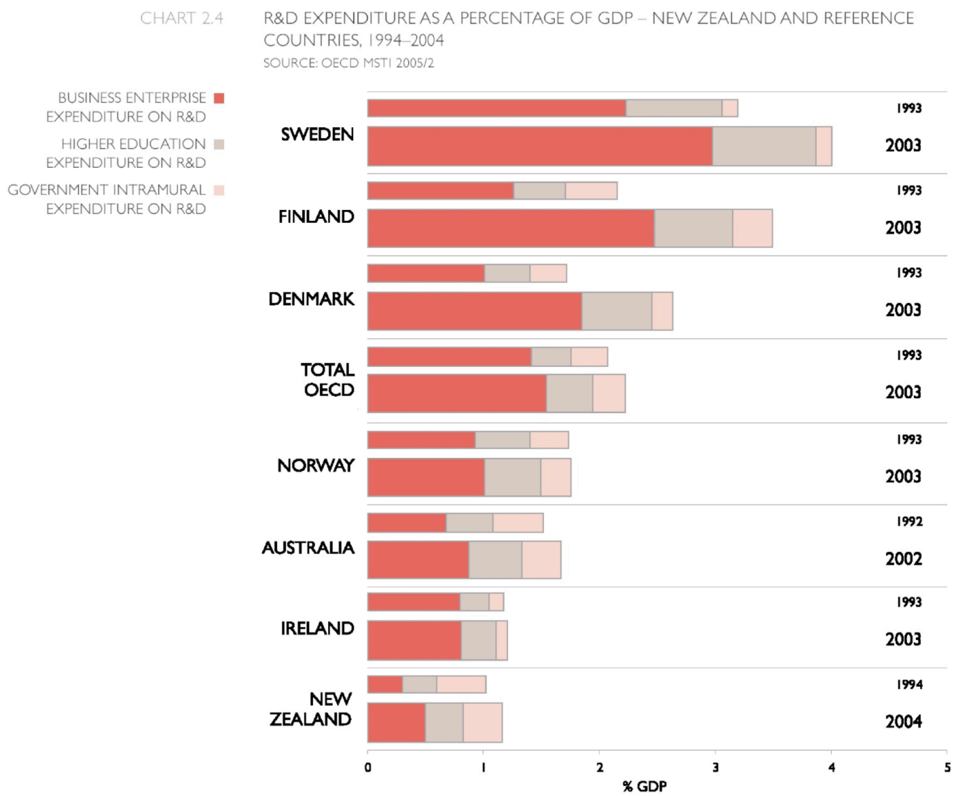


Figure 12: New Zealand comparative R and D investment (http://www.morst.govt.nz/publications/statistics/decade-in-review/)

Government R and D investment 0.52 % GDP
OECD average 0.68 % GDP

Nanotechnology R and D investment

Estimated Government Nanotechnology R&D Investments in 2005 (US$ Millions).
Source: President's Council of Advisors on Science and Technology (2005).
The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel.

	Per annum US$	Per capita US$
USA	1081 m	US$ 3.7
Australia	76 m	$3.8
Japan	950 m	$7.5
EU	1050 m	$3.3
New Zealand	4 m	$1
Israel	16 m	$3.3

Figure 13: Nanotechnology investment levels. Note, the NZ estimate ranges from $4 m per annum to $8 per annum, depending of definition.

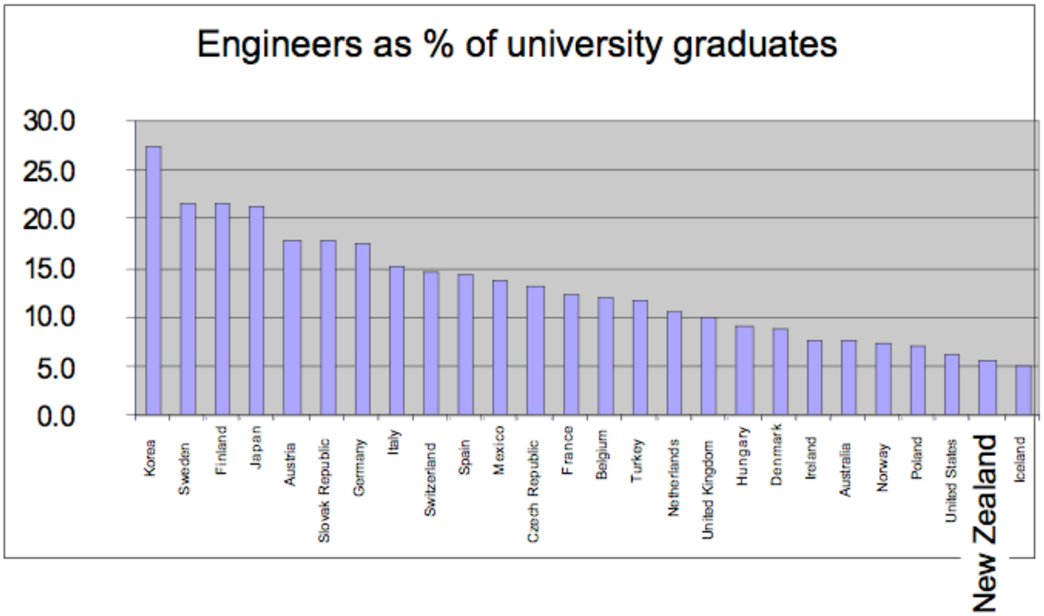


Figure 14: Percentage of engineering graduates per annum.

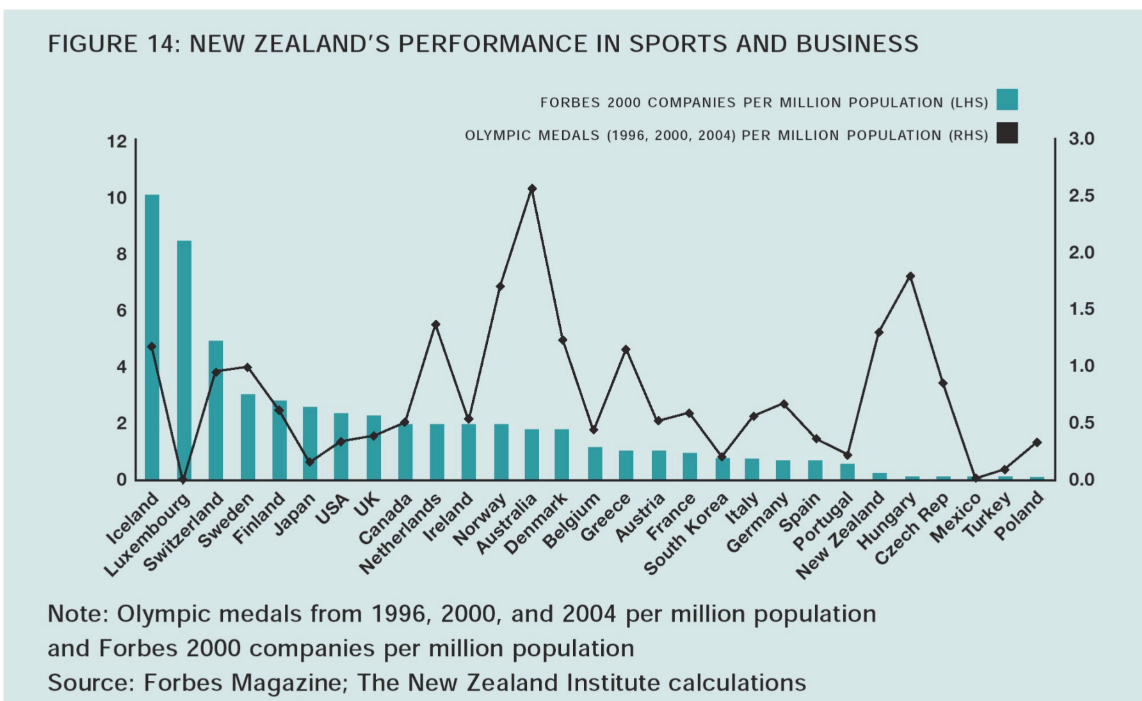


Figure 15: Comparitive performance in business and sport (from New Zealand Institute)