Future Development of New Zealand's Science and Technology System

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ABSTRACT *A new science system was set up in New Zealand from 1989–97, and it is now time to focus on its future development. Further development of New Zealand's science system must be driven by a new understanding of how science and technology drives economic growth. The future enhancement of New Zealand's science system must be placed within a system of innovation framework, it must focus on outcomes and on differentiated technological learning and knowledge application, and it must place more emphasis on the role research plays in creating human capital. New Zealand must also focus more effort on policies that foster technological innovation, including through an increased focus on skill development in firms, and the development of demand-side interventions.*

Keywords: human capital, New Zealand, science systems, systems of innovation, technological learning.

Introduction

Since New Zealand's science system was restructured between 1989 and 1997 a lot of progress has been made in achieving efficiency and transparency in the funding and conduct of science, and placing it within a longer-term strategic framework that is better related to national needs. Winsley and Hammond[1] recorded the history of the restructuring of New Zealand's public science system, outlined the development of an overarching policy framework for the new system, and highlighted new initiatives in areas such as science evaluation. This article addresses how New Zealand's science and technology system as a whole can build from the restructuring and contribute more effectively to New Zealand's future economic performance.

This article places the future development of the science and technology system within a national systems of innovation framework. It advocates focusing it on outcomes and on differentiated technological learning, giving greater emphasis to human capital (rather than knowledge) creation, and extending the portfolio of technology policy instruments. These proposals aim to help catalyse the extension outwards of New Zealand's 'technological production possibility frontier', and the migration of firm strategy and industry structure away from commodity-based competition to that based on new functional properties and technical performance characteristics.

It is helpful to ground the future evolution of the science and technology system in an understanding of the relationships between technical change and economic outcomes. This article therefore begins by elucidating the key mechanisms through which scientific

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and technological change driving economic growth and then goes on to apply this to specific new policy initiatives.

How Technological Change Contributes to Economic Outcomes?

It is widely accepted that technological change is at the heart of economic growth.[2-4] The mechanisms and processes underlying the contribution of scientific and technological change to economic growth can be examined at a macroeconomic level and at the level of the firm.

Technological Change and Economic Growth at the Macroeconomic Level

It is argued that the major mechanisms underlying economic growth are the non-rivalry of significant new technology, the irreversibility of technical change, disembodied human capital within an organisational (typically a firm) context, and the technical platform effects of new technology. There is a dynamic and synergistic interplay between all of these factors. The arguments are as follows.

Non-rivalry of Significant New Technology

Romer[4] argues that:

> ... all increases in standards of living can be traced to discoveries of more valuable arrangements for the things in the earth's crust and atmosphere.

Romer attributes these new arrangements to the adoption and application of 'non-rival goods', that is goods where the marginal cost of each new application is very low compared to the cost of its production.[4,5] Non-rival ideas and technology can be used in many different applications in different firms and economies at the same time and one's consumption of it does not stop another from using it. The declining marginal cost of the dissemination of non-rival goods helps explain rising output for fixed or diminishing inputs.

Non-rival goods are disembodied in the sense that they are not embedded within a physical object. For example, embodied human capital is rival in that the training of each additional computer programmer costs the same as the first one trained. But the software programme that each programmer uses is disembodied and non-rival, that is the programme is independent of any one physical object and the marginal costs of each extra person being licensed to use it is minimal.[5] A key challenge for any R&D funding or purchasing system is to develop the capability of recognising *ex ante* the kinds of scientific or technological investments that are likely to give rise to non-rival goods.

Irreversibility of Technical Change

Technical change is irreversible in the sense that technology can be superseded but not uninvented. Irreversibility means that the world's technological production possibility frontier is endlessly extended, as improved technological capabilities make rising output from fixed or reducing inputs possible.

The irreversibility of technical change is greatly influenced by two mechanisms: the higher utility value of significant new technology and its asset specificity.

Higher utility value. Significant new technology delivers improved functional properties and technical performance characteristics, that is, higher utility value for users. Invention is the mother of necessity in that people will not go back to inferior technology: inventions cannot be uninvented. Technology can therefore be superseded but not reversed, so that over time technological capability grows by successive additions, and advances in the utility value of technological innovations catalyse ever-rising enhancements in new technology embodying improved functionality. Public R&D must be conducted interactively with end users and the performance and utility value required by users must inform and help drive the technological development process.

Asset specificity. Specialised assets are those with a higher value in their specialised than in alternative uses. Investments of high asset specificity are associated with high sunk costs since their value in alternative, non-specialised uses is low, and perhaps zero. Specialised and irreversible investments tend to create barriers to competitive entry and therefore allow premiums to be earned. This is partly because competitors lack specialised assets built up cumulatively that would enable them to compete, and also because many of the specialised assets created include localised, tacit elements that are difficult to imitate.

Disembodied Human Capital in an Organisational Context

Disembodied human capital includes ideas, organisational routines etc. that are not embodied in any one physical object, including in an individual. When a person who has acquired skills dies so does the human capital embodied in him, but a meme[6] or non-rival good that this person has produced—a scientific law, a software programme, or a technological principle, survives and feeds into future technical change.

Collectively, skills in a firm or research institute constitute its disembodied human capital base. This human capital base includes specialised elements, and generic capabilities that give rise to economies of scope that may underpin a wide range of different applications. A key challenge for firms, industry sectors and research institutes will be to identify the generic and specific skills they require and then being prepared to manage them differently.[7]

Technical Platform Effects

Innovations do not exist in isolation but build from antecedent innovations and techniques in use, with the quality or functionality of a new innovation being higher than its antecedents. Innovation in one time period seeds new developments and creates technical platforms for innovations in a later time period. An example is the (irreversible) invention of the transistor, which laid a technical platform in solid state physics that led to the integrated circuit, and then to the extraordinary advances that have transformed information technology and electronics.

The mechanisms underlying technical platform effects can only be understood in a dynamic context over time, and in relation to behavioural aspects of the management of technological change. The dynamic process of technical change can therefore be likened to an ascending ladder of ever-changing technical performance characteristics, with each step in the ladder depending on those that have gone before.

The Aggregate Effect: A Shift in the Technological Production Possibility Frontier

Inside a technological production possibility frontier are the technologies known to and applied in a firm, an economy, or the world. Outside the frontier is the unknown and unexploited. The above drivers of economic growth at the level of the individual firm or technological innovation aggregate at the macroeconomic level and cause a shift outwards in an economy's technological production possibility frontier. The goal of science and technology policy is to advance the technological frontier of the economy as a whole. But because wealth creation comes from individual firms the extension outwards of the technological production possibility frontier, and therefore economic growth, will come from the performance of thousands of firms, thereby extending the aggregate technological frontier of the country as a whole. It is therefore essential to address technological change at the firm level.

Technological Change and Economic Growth at the Firm Level

The technological innovation process can be conceptualised as 'technology times human capital times social processes times technological learning, within the strategic governance framework of a firm'.[7] Technological innovation must form part of a firm's wider business strategy to create and sustain competitive advantage in the market through long-term and cumulative technological investments. A firm's strategy should encompass its links with the wider economic and policy framework in a country's national system of innovation. Within this strategic framework, the dynamics of significant new technology, human capital and social processes are catalysed and made productive by differentiated technological learning processes.

Human capital in the widest sense forms the key resource underpinning the creation of significant new technology and is intimately linked with it. Skills and knowledge are needed for innovation within the firm, to search for, interpret and adopt external sources of ideas and new technology, and they are at the heart of a firm's competencies in technological learning and knowledge application.

The initial output of research and other creative activity is disembodied information which in turn can be regarded as a form of human capital. However information, whether in the form of a scientific publication, a dataset, or an idea does not become a knowledge-based form of human capital until it is absorbed, interpreted and understood. Differentiated learning processes are the catalyst through which information is turned into a knowledge form of human capital.

Through technological innovation this knowledge form of human capital then become productive when it is embodied in new products, processes or services. Without embodiment, the valuation of human capital, for example that of an R&D lab that is a provider of research results but which lacks links to users and adopters, will always be discounted. At the same time, part of a firm's human capital should remain disembodied in the sense that a firm must retain, independently of its sales of products and processes, a technical platform of human capital that accumulates over time and which can be applied generically to future product and process development. When human capital is embodied, the dynamics of significant new technology induce further learning processes and help shape the course of further human capital development and pathways of learning.

The outputs of the innovation process are new products and processes delivering new functional properties and performance characteristics. These products and processes embody sufficient asset specificity, embedded uniqueness, or other barriers to competitive entry to allow a firm to earn premiums and a stream of profits that can finance further innovation. Products and processes embodying significant new technology produce more output with fixed inputs, include non-rival technology, and create technical platforms for future innovation. The economic outcome of this is an extension of the technological production possibility frontier of individual firms, and in aggregate of the national economy, thus making long-run economic growth possible.

The Science and Technology Policy Implications

Given our understanding of the relationships between technological change and economic growth it is helpful to discuss weaknesses in New Zealand's technostructure and then to assess how the system can be improved.

Weaknesses in New Zealand's Existing Science and Technology System

Weaknesses in the public and the private technostructures in New Zealand include:

Weaknesses in the Public Technostructure

In New Zealand there is very poor horizontal, cross-departmental communication across government, compounded by the lack of any high-level agency with responsibility for long-term vision creation and strategic planning. Public purchasing power and regulatory intervention is not strategically managed to foster technology-based industry. New Zealand's education and training system is driven by the choices students make in the absence of good advice on career prospects, and by tertiary sector funding formulae rather than by the longer-term strategic needs and opportunities of a technology-based economy.

The science and technology system is based on input and output not outcome purchasing and is still overly influenced by a linear model of R&D. Too much of the research system focuses on knowledge creation rather than the creation of disembodied human capital, and science purchasing and provider agencies are not sufficiently fine-grained and differentiated in their approaches to technological learning and knowledge application.

Weaknesses in the Private Technostructure

The private sector in New Zealand invests little in R&D and technological learning and knowledge application. Because of this, the direction of technical change and the job market for technologists is controlled by the public rather than the private sector. The ability of New Zealand businesses to exploit the results of publicly-funded research is limited by their inability to evaluate technological opportunities. Business managers in New Zealand do not have the skills or experience needed to manage the risk and uncertainty associated with technological innovation. Technological innovation requires a high trust environment, and growing evidence of self-seeking behaviour and fraud in both the public and private sector, much of which goes unchallenged or unpunished, is eroding this trust-based environment.[8]

New Zealand's industrial base is broad but thin, which means in many sectors there has been just one New Zealand firm in the market. These firms have often lacked domestic competition and rivalry as a stimulus for innovation. New Zealand-owned technology-based companies are largely confined to narrow niches that are too small to attract the attention of major international competitors, but are often too technically difficult for low cost third world competitors. These niches can be very profitable, but cannot deliver the total economic outcomes achieved by firms in small countries such as Sweden, Finland and Denmark that have grown to become multi-billion dollar enterprises despite the limited size of their domestic market. Factors such as the small size of the domestic market have limited the development of technology-based clusters around core sectors such as agriculture, forestry and fisheries. Emerging technology-based firms in New Zealand have lacked a domestic market of sufficient size to provide a stepping stone for growth, nor has this domestic market often acted as a discriminating microcosm of a larger world market.

New Zealand's colonial past has meant that its economy developed to provide commodities to overseas markets. In some sectors overseas ownership has truncated development because subsidiaries of overseas firms are primarily involved in marketing, distribution and servicing, and the only local technological development they undertake tends to be adapting overseas technology to the New Zealand market.

A benefit from an open trade policy is that overseas and domestic R&D become complements and not substitutes, and the interaction between them is synergistic and involves scope economies rather than being additive. As Coe and Helpman[9] point out:

> ... own [domestic] R&D enhances a country's benefits from foreign technical advances, and the better a country takes advantage of technological advances in the rest of the world the more productive it becomes.

However, because the international technology base is available to all countries on broadly the same terms, little or no competitive advantage can be obtained from passively adopting it. The price of technology adopted from other countries embodies the cost of the R&D needed to develop it. Competitive advantage can only be achieved by New Zealand firms being creators, commercialisers, marketers and earners of premiums from new technology, not by being passive adopters.

Future Enhancement of New Zealand's Science and Technology System

The future enhancement of New Zealand's science and technology system must be placed within a national systems of innovation framework.

A National Systems of Innovation Framework for New Zealand

Technological change in an economy is systemic; that is, it occurs through the synergistic and complementary workings of a country's national system of innovation., rather than being the direct outcome of specific institutions (such as research institutes, universities or firms) within that country. A national system of innovation involves many points of domestic and international interaction between a country's technostructure and firms, and among firms. It includes education, training, research and property rights institutions, the flow of ideas, knowledge and human capital, and is substantially influenced by a country's economic and trade policy framework and by the interplay between all these factors.

A science and technology system must form part of a national system of innovation that traverses the public and private sector, and ensures that public policy and the major structural elements of the economy work together in an integrated and complementary way. This implies substantially improved vision creation at the top levels of government, and enhanced cross-departmental interaction and coordination.

A science and technology system that meets New Zealand's future needs must evolve from the cumulative competencies that have been built up over many years and are embodied in research and tertiary institutions and in the private sector. But performance gains require a significantly modified set of institutions, entities and processes that better match the differentiated forms and sources of technological learning and knowledge application and better reflect how technological change leads to economic growth.

Flowing from this national systems of innovation framework the key future drivers of New Zealand's science and technology system must include the focusing of the science and technology system on outcomes, not inputs or outputs. Differentiated technological learning should be a key driver of the science and technology system, with a strong focus on exploiting the international body of knowledge in a more fine-grained way. Human capital creation should be given greater emphasis in both public research funding and firm-level strategies, and the industrial technology portfolio must be substantially enhanced.

Focusing Strategic Research on Outcomes

Most of New Zealand's public research investment is through the Public Good Science and Technology Fund (PGSF). This purchases research outputs such as new knowledge and new technologies that are intended to contribute to outcomes such as international competitiveness. The ability to turn these outputs into outcomes depends on the learning abilities of users and their ability to interpret and apply scientific results in productive activity. This can be substantially influenced by how research funding is used to foster the relationships, dynamics and interactive learning processes between providers and users.

The argument that the low uptake and application of publicly-funded research results has been a user rather than a science provider problem and that the science system can only be judged on its output delivery is no longer acceptable. The Government invests in the science system to deliver outcomes, not to fund inputs or intermediate outputs, and the purpose as well as the ultimate performance measure of the system is its contribution to outcomes. In future, PGSF purchasing will be replaced by a focus on research and on forms of technological learning and relationships between providers and users that contribute to or give rise to outcomes.

The Foundation for Research, Science and Technology will need to be able to recognise research portfolios, success factors and dynamic relationships that are associated with outcome delivery. This will require, *inter alia*, an in-depth understanding of the characteristics, major trends and dynamics of stakeholder groups aligned with different PGSF research, linking PGSF strategies to those of external stakeholders, and ensuring that research purchased is of a nature and has a delivery mode that aligns to appropriate sources of technological learning for stakeholder groups. Relating to this the process of setting specific research objectives, end-points and specifications to be achieved should be devolved to research institutes and the sectors and stakeholder groups aligned with them.

Differentiating Technological Learning and Knowledge Application

Technological learning, rather than being confined to one model, is a highly differentiated process, depending on variables such as type, size and ownership of firms, industry structure, nature of the technology and the market, the way the science base is changing, and a host of internal and external relationships.[10–12] The type and sources of learning include, *inter alia*, systematic research and development, learning by doing,[13] learning from users,[14] learning from suppliers, from employees, from competitors[15] and network learning.[16]

The ability to turn research results and human capital into performance is very context-dependent. Learning develops from existing competencies and technological and market paradigms. The limits of a learning domain are set by the human capital competencies within a firm and by its external interactions and sources of stimuli. A firm needs strong 'learning to learn' abilities. Typically this will require external networking and interactions, the recruitment of new technologists, links with sources of new ideas and stimulus, accessing new forms of human capital, active networking, and the ability to draw on external sources of ideas, technology and specialised skills that it would not be feasible to internalise.

Technological learning is an interactive and social process in the sense that people learn by interacting with each other rather than in isolation.[17–19] Individuals learn in teams, teams also foster the learning of other teams they interact with, and firms often learn through networking with other firms. Innovation, performance gains, and rising output from fixed or diminishing inputs comes from new combinations of human capital, people and skills as well as from new combinations of raw materials.

The rate and effectiveness of technological learning and innovation is not solely determined by the scale of the learning effort but also by the extent to which it involves openness to new ideas and challenges. Interactive learning also occurs at the level of a national innovation system[18,20] and in New Zealand. This must include a strong emphasis on exploiting international sources of scientific and technological learning.

Emphasising Human Capital Creation

The writings of economists such as Gary Becker suggest that human capital[21] is a conventional tradeable good and education is an investment in human capital that has a privately appropriable and a public good element. Neoclassical economics holds that the price of skilled labour will be a function of scarcity and that countries with less human capital will see more people train or immigrate to chase the higher salaries that they can earn. This will eventually lead to economic convergence and a closing of the technological and per capita income gaps between countries.

However, human capital development creates spillovers and wider public benefits in ways quite different to a standard public/private good split in the benefits of education. Lucas[22] observes that people who are richly endowed with human capital migrate from countries where it is scarce to countries where it is abundant.[23] The work of Lucas and Romer establishes that it is investment in human capital rather than physical capital that has spillovers that increase the level of technology. The indivisibility of much education and human capital creation, and the interplay and synergies that occur within educated communities, means that when individuals accumulate new human capital, they inadvertently contribute to the productivity of the capital embodied in others. This occurs at the level of individuals, firms and countries.

Research-based human capital development is needed to absorb new technology and R&D results from both local and international sources. It helps create the networks and technical competencies that allow both countries and firms to scan the environment, interpret, adapt and commercialise external technology. Strategic research should place more emphasis on creating skills and less on creating knowledge. This is especially so with strategic PGSF research that is aligned to differentiated sectors where innovation is typically firm-specific and often more dependent on skills and on in-house innovation than on new scientific advances from research institutes, and where it is difficult to identify generic knowledge gaps of importance to more than one player.

In the manufacturing sector, firms are very differentiated, their markets and competencies are often firm-specific, and commercial success may depend significantly on tacit and uncodified forms of knowledge, for example the knowledge a firm's staff have about the production process. The context dependency and firm-specificity of innovation means that in some sectors much publicly-funded R&D in future may best be conducted in firms rather than in centralised public research institutes. The tacit and uncodified nature of human capital means that the mobility of people through the economy is the best form of technology transfer, so that increasingly, porous boundaries need to be encouraged between the public technostructure and firms.

Restructuring Undirected Research Funding

From the 1940s, great technological advances gave rise to unbounded confidence in the outcomes from basic, undirected, science-push research, a confidence epitomised in Bush[24] and much later in the establishment of the Marsden Fund to support undirected research in New Zealand. However a more careful analysis suggests that achievements such as radar, nuclear fission, the jet engine and space exploration were driven by the pressing needs of users and public purchasing agencies and by clear demand-side specification of the technical performance and the user functionality that was required. Often, basic scientific understanding has been created as a spin-off from tackling applied technical problems rather than the other way round. The post-World War 2 competitiveness of Japan, Taiwan and Korea can to a great extent be attributed to a strong focus on creating technology that delivers functional performance and utility value for customers, with more basic research then being driven by the need to solve technological problems for users, not to create basic knowledge for its own sake.

Basic, undirected research undertaken in New Zealand may of course lead to fundamental discoveries of international significance, but far less frequently than many believe. While basic research is typically funded to create knowledge, the outcome of such research is in fact co-produced goods: systematically created knowledge and the creation of human capital. Studies have shown that:

> ... the main economic benefits from basic research are not published information but a supply of scientists and engineers with problem solving skills, comprising background knowledge, familiarity with research methodologies and instrumentation, and membership of informal and often professional networks.[25–29]

Undirected science-push research that is focused on knowledge creation only, and is independent of user domains, interactive two-way learning and human capital creation, is generally a poor investment, especially for small economies. However, basic research can be justified on the basis of its contribution to human capital creation and skills development. The formally published and codified knowledge created through such research is less important than the skills it develops and the tacit and uncodified knowledge and competencies in the minds of young graduates who then work in industry.

For these reasons, it is strongly argued that basic and strategic research should either be purpose-driven PGSF research focused on particular problems or opportunities, or it should have a strong human capital development component. The Marsden Fund should be substantially expanded but focused entirely on research in world-class science and technologies likely to be important to New Zealand in the long-term, where this research involves skill development and human capital creation for post-graduates. The mode of funding for this research should ensure the mobility of these skilled people into the industrial economy. As long as people are mobile through the economy, and end up in or working with firms, the output of disembodied human capital can become productive and be embodied in outcomes. With an expanded funding base, a structured Marsden Fund could both substantially expand the future advanced skill base needed for industry, and also provide direction and resources for a tertiary research effort that currently has no explicit funding mechanism or sense of purpose.

Enhancing the Industrial Technology Portfolio

An important implication of the irreversibility, and therefore the cumulativeness of technical change, is the creation of technology gaps between countries. It is futile to close this technology gap through a relay race, or by transferring yesterday's technology. To transfer historical technology without any improvements and adaptations simply entrenches a technology gap. It is more productive to research and develop new technology in close interaction with lead users and to focus this research as much on skill development and absorptive capacity as on creating new knowledge and new technology.

The aim of technology policy must be to lift the level of technological competence over the whole spectrum of business, but not to support innovative activities that are already within the established technical competency of firms. For example, technically weak firms may need to start with product development, while firms already competent in product development may, for the first time, invest in ambitious R&D with the encouragement of technology policy instruments. For example, a technology policy instrument such as the Graduates in Industry Fellowships scheme may support applied technology masterates in some companies, more ambitious PhDs in firms taking a longer term view of research, and post-doctoral research that may allow some firms to make major, world-class advances through technological innovation.

Technology policy must allow diversification by firms into new markets and new technological paradigms. That is, it must support projects which are both outside a firm's technological frontier and which a firm could not undertake using its own resources. This should form part of a strategy of allowing diversification by firms from price-driven commodity markets into new technological regimes where competition is through new functional properties and technical performance characteristics. This allows firms to earn premiums and allows a migration in industry structure from low-margin sectors to those that are more R&D intensive. To survive in these markets firms then need to sustain higher levels of R&D and technological learning investment, which in turn will provide more direction to public sector scientific and technological investment. Existing technology policy instruments make productive the results of more basic or strategic research that would otherwise not feed into the economy, open up access for firms to new ideas and to international technologies, and create long term links between Institutes, Universities and companies. They help foster the relationships between the industrial economy and the public sector science system that allows industry to provide feedback and strategic direction to institute and university research. Specific foci for further technology policy development include:

Removing regulatory barriers to technological innovation. Regulatory barriers to technological innovation include the potential for excessive regulatory constraints on biotechnology developments, a tax regime which is not sufficiently responsive to the needs of technology-based companies, and an overly restrictive application of resource management and fisheries legislation, for example in relation to aquaculture. These barriers must be addressed.

Developing demand-side purchasing policies. The major advantages of demand-side technology policy interventions are that they can foster externally-driven and interactive technological learning and can provide leading-edge customers that force technological upgrading and continuous improvement. They provide a tight focus to R&D and technological innovation, often to the point of stipulating demanding technical specifications that need to be achieved, and forcing a leveraging up of the technological capabilities of firms. Depending on the nature of the customer, demand-side interventions can provide a microcosm of a larger world market for technology. Demand-side interventions can have a particularly significant impact on smaller and emerging firms, since they can provide early customers and cashflow that provide a basis for future growth.

Demand-side public purchasing of technology-based products, processes and services have been among the major stimuli to technological change in the 20th century, including in fields such as energy, medicine, military technology, aerospace, optics, metallurgy and new materials, biotechnology and computing. Within New Zealand, public purchasing helped underpin the emergence of companies such as Marine-Air-Systems and Oscmar (defence electronics), Tait Electronics (mobile phones for the fire and police services), PEL (military equipment and security technology), Vega (marine signal lights and lighthouses), Pulsedata (electronic sensory aids), as well as many software companies and Fisher and Paykels' medical technology business.

Superficially, demand-side public purchasing seems at odds with the philosophy of a market-driven economy. It also appears difficult to implement because of the small size of the New Zealand economy and because privatisation of most state trading activity has deprived government of much of its technology purchasing power. However, there are several policy domains within which public technology purchasing initiatives can be developed. These domains include technology purchasing within a CER context, use of public sector buying power in areas such as health, defence and State Owned Enterprises, and "Good Corporate Citizen" and "Partnership for Development" type policies that use moral suasion to encourage overseas-owned firms to source technology from New Zealand suppliers.

Fostering human capital development in firms. The most effective mechanism to increase private sector R&D and technological learning and knowledge application may well be public funding of the key input, human capital, rather than subsidising industrial research *per se.* But the outcomes of human capital development depend on the strategic governance framework in which that human capital is developed. Extensions to the existing technology policy portfolio must therefore primarily focus on developing human capital in firms that have a vision and which are committed to making technological innovation a core part of business strategy.

The best economic outcomes are likely to come from investment in human capital creation and technological learning that is appropriate for the firm, industry sector or stakeholder group concerned, and which gives rise to 'goods' with significant non-rival and technical platform properties and which are managed strategically. This requires strategic management by both firms and the public science and technology system, and a fostering of interactive technological learning relationships within New Zealand's system of innovation and with international sources of new ideas and technologies.

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