Green Growth and Innovation Theory – Appendix to the Royal Society of New Zealand submission in response to the Green Growth Advisory Group discussion paper

A constrained world is demanding cleaner technologies

The planetary constraints upon our economy will become ever more obvious

In the Twenty-First Century, the unavoidable limits upon humanity will become ever clearer causing the pressures for greener economic growth to become ever stronger.[1] Climate change is recognised as one factor that imposes increasingly harsh impacts from the sum total of greenhouse gases that we can emit to the atmosphere, but that is far from the only constraint. We face multiple boundaries that will constrain our behaviour, including our nitrogen and phosphorus footprints, our use of freshwater and land, and our impacts upon biodiversity.[2] These constraints set hard limits upon the environmental footprint of our global economy, yet the desire for economic growth and the increase in human well-being appears unconstrained.

In response, we need technological change at a rate never achieved before

There is increasing pressure for structural change in economies, with accelerating rates of industrial upgrading, and also increasing pressure for corresponding changes in institutions and social norms.[1]

If economic growth is to continue to increase within global constraints, then sustainable growth strategies will need to address these limits. For example, considering greenhouse gas emissions alone, the emissions intensity (the amount of wealth created per unit of emissions) needs to increase at a rate higher than the rate of economic growth. To achieve targeted cuts in greenhouse gas emissions whilst continuing economic growth, the rate of improvement needs to be substantially higher than has ever been achieved before. It needs to remain high for decades. For instance, to achieve NZ's "50% by 2050" emissions target whilst continuing recent economic growth of 2.5% implies that our emissions intensity will need to improve around 4.5% per year for forty years. The UK, with strong government policies, the rapid shift from coal to gas and renewables for electricity generation, and the demolition of manufacturing, has achieved only 3% over 25 years.

This suggests that unprecedented efforts will need to go into both increasing the rate of technological progress and the rate of uptake of cleaner technologies – the UN has described the

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[1] "World Economic and Social Survey 2011 - The Great Green Technological Transformation", UN Department of Economic and Social Affairs, 2011

[2] Rocktröm *et al*, "Planetary Boundaries: Exploring the Safe Operating Space for Humanity", Ecology and Society 14(2): 32

Rocktröm *et al*, "A safe operating space for humanity", Nature 461, 472-475 (24 September 2009)

level of effort needed as a "technological revolution" [1] and the OECD has called for eco-innovation to deliver "radical and systemic" change.[3]

In the very long term, tensions between global constraints and the desire for unconstrained increases in well-being may not be resolvable as it may not be possible to completely decouple economic growth from environmental damage. However, in the medium term, these boundaries provide an impetus for policies and other changes that accelerate the development of technologies and services to increase the efficiency of resource use. This impetus will push the demand for cleaner technologies, but also for better methods of delivering on innovation, for social changes in business models, commercial practice, purchasing patterns, and lifestyle decisions.

The response of other nations is already underway

Other nations are responding to this impetus with stronger policies to raise the rate of technological change. For instance, on top of implementing stronger pricing signals through the European Union Emissions Trading System, Germany has feed-in tariffs to subsidize a domestic market for renewable power. Around NZ$17 billion was spent in 2010 to support photovoltaic installations, combined with policies to provide further market incentives for renewable energy sources, those incentives also measured in the billions of Euros.[4] Similarly, the Chinese photovoltaic industry is supported by low-cost development loans totaling tens of billions of dollars per year. There will be in increasing pressure for global programs of similar scale and audacity.

From an innovation perspective, policies like this can be viewed as also acting as industrial development policies supporting German manufacturers of photovoltaic systems and driving down unit cost by raising scale. A consequence of these policies is to support users of those technologies, both in Germany and abroad. New Zealand will benefit passively from this, but the global impetus creates substantial opportunities for innovators in New Zealand. For example, global investment in renewable energy and fuels alone exceeded NZ$240 billion in 2010, creating an immense global market for innovation.[5]

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[3] "Sustainable Manufacturing and Eco-Innovation: Framework, Practices and Measurement – Synthesis Report", OECD, 2009

[4] "Renewable energy sources 2010", Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), 2010

[5] "Renewables 2011 Global Status Report", REN21, 2011

How innovation for green growth differs from other innovation

Recent thinking about innovation builds on the overall idea of an ecosystem of niches into which innovations fit. There are three novel factors that should inform thinking about innovation policies: 1) the realization that this ecosystem is ever-more complex; 2) that this ecosystem is dynamic and self-interacting; and 3) the role of competition between networks of technologies. These factors can be thought of as an information externality, a co-ordination externality, and a source of local market minima and each can be used to consider how innovation for green growth differs from innovation for other purposes.[6]

What is an ecosystem of niches?

Hidalgo introduced the idea that all products can be viewed as components within an interconnected product space, where the connections are the dense networks of technologies, capital, institutions and human capabilities needed to produce those products.[7] Similar products are co-located in clusters within an overall product space. Higher technology, higher value products tend to be located in the dense core of the product space, reflecting greater connectedness with the capabilities needed to create those kinds of products.

This analysis extends factors beyond the traditional (land, labour, capital) to a much more complex and interacting set of factors. This complexity and interdependence lends itself to being described as a product ecosystem, where innovations try to find profitable niches within a multi-dimensional fitness landscape. That landscape is constantly being reshaped by other innovations, by the whims of market forces, by the effects of existing technologies, by competing innovations, and by outside factors such as regulatory frameworks, pricing signals, market rules, and social trends.

New Zealand's capabilities have been noted as placing us just within "the group of relatively diversified countries producing relatively exclusive products".[8] One analysis would suggest that New Zealand is best placed to build upon our comparative advantage by producing new products that are similar to the products we already produce. However, as the products we currently produce are typically low value goods, similar products are likely to be similarly low value. Hence a more sophisticated analysis is needed.

The profitability of any given innovation, at any point in time, depends upon ever-changing, evolving factors. The product space defined by these factors is fine-grained and increasing in complexity. It is volatile, deeply uncertain, and deeply connected.

The explosion of possibilities - the information externality

High-technology, high-value goods and services exist in narrow specialized niches in highly and increasingly sub-divided markets. An innovative product like the iPod creates a new niche for itself, but even in mature sectors, there is a prolific complication of technologies and markets. Welding is a sector that is regarded as a traditionally mature. However, one century ago, there were three welding technologies; there are now in excess of twenty. There is a corresponding increase in

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[6] An externality is a cost or benefit that is not included in prices and is incurred by a third party.
[7] Hidalgo, C.A. Klinger, R.B. Barabási, A.-L. Hausmann, R. "The Product Space Conditions the Development of Nations"
[8] Proctor,R. "Enhancing Productivity: Towards an Updated Action Agenda" MED, 2011

specialized market sectors, e.g. not just machinery for welding plastics, but machinery for radio-frequency welding of small plastic tubing for producing medical catheters. The profusion of both technologies and market sectors shows the ever-finer complexity of the product space in which innovations try to find their profitable niche.

By definition, innovations aim to fill niches that are not yet occupied. The profitability of any innovation in a specific niche is undiscovered and entrepreneurial innovation can be thought of as the process of discovery. This process of discovery reveals information that others can profit from, limiting the profits of the initial discoverer and creating an externality whereby entrepreneurs are not fully rewarded by the market for risks taken. Thus there is a clear case for government supporting initial entrepreneurs to create that market information. However for the development of high technology and high value innovations in New Zealand, the increasing diversity of products and market niches increases the impact of this externality and correspondingly requires more action to address.

The dynamic ecosystem and the creation of new niches – the co-ordination externality

In a dynamic economy, the success of any innovation (whether it is a new policy, technology, product, technique, or service) depends upon the readiness of numerous other factors, including the presence or absence of other innovations. The product space is volatile, with continuous diversification and exploration and these changes result in the creation of new niches.

Given that the success of a particular innovation depends upon the success of other innovations and changes, there is a classic co-ordination externality. One response to this co-ordination problem are clusters of innovators that can share capabilities and benefits.

When existing commodity-based industries attempt to move from low profitability niches into neighbouring niches with higher value products, industry-good activities have often been justified on the basis of supporting the higher fixed costs associated with, for instance, market research or process development. However, these new niches also have a higher degree of co-ordination with other activities and this requires more industry co-ordination to cope with the increased complexity of operating in those niches. This raises the importance of industry-good activities and implies that a stronger role for government in this co-ordination is warranted.[9]

Markets can have multiple equilibriums – Shifting systems from existing to innovative technologies

Competitions between products and between technologies are increasingly becoming choices between networks of technologies. For a topical example, the choice between mobile phones is also a choice between network service providers, cellular networks, on-phone operating systems, cloud-based digital ecosystems, application marketplaces, and application developer communities. Each agent (in this case, each phone user) many place very different values on advantages at each of these levels. Technological choices need to take into account the likely future performance of those networks, often by considering the resources put towards research and development to advance

[9] Rodrik,D. "Industrial Policy for the Twenty-First Century", UNIDO, 2004

each network. The cost of switching between networks of technologies can be substantial, both for individual users and for the industries involved.[10]

Existing networks of technologies can have substantial installed-base advantages. For instance, when comparing petrol-fueled vehicles against electric vehicles, petrol-fueled vehicles benefit from the existence of copious numbers of petrol stations sized and sited to suit existing fleets of petrol vehicles. The huge installed user base also supports ongoing research into sustaining the continued use of a fundamentally dirty technology, whereas research into replacing that technology by electric vehicles is supported by the weak hope for what may happen in the future. To quote Aghion: "Where the dirty technology enjoys an initial installed-base advantage, the innovation machine will work in favour of the dirty technology."

This innovation ecology results in multiple local market minima – equilibrium points in technology network choice where market forces prevent or delay shifts to technologies that have superior prospects of delivering higher productivity at lower cost in the long run. Fostering these shifts should be a key goal of green innovation policies. To quote Aghion again: "The clean technology may never take off unless the government intervenes."[10]

Recommendations for innovation policy

The complexity described here implies that effective innovation policy will need to move beyond just identifying and addressing market failures. Instead, information and coordination externalities suggest that the effective approach is a strategic collaboration between government and industries to optimize the environment the discovery process to deliver innovation in policies, technologies, and products.[9] To quote the UN "World Economic & Social Survey", it is no longer sufficient to just address specific market failures:

> "Overall, policies in the green national innovation system should promote technological capacity-building, technology transfer, interactive learning and entrepreneurship based on education, knowledge spillovers and learning-by-doing".[1]

What is the best path for greener growth through the smarter use of technology and innovation by business? Where does it all begin?

Recognise the competition of networks – Choose greener networks of technologies

As there is a global impetus to deliver cleaner technologies at a rate never seen before, then Government is the only body able to shift markets from one equilibrium to another. The goal of greener growth should be to deliver these kinds of shifts.

Where uncertainty between future technological choices is present (and it almost always is), then Government policies should aim to be technology agnostic. The impact of policies should be reviewed to avoid prematurely closing off technological options. For example, as battery-electric vehicles grow in use, the electricity demand from recharging at home will increase the load on generation and transmission. Setting minimum standards for smart charge management will favour renewable energy as this allows for variable generation to match smart demand. Not setting these standards creates an inflexible demand that closes off variable generation in favour of on-demand

[10] Aghion, P. Hemous, D. Veugelers, R. "No green growth without innovation" Bruegel Policy Brief, November 2009

peak power using fossil fuels. Both options make technological choices and this must be recognised in policy decision-making.

What are the barriers to technology take-up and innovation? How can businesses become more responsive to drivers for innovation?

Address the information externality – Increase discovery

Exploring the product space to discover which innovations will be commercially successful at any particular point in time should be viewed as a process of entrepreneurial discovery. The unpredictability of the results of this process means that successes will only be increased if the number of attempts increase, suggesting that to the approach to take is to reduce the cost of each endeavour. For the higher value, more highly connected innovations found in greener technology, the information externality is stronger than for lower-value innovations, thus policies here should be stronger than for other innovative areas. These should include lowered fixed costs on research and development, schemes to help bear the costs of early stage development, and policies to increase the use of higher-risk finance (such as angel and venture capital).

As the success of any endeavour is not known beforehand, it may also be helpful to consider the ease of cutting losses when it is discovered that a particular niche may not be profitable.[9] Letting failing businesses to die, frees up human, financial, and intellectual capacity for more productive use. Increasing the willingness to fail is also a tool for increasing discovery and innovation.[11]

Address the co-ordination externality – Industry-good activities are industry-specific

Co-ordination problems tend to be industry specific and difficult to discover without substantial involvement with that industry. Identifying and supplying capabilities that the market would fail to provide on its own requires new and stronger efforts at multiple levels within each sector, guided by accountability and transparency to avoid rent-seeking behaviour and promote profit-seeking behaviour by those industries.

These co-ordinating actions can involve helping innovations make the leap overseas through accessing international networks of knowledge, business, and finance.

This suggests that New Zealand should look to invest in areas that are both on the edges of our current existing comparative advantage but that extend into higher value niches and have the potential to create substantial knowledge-spillovers.

For example, New Zealand's capability in geothermal power generation was developed by Government and embodied in the expertise of a cadre of highly regarded individuals who, after the closure of the DSIR and the privatization of the electricity industry, moved into private consultancies and built several businesses with global impact. However, there was no incentive for those businesses to co-ordinate in investing in educating the next generation of experts – the geothermal industry in New Zealand has coasted on publically funded capability ever since. This is one area where Government has recognised its sole responsibility for this capability with support for the Geothermal Programme at the University of Auckland. In doing so, it enables the continued growth

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[11] Fogela, K., Morck, R., Yeung, B. "Big business stability and economic growth: Is what's good for General Motors good for America?", NBER Working Paper No. 12394, 2006
Ormerod, P. "Dealing with success and failure", 2002

and internationalization of an industry founded on New Zealand's rare endowment of geothermal resources.

What types of policy action might encourage and support businesses to make the right types of investment in technology and innovation?

Build and focus underlying capacity

The deep uncertainty inherent in innovation implies that Government should enable the process of discovery at a broad level by supporting the underpinnings of human capital: health, education, and training. The dynamic nature of innovation implies that these investments need to be pre-emptive, that these capabilities should be developed in advance of the economy's requirement for them.[12]

While innovation at a low level cannot be predicted, at the strategic level the strength of demand for greener growth justifies investment in human capacity to be focused at a broad level to match this long-term social and technological trend.

Helping the competitiveness of NZ innovators – matching NZ conditions for innovation to conditions overseas

What causes a difference in the competitiveness of New Zealand firms in domestic markets as opposed to their competitiveness overseas? The distinction is caused by the different all the factors that influence business activity in respective markets, including the soft infrastructure of regulatory frameworks and the readiness of the rest of the economy for any particular innovation. This suggests there will be a cost to NZ firms' international competitiveness if the conditions for green innovation lag those in our export markets.

If we lag behind the developed world, then we will continue to benefit from overseas investments in research, development, and deployment that will make cleaner technology available to us more rapidly and at a lower price. For the majority of technologies, NZ will be an importer and price taker, so this approach is a tempting one. However, the cost of free-riding is to increase the difference between the NZ innovation environment and the environment overseas. This decreases the likelihood of domestic innovation being fit to succeed overseas and reduces our competitiveness.

Conversely, if we lead by creating the innovation environment that favours greener technology, then we can provide our innovators with a head-start against their competitors overseas.

For example, renewable energy targets and policies can now be found in 118 countries. Policies include feed-in tariffs in sixty countries and capital investment subsidies, grants, or rebates; tax incentives; energy production payments or credits; public financing; net metering; green energy purchasing; labeling; and solar hot water mandates.[13] As these policies strengthen, then they create a commercial imperative for NZ to have environmental legislation and pricing signals that match and then lead the rest of the world.

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[12] Yifu Lin, J. "New Structural Economics – A Framework for Rethinking Development", World Bank, 2009

[13] "Renewables 2011 Global Status Report", REN21, 2011 http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf