SUBMISSION TO THE PRODUCTIVITY COMMISSION INQUIRY INTO PUBLIC SUPPORT FOR SCIENCE AND INNOVATION.

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1. STATUS OF SUBMISSION

This is a personal submission, and should not be taken to represent the views of clients of Cutler & Company nor of organisations or institutions with which I am affiliated. It should also be noted that this submission is related to, and informed by, submissions associated with the ARC Centre for Creative Industries and Innovation. I am Chairman of the Advisory Board of this Centre. As a matter of disclosure I am also Chairman of the Australian CRC for Interaction Design (ACID Pty Ltd), a member of the Council of the Queensland University of Technology, a Director of the Malaysia's Multimedia University and Malaysia's MSC Technology Centre, and a Director of the CSIRO where I chair the Board's Commercial Committee.

2. INTRODUCTION

This Inquiry is to be welcomed because it addresses a subject that is central to the sustainability of Australian industries and the well being of Australians.

I will argue that innovation, whilst central to economic development and change, has not been comprehensively addressed by economists and mainstream economic theory and that, whilst there is frequent invocation of a "national innovation system", there has been a lack of attention to spelling out just what such "national innovation system" might look like. As a consequence we run the risk of working with inadequate frameworks for decision making about investment in science and technology, and for determining relevant metrics for assessing returns on such investment.

The attachment to this submission is a working paper, very much a work in progress, which attempts to provide a conceptual framework for a 'national innovation system'. This submission begins, but does not complete, the challenge of addressing the question of how such a conceptualisation of a national innovation system might shape investment planning by governments and public sector institutions, and the vexed issue of how to determine appropriate methodologies to assess and evaluate the returns from public investment in science and innovation.

3. COMMENTS ON TERMS OF REFERENCE.

This subject matter of this Inquiry is "public support" for "science *and* innovation".

I submit that the examination of the role of public *versus* private support for science and innovation must be considered within the context of an appreciation of an overall *national innovation system*, and that any such national innovation system must take cognisance of the global trends driving international changes to the comparative economic competitiveness of individual country economies. The national benefits accruing from science and innovation will necessarily be *co-produced* by a wide range of private and public sector agents. It follows that the overall national benefit cannot simply be calculated from the intermediate outputs of the contributing parties. The national benefit from innovation is more than the sum of the parts because the impact arises from the interaction of these parts. Few studies have succeeded in surveying systemic impact, and BankBoston's 1997 study of MIT's economic impact remains a pioneering effort[1]. The biological and life sciences remain at the forefront of the systemic analysis of complex systems.

The coupling of the words "science *and* innovation" is significant. Nobody seems to have come up with a simple one-word descriptor of the subject matter (although we have started to use 'innovation" as an umbrella term to subsume 'research and development'). The resort to portmanteau phrases like 'science and innovation' usually reflects a recognition that we are dealing with something complex. Both science and innovation are certainly complex systems. And complex systems have become a specialised field of inquiry in its own right.

The Commission's Issues Paper of April 2006 can be read as reducing the scope of the Inquiry to an investigation of 'science *for* innovation', where innovation is primarily the matter of "product and process innovation" within industrial markets. Further, the Issues Paper reduces the Commission's four terms of reference to three, collapsing the separate clauses dealing with economic impacts on the one hand, and the broader social and environmental impacts of public support on the other. The Issues Paper then tends to concentrate on the economic in its discussion of impact analysis. The danger is that this approach could lead to a narrow interpretation of the terms of reference and, if this reading is correct, this would be unfortunate. Many public good outcomes, pursued as objectives in their own right and funded accordingly, nevertheless produce significant private opportunities and industrial benefits. Medical science and environmental research are prime examples.

The Issues Paper outlines a set of key concepts and their interpretation. I submit that many of these interpretations are problematic, mainly because the notion of an 'innovation system" continues to be largely undefined, and conceptually fuzzy. Hence 'science' and 'research and development' become defined in overlapping and tautologous terms. There are two particular problems with the concept of 'relevant' science in the paper.

First, the exclusion of the social sciences and the liberal arts from the purview of relevant science is particularly regrettable. This exclusion ignores the growing recognition in the literature of the importance of inter-disciplinary research in both breakthrough science and in innovation. Further, creative disciplines like design and computer gaming have become embedded in cross-sectoral practice and applications. The establishment of the ARC Centre for Creative Industries and Innovation reflects the growing recognition of these roles within a national innovation system.

[1] BankBoston, *MIT: The Impact of Innovation*, Massachusetts, 1997

The second problem is the exclusion of "scientific and technological services". Many of these comprise publicly funded 'national facilities' or the publicly funded roll-out of general purpose technology platforms (such as ICT, which has been the focus of major public programmes). A collection of general purpose technologies has been recognised as *innovation technologies* in recognition of their crucial role in supporting innovation. These include such technology tools as data mining, visualisation, collaboration, simulation, and rapid prototyping. Australian academics are among those highlighting the important role of these technologies in contemporary innovation[2].

The Issues Paper draws attention to the lessons which may be drawn from other countries. Three initial comments are offered on this aspect. First, cross-country comparisons on specific points frequently ignore externalities unique to a particular country situation, and to the role of path dependency in economic change and industrial development. Particular attention needs to be paid to the strategic options available to *small country economies* within a global economy, with particular regard to the challenges confronting a small country economy facing the compounding effects of the tyranny of distance and the tyranny of density. Few countries are more remote than Australia from the world's major markets, and few have such a low population density.

Second, all countries confront a set of emerging global trends and technology change which will impact on them differentially, depending on a country's historical circumstances. The options available to remote small country economies will be very different from countries within the market conurbations of North America and Europe. Propinquity matters.

Third, many of the metrics used for international comparisons are flawed and can lead to distorted interpretations. A classic example is the OECD taxonomy for categorising countries according to the mix of their industrial base from low technology to high technology. On these metrics Australia stands out as predominantly a "low technology" economy, and this conclusion is then sometimes used to support an argument that Australia's present industry structure is a given[3]. This taxonomy disguises the crucial role of superior technology and innovation in maintaining Australia's competitive in natural resources and primary production.

Finally, an effective innovation policy for Australia, and its supporting funding and institutional arrangements, needs to distinguish between areas and sectors where Australia has a natural or built comparative advantage globally, and those many areas where it will always need to be in strong position to acquire and import technology and knowledge from the international community in a timely and effective manner. Different strategies and approaches will be required for each case.

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[2] Mark Dodgson, David Gann, and Ammon Salter, *Think, play, do: technology, innovation and organisation*, Oxford University Press, 2005

[3] This is the implication of several recent Treasury working papers.

4. THE NEED FOR A ROBUST FRAMEWORK FOR INNOVATION POLICY – AND ITS ASSESSMENT.

Whilst the notion of a national innovation system is much invoked, it is hard to find a comprehensive description of such a system, nor of how it functions[4]. In other words, we do not have a commonly accepted theory of innovation. The attached working paper – and it must be stressed that this is very much a work in progress and it stops short of spelling out fully the implications of the conceptual models proposed – attempts to develop or bring together out some building blocks for better understanding the dynamics of innovation as a complex system within a national setting. Some of the key points and propositions made in the paper are as follows.

1. Words and semantics matter.

The language we use around the subject matter of innovation is confused and confusing. As in patent law, there is merit in examining claims about innovation against commonly accepted usage, based on the codified definitions of the English language. In the attached paper, therefore, I make a distinction between invention and creation – as the precursors of and prerequisites for innovation – and innovation itself as the process that triggers economic change and industry development. A further discrete function within national innovation systems is the transfer, diffusion or take up of innovations. A conceptual model for a national innovation system, therefore, must comprehend the origination, the introduction , and the diffusion and adoption of novel ideas and innovative practices.

2. Evolutionary economics supports a new theory of innovation

The concepts of origination, introduction, and adoption, introduced above, support a theoretical model for innovation revolving around the factors of:

(a) Variety and diversity of ideas within the pool of knowledge;

(b) Effective selection and choice mechanisms in applying ideas and inventions to the competitive challenges of markets and the sustainability and growth requirements of communities; and

(c) Efficient testing and propagation mechanisms as platforms for the diffusion and roll out of the new.

This model, which closely follows theories in thermodynamics and biology, has immediate implications for assessments of innovation, especially with regard to regard to efficiency and the need for 'waste" and "failure', the lack of attention to selection processes in an environment of uncertainty, and the role of path dependencies in the survival or flourishing of innovations.

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[4] The closest so far is a still unpublished working paper by Christina Chaminade and Charles Edquist from Lund University in Sweden – *Rationales for public policy intervention in the innovation process: A systems of innovation approach*, Unpublished draft paper, 2006.

3. The incentives for innovation are as varied as the possible returns.

There are different modes of innovation, and there is a broad spectrum of different types of innovation across the life cycles of firms, industries and markets.

4. From a government and public policy perspective, innovation is a 'cross-domain' issue, cutting across traditional administrative silos.

As a change process, innovation has little respect for institutional or organisational boundaries. This calls for a "whole of government" approach.

5. Innovation is a complex system and operates across a hierarchy of inter-connected levels.

Distinguishing the different levels within this complex system that is innovation helps to "create a connecting path between global and individual activities"[5].

Combining this hierarchy of different levels of innovation activity with the different innovation horizons and timeframes, produces a framework matrix for mapping relevant activities and requirements, and for assessing possible policies and approaches for promoting innovation.

6. There are discrete roles and functions within a national innovation system.

The attached working paper proposes a portfolio model for national investment planning and capability evaluation. This model has regard to investment horizons (short or long run), purpose and strategic intent, and supporting infrastructure and capabilities.

[5] Robin Batterham, "Sustainability – the next chapter", unpublished paper, 2004.

A FRAMEWORK FOR INNOVATION POLICY

Working Paper

Whilst we frequently talk about a national innovation system, it is hard to find a comprehensive description of such a system, nor of how it functions[6]. In other words, we do not have a commonly accepted theory of innovation. This working paper – and it must be stressed that this is very much a work in progress and it stops short of spelling out fully the implications of the conceptual models proposed – attempts to develop or bring together out some building blocks for better understanding the dynamics of innovation as a complex system within a national setting.

Terminology and constructs

The language we use around the subject matter of innovation is confused and confusing. A prominent academic and advisor on innovation, Mark Dodgson, recently commented that:

> the word 'innovation' is confusing and misused, and associated terms like 'research' and 'development' are past their sell-by date. We need a new and better language to explain what innovation is[7].

He is right. Examining the numerous reports and writings on the subject produces a bewildering array of definitions[8]. These reflect divergent views on what is important about innovation. Innovation is a big topic, and too often an emphasis on one particular aspect has been at the expense of attention to others, sometimes at the cost or risk of skewed and distorted outcomes..

Words matter. As in patent law, there is merit in examining the claims about innovation against commonly accepted usage, based on the codified definitions of

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[6] The closest so far is a still unpublished working paper by Christina Chaminade and Charles Edquist from Lund University in Sweden – *Rationales for public policy intervention in the innovation process: A systems of innovation approach*, Unpublished draft paper, 2006.

[7] Mark Dodgson, The Language of Innovation, Ockham's Razor, ABC, 29 January 2006 http://www.abc.net.au/rn/science/ockham/stories/s1556387.htm

[8] For example, a recent sample provides the following:

- Business Council of Australia: "*innovation involves the commercial application of old or new knowledge to create additional value and wealth*".
- Victorian Government Innovation Statement: "*innovation means finding new or better ways to do things, creating new products or services, applying new technologies to solve existing problems, or using existing products and technologies to meet new needs.*"
- OECD description: "*Most of the rise in material standards of living since the industrial revolution has been the consequence of innovation. New or improved products and services – and new and improved ways of producing them – have for a long time been the main motor of economic growth.*"
- Australian Bureau of Statistics: "*innovation is defined as introducing new or significantly improved goods or services and/or implementing new or significantly improved processes.*"
- Federal Government definition: "*Innovation – developing skills, generating new ideas through research, and turning them into commercial success*".

Interestingly, few of these examples encompass or explicitly focus on innovation within the setting of public or community good.

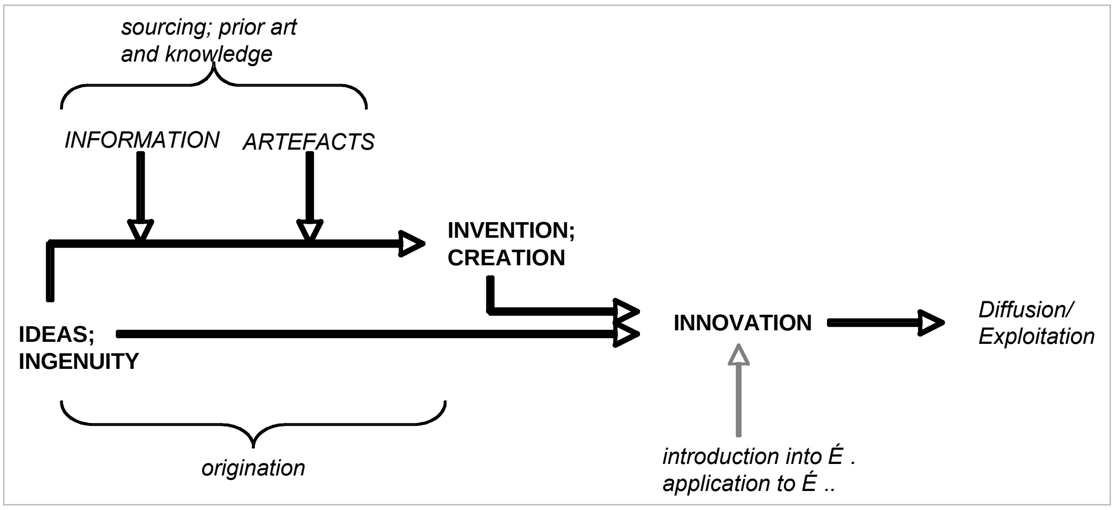
the English language. As a beginning, therefore, we should look at the commonly accepted meanings of the term innovation, and the related concepts of invention and creativity, and their typical usage within the fields of science, research and economics.

Innovation, and its variant word forms, is a relatively new word in the English language, becoming popular only in the mid 16th century. The Oxford English Dictionary defines the term as being about introducing something new, such as bringing something to market, introducing change, or making changes to something established. The sense of the term, therefore, is clearly about change processes, including economic change.

There is a linguistic and conceptual distinction between the matter or process of change, and the source of that which is used to produce or to cause change. The source of change is described by the terms invention[9] and creation, whether as the development of new artefacts or products, or the birth of ideas and knowledge. It is the application of these artefacts or ideas into human systems, whether economic or social, which becomes innovation. The subsequent impact of the changes arising from the process of innovation relates to the diffusion or adoption of the changes across industries or within the community.

The following diagram attempts to represent these distinctions visually.

FIGURE 1: **INNOVATION: A TAXONOMY OF TERMS AND RELATED CONCEPTS**



A conceptual model for a national innovation system, therefore, must comprehend the origination, the introduction , and the diffusion and adoption of novel ideas and innovative practices.

An additional factor highlighted in this diagram is the fact that innovation can originate through either formalised or informal paths, corresponding to the distinctions we make between different types of intellectual capital. It is generally

9 According to the Oxford English Dictionary the word invention appears to connote an idea being fixed in a physical or tangible manifestation, whereas creativity is more commonly associated with the world of ideas.

accepted that the skills, knowledge and capabilities associated with intellectual capital can be divided into two categories[10]:

(i) formal, codified skills and knowledge, represented by curricula, qualifications or certifications, investments in formal R&D, patents, and publications. This has been popularised[11] as "know what" and "know why". This is the area covered by intellectual property rights.

(ii) tacit or informal skill sets and knowledge, much of which arises in a socio-economic setting ("tacit knowledge resides in the minds of individuals and the practices and shared understanding of social groups"[12]). This is popularized as "know how" and "know who".

This later domain of human "know how" is often neglected in discussions of innovation and its sources, or exploitation.

Apart from recognising the centrality of intellectual capital in this cluster of generic functions around innovation, two other key points emerge from this initial explication of the terminology in use. First, by definition, innovation involves multi-part and multi-stage activity and, as we will argue, this will normally - if not necessarily - involve path dependencies in development processes. Second, invention and innovation may involve different agents, and the identity and location of these agents may vary, both locally or globally. This last point is important to understanding the implications of emerging trends around "open innovation", of which more later.

A conceptual model for a national innovation system, therefore, must comprehend the origination, the introduction , and the diffusion and adoption of novel ideas and innovative practices.

Towards a theory of innovation

The literature on innovation is broad and diverse. This literature is dominated by public policy analysts and industry or business management texts. Upstream, there is a huge literature on creativity, largely populated by psychologists and neuroscientists. Curiously absent from the field in any significant way, however, are mainstream economists in the neo-classical tradition. Traditional neo-classical economics simply cannot account for innovation. This is because for the last hundred years or so neo-classical economics has concentrated largely on questions around price mechanisms and money supply. The related economic theory is grounded on static assumptions about equilibrium models. In this view of the world a perfect market is one which has achieved equilibrium between supply and demand.

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[10] This section draws on an earlier report by Cutler & Company, *Skills and Capabilities for Technology Commercialisation and Exporting*, A Report for the Victorian Department of Innovation, Industry and Regional Development, February 2005 (available at: http://www.business.vic.gov.au/busvic.18022564/standard/1527639521/pc_60954.html

[11] B. Lundvall and B. Johnson, "The Learning Economy", *Journal of Industrial Studies*, Vol 1, no. 2, 1994

[12] Ken Ducatel, "Learning and Skills in the Knowledge Economy", DRUID Working Paper No. 98-2, Aalborg University, 1998

A consequence of the thinking grounded in equilibrium theory has been that public sector economists have, traditionally, only been able to deal with subjects like "research and development" through the rationales of "market failure" and of "spillovers" that might justify state intervention and action in the public interest. On this basis mainstream economists could accommodate public science and technology interventions because, by and large, these areas of market failure largely remained several steps removed from the disciplines of market operations in the "real" world. Typically the progression from research to "development" was seen to occur well upstream from production processes and markets, and saw technology transfer taking place as part of a linear development model. In other words, in this world the "exceptionalism" of the arguments about market failure remained at a safe arms length from economists' primary interest in market mechanisms and their efficacy. Innovation described as "R&D policy" could thus be effectively quarantined from the central economic concerns of competition policy and market efficiency. This accommodation has been brutally undermined by the collapse of linear models of technology development and transfer, caused by the new industrial practices of "open innovation" and "user driven innovation". In this new world market "pull" is as important, if not more so, than science and technology "push". Emerging lines of economic thinking are beginning to assert that **an innovation policy *is* competition policy**.

An innovation policy *is* competition policy. This is a very bald statement of what is argued in considerable detail by emerging streams of economic thinking variously categorised as neo-Schumpeterian "evolutionary economics" or as "complexity economics". Lucid Australian proponents include University of Queensland economist Jason Potts, who is furthering this approach through projects under the aegis of the Centre of Excellence for Creative Industries and Innovation sponsored by the Queensland University of Technology in Brisbane. Other important contributions come from economic historians – providing an empirical insight into the development of industries and markets – and from economists examining institutional and organisation structures. Amongst the latter Douglass North the Nobel Laureate stands out, particularly in one his most recent books[13] which examines the interplay between organisations and institutions in economic change. By presenting a forensic analysis of the processes of economic change North, like his colleagues working in evolutionary economics, is reconnecting the discipline of economics and the subject matter of innovation.

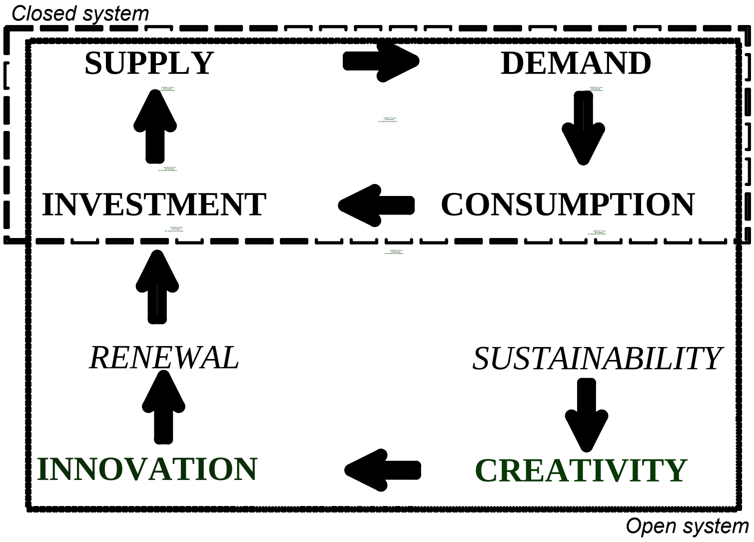
If change is taken as the *sine qua non* of civic and economic development, then understanding and addressing the subject matter of innovation becomes an overwhelmingly important preoccupation for us all. Innovation becomes that which fuels change and growth and adaptation. It is to the political economy what natural selection and adaptation are to biology. The parallels between biological and human ecosystems are not stretched, because both involve the complex environment and behaviour of living systems. From this convergence, and the recognition that contemporary human society functions as a highly complex system, we can begin to

[13] Douglass North, *Understanding the process of economic change*, Princeton University Press, 2005

postulate a theory of innovation as a model of economic and social change and development[14].

The starting point is the premise that growth and development –economic changes – arise from *dis*equilibrium and dynamic competition over the re-ordering of the status quo. Invention and innovation thus represent the forces of "negative entropy" which prevent things grinding to a halt and running out of energy in line with the laws of thermodynamics. Invention and innovation, therefore, are the means by which social and economic systems are renewed and re-energised.

FIGURE 2: CREATIVITY AND INNOVATION IN THE SUSTAINABILITY OF MARKETS

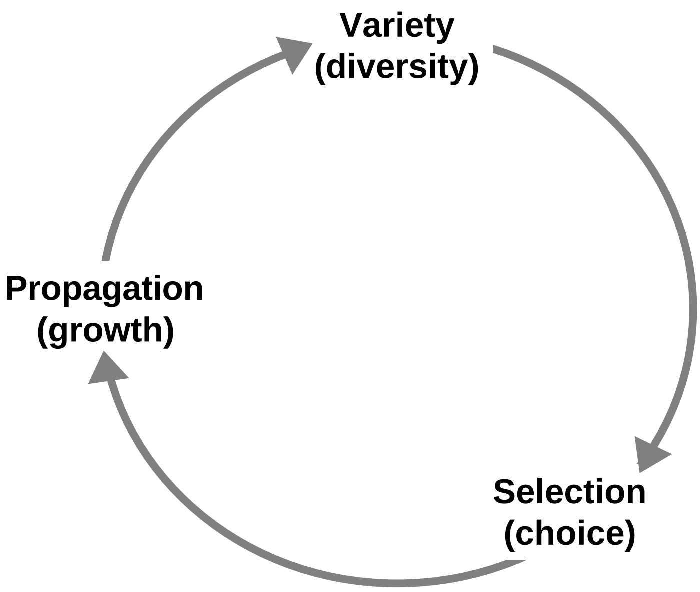


In this view of market dynamics it is the "below the line" activity and culture around creativity and innovativeness that shapes broader economic prospects and national competitiveness.

On the premise that disequilibrium drives economic change, we can begin to articulate a general theory of innovation as an evolutionary system. Figure 3 provides a diagrammatical representation of a working model. There are three crucial elements within this system.

FIGURE 3: **INNOVATION AS AN EVOLUTIONARY SYSTEM**

[14] A broad-ranging overview is provided by Eric Beinhocker, *The origin of wealth: Evolution, complexity and the radical remaking of economics*, Harvard Business School Press, 2006



Source: Cutler, 2006

First, the generation of options for introducing something new into the market. This boils down to the generation and nurturing of a pool of intellectual capital and is comparable to the notion of biodiversity in the life sciences. The increase of the knowledge stock, and access to that knowledge stock, is a precondition for innovation. This produces the first proposition that diversity and variety fuel innovation. Corollaries to this proposition are that, at any point of time, diversity is also wasteful (but not necessarily in the long run), and that discoveries, ideas or inventions that are wasted by one organisation or industry may be of value and use to another organisation or industry.

The biggest threat to diversity and variety is constraints on freedom and contestability. Creativity for the origination of fresh thinking and ideas requires a political climate of permission and contestability, suggesting that innovation flourishes best in democratic societies and open institutions. This is a point made strongly by Amartya Sen when he talks about the effect of 'unfreedoms', in their many guises, on prospects for economic development[15].

The second part of the involves the selection processes by which organisations and markets reward one putative innovation over another. As Douglass North explains, what distinguishes selection in biological and human systems is that in human systems selection involves a large element of intentionality. There are fewer "natural selection" processes. It is, therefore, very important to examine the various selection or filtering processes at work in markets and in civil society, and the test their adequacy and effectiveness. Inefficient selection processes or the very absence of intelligent filters and gateways, will limit the potential exploitation of stocks of intellectual capital, and the inventions and ideas to which they have given rise. One source of imperfect selection processes is information asymmetries which increase uncertainty and risk; another is differential access to knowledge or limitations around the ability to exploit knowledge.

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[15] Amartya Sen, *Development as Freedom*, Alfred Knopf, New York, 1999

The introduction of intentionality in the selection processes within market settings brings with it the corresponding notion of path dependence.

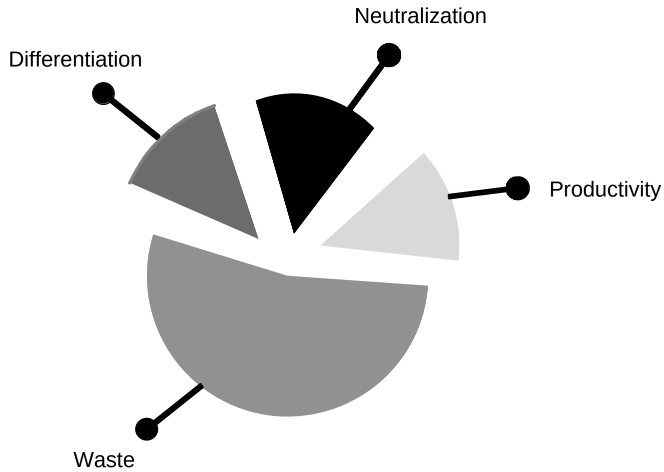
> *Path dependence is … the constraints on the choice set in the present that are derived from historical experiences of the past. Understanding the process of change entails confronting directly the nature of path dependence in order to determine the nature of the limits to change that it imposes in various settings*[16].

Path dependence arises at each of firm, industry, and country levels. Innovation does not occur upon a level playing field.

The third element refers to the processes associated with the roll-out of innovations and their embedding within market and institutional settings. This is about the diffusion of knowledge and the take up of new technology. It is at this stage that frequent and incremental innovative adaptation takes places. This often occurs in the technology integration within complex systems, or as "process innovation. We posit that technology integration, as opposed to technology invention, will become an increasingly important innovation driver

We have noted that waste, or blind alleys, are a natural outcome of any evolutionary model of economic change. This has been dramatically illustrated by the industry analyst and advisor Geoffrey Moore in his seminal text on firm level innovation[17].

FIGURE 4: RETURNS ON INNOVATION



Source: Moore, 2006

While Moore is looking at the spread of outcomes from innovation within a firm, his insights are readily generalised to industry markets or economies at large. For example, we might postulate that it is to be expected that some number of new firms will fail, and that without a certain level of failure there will be less likelihood of successes and long run innovation. The boom and bust cycles associated with major tipping points in the evolution of economies – such as the introduction of railways, broadcasting, ICT and biotechnology – seem to exemplify this point dramatically.

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[16] North, op cit., p. 52
[17] Geoffrey Moore, *Dealing with Darwin: How great companies innovate at every phase of their evolution*, Penguin, NY, 2006, p. 6

If this line of argument holds true, then attempts to account for returns on investments in innovation need to be careful to examine the calculus not only in terms of the individual firm, but also of industry clusters and markets, and for both the short and long run. This may be a big ask for government auditors wanting to justify public investment in science and innovation, but it is a necessary counterpoint to the dangers inherent in static, point analysis commonly applied to this area.

Different modes of innovation

Time frames are important. The temporal dimension to innovation is potentially complex. Management consultants often speak about planning and innovation horizons[18], ranging from the immediate incremental application of existing knowledge to "over the horizon" discovery and basic research. For years the distinction between basic, or curiosity driven research, on the one hand and mission directed or applied research on the other hand has bedevilled debates about science policy.

Mehrdad Baghai and colleagues at McKinsey & Company developed a three tier model to describe discrete development horizons. These different growth or innovation horizons correlate with the discrete drivers for the origination and sourcing of ideas and inventions for different types of innovation. Building on his "3 horizons" model, Baghai worked with CSIRO to suggest three planes of innovative activity within a national system.

Science Intensive Innovation	*Curiosity driven* *Addresses frontiers of knowledge which can produce knowledge and technology breakthroughs.*
R&D Intensive Innovation	*Mission directed research* *Outcome focussed* *Often associated with transformational or "disruptive" innovation*
Knowledge intensive innovation	*Incremental innovation* *Applied and integrated solutions* *Outcome focussed*

Adapted from CSIRO 2004

These distinctions are useful as they suggest different types of relationship between the upstream activity around creativity, discovery and invention and the downstream acts of innovation. One of the implications is that there are likely to be different models for technology transfer and knowledge diffusion in each case, reminding us of the danger of thinking in terms of 'one size fits all' policy or business solutions. As others have pointed out, however, such categorisations do not always or necessarily map neatly into timeframes or considerations of purpose and use. Solving immediate problems can drive scientists into ground-breaking research, and Louis Pasteur is often being cited as a good example of this. In his seminal and landmark explication of the policy tensions between basic and applied science, Donald Stokes noted the need for processes to bring together

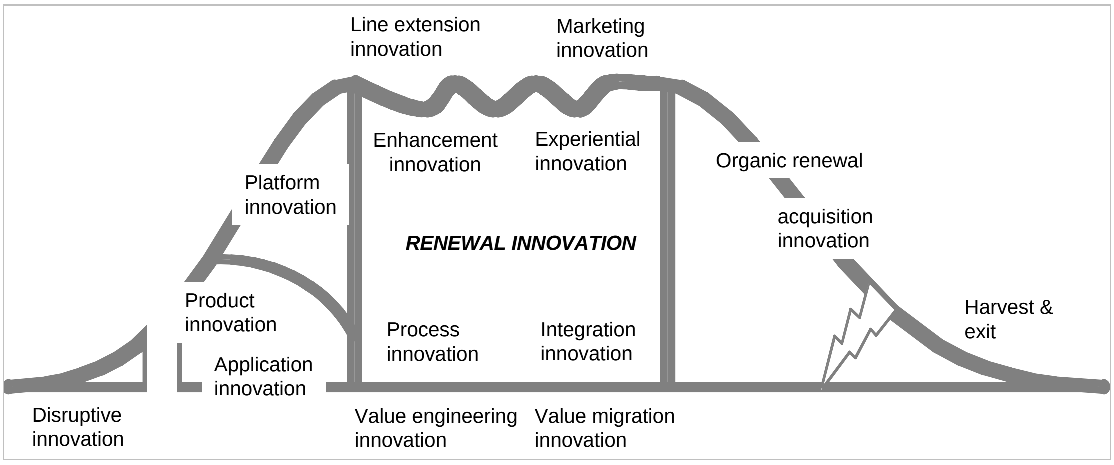
[18] Merhdad Baghai, Stephen Coley and David White, *The Alchemy of Growth*, Orion Business Books, New York, 1999

the two quite disparate kinds of judgments that shape agendas of use-inspired basic research – scientific judgments of research promise and political judgments of societal need[19].

Real dysfunctions within national innovation systems arise when the equation of "science *and* innovation" is reduced to "science *for* innovation". In this context 'use' becomes the independent and absolute determinant of public investment. (This is at odds with our distinction between upstream preconditions for innovation and the innovative uses to which inventions and ideas can be applied; it is also at odds with the imperative within our evolutionary model around the generation of options and the nurturing of diversity and variety within the system.

Finally, there is a spectrum of activities and outcomes associated with innovation, and not to have regard to the whole spectrum in considering public policy will weaken any national innovation system. In considering innovation over the life cycle and growth stages of firms, Geoffrey Moore has identified seventeen varieties of innovation at play at different times and in different circumstances. These range from the revolutionary "disruptive" innovations which transform markets and industries, through to the submerged endeavours of continual improvement.

FIGURE 5: THE VARIETIES OF FIRM LEVEL INNOVATION



Source: Moore, 2006

A taxonomy for innovation as a system

Challenges like innovation policy – or infrastructure and sustainability - do not sit comfortably within the traditional silos of institutional and administrative structures. Most of us are tempted to narrow down our focus to bite-size chunks, but in so doing we run the danger of missing the many linkages between policy areas and the examination of cross-impacts, to the detriment of policy coherence and eventual impact. This is no different to research methodologies where new knowledge – and innovation - often comes from the cross-over or cross-pollination between scientific disciplines or different industries.

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[19] Donald Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution, Washington DC, 1997

The challenge, therefore, is to synthesise a strategic framework encompassing the whole dynamic and ecology of a national innovation system. We need to see the whole wood, and not just the nearest trees. We need working models against which we can then begin to re-evaluate, examine gaps in our attention, as well as to contemplate the differing timeframes and possible intervention strategies associated with promoting particular outcomes. This section examines three frameworks as scaffolds for the policy analysis of innovation:

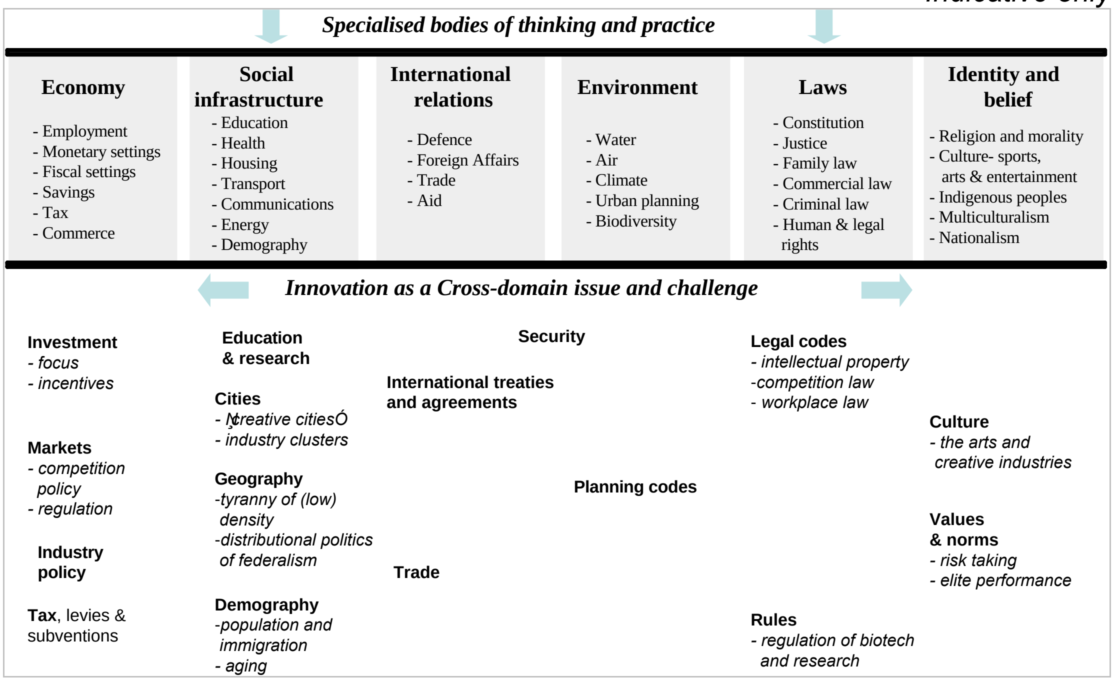
- "whole of government" frameworks and linkages
- a taxonomy of the different levels of activity
- a portfolio model of innovation roles and functions.

Developing "Whole of Government" perspectives

Innovation is one of those horizontal policy themes that cuts across the various ways in which public administration is compartmentalised. Figure 5 provides an indicative mapping of how innovation intersects with the various domains of public policy.

FIGURE 6: INNOVATION AS A CROSS DOMAIN ISSUE

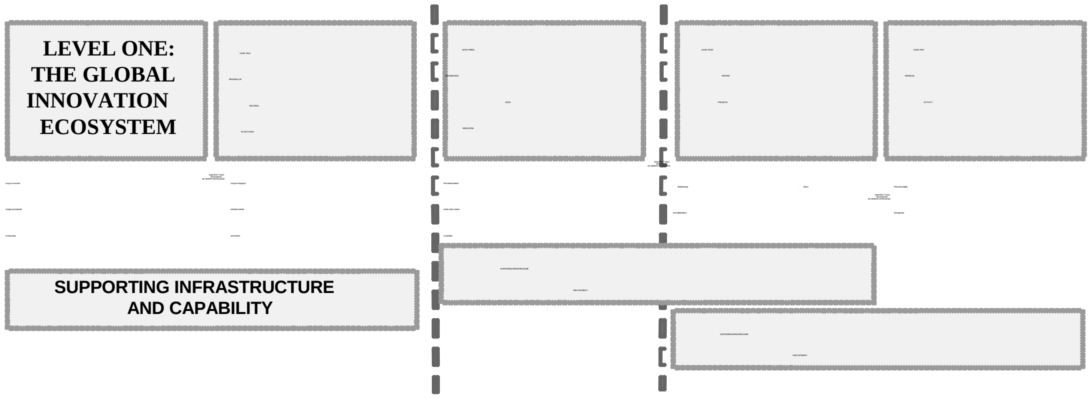
Indicative only



The different levels of activity within an innovation system

Distinguishing different levels within this complex system that is innovation helps to "create a connecting path between global and individual activities"[20].

FIGURE 7: LEVELS OF ACTIVITY WITHIN AN INNOVATION SYSTEM



Optimal outcomes require balanced attention across this spectrum of activity shaping innovation. Top-down policy processes probably skew our attention to the shaping and support of formal institutional arrangements and organisational linkages represented by the left hand side of this spectrum, to the relative neglect of attention to the activities within the engine rooms of creativity and innovation.

Levels 4 and 5 remind us that innovation fundamentally revolves around the activity of individual and their collaborations. The policy challenge is not only how to invest in building pools of talented people, but also in how to invest in them over their careers so as to maximise the national benefit that it is possible to accrue from these valuable people assets. It also means investing in platforms and programmes to support their collaboration in project teams and knowledge sharing. People strategies need to be at the heart of innovation policy. What motivates and empowers people to exercise their talents is largely intrinsic. Increasingly skilled professionals are pursuing self-managed careers, increasing the importance of informal networks and linkages over structured organisational relationships.

Robin Batterham comments that "specific projects are the small finite steps which can lead the way forward … for the rest of the enterprise and even the rest of the industry"[21]. At the other end of the spectrum, Levels 1 through 3 crucially shape the environment in which actual people think, experiment, and act.

Combining this hierarchy of different levels of innovation activity with the different innovation horizons we examined earlier, produces a framework matrix for mapping relevant activities and requirements, and for assessing possible policies and approaches for promoting innovation.

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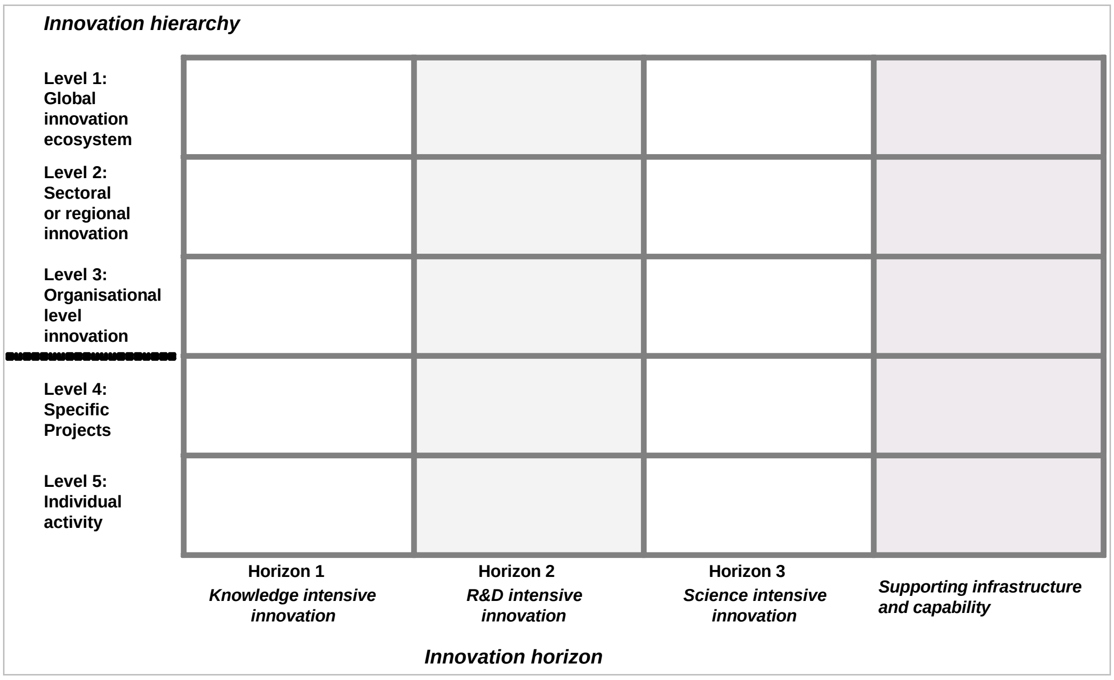
[20] This discussion draws inspiration from Robin Batterham, "Sustainability – the next chapter", unpublished paper, 2004.
[21] *Ibid.*

FIGURE 8: AN INNOVATION POLICY WORKSHEET



This matrix serves two useful purposes. First, it starkly reminds us of the importance of formulating a coherent set of policies across the five hierarchical levels. Gaps or inconsistencies of treatment on the vertical axis will undermine the effectiveness of the innovation system. There is, moreover, no one level which is more important than the others. Each is important, and mutually reinforcing.

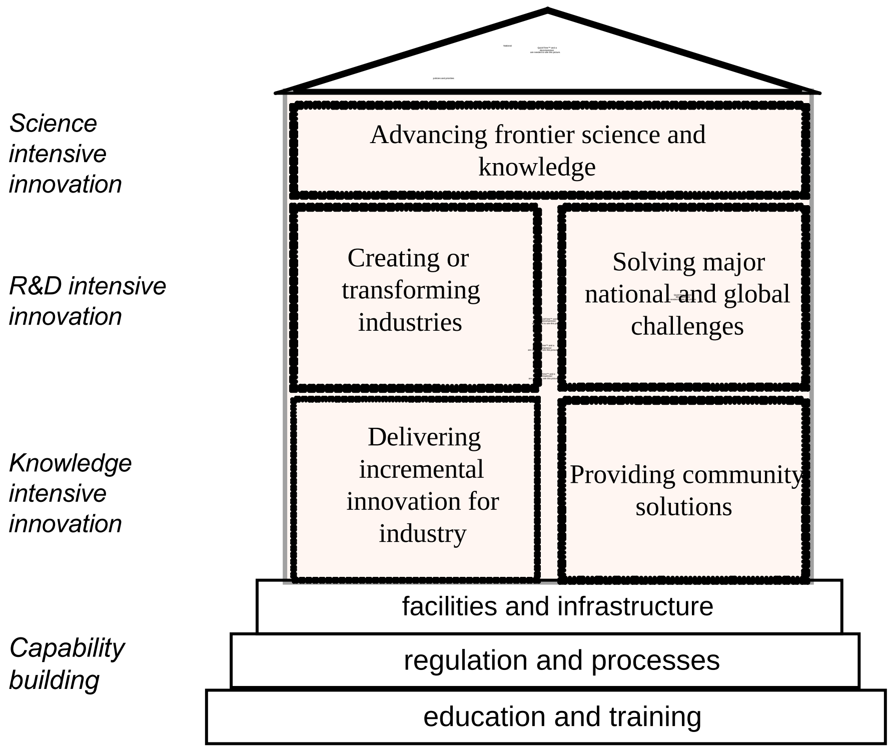
Second, a comprehensive innovation framework will address each of the three innovation horizons. Again, these are mutually reinforcing but each will require its own supporting infrastructure and capabilities.

Roles within a national innovation system

What is the balance between the short-term harvesting of intellectual capital and longer term investment in new capability? What is the balance between "seeds" and "needs", as the American policy makers put it: how much relative effort do we put into new thinking to solve immediate industry needs, compared with effort directed at "seeding" new economic opportunities? These are tough questions. A robust national innovation system will be comprehensive and attend to all the constituent parts that address the various needs of a sustainable economy and society. Investment in innovation both at an institutional and at a firm level will benefit from an explicit portfolio model to underpin decision making, to highlight trade-offs, and to support the identification of the right metrics for assessing risk and return.

Figure 9 provides a portfolio model for national investment planning and capability evaluation. This model has regard to investment horizons (short or long run), purpose and strategic intent, and supporting infrastructure and capabilities.

FIGURE 9: PORTFOLIO MODEL FOR NATIONAL INVESTMENT PLANNING AND CAPABILITY EVALUATION.



Source: adapted from Stokes 1997 and CSIRO

The left hand side of the model is driven predominantly by firm competition in industry markets, although governments may have an interest in growing capability in emerging industries and in promoting wide scale technology and knowledge diffusion. The right hand side is driven by societal needs and development priorities, such as national challenges like health, energy, environmental sustainability, or water use.

This model can be applied to investment planning and decision making at both broad institutional and regional levels.

Roles are not standalone with definitive boundaries; rather they are porous, with high levels of inter-dependence and mutual reinforcement. For example, public funding of science and research to address defence, security, health or environmental challenges can open up new industry and firm level opportunities off the back of new capabilities and breakthroughs.

Key points to note about this model are that:

- specific capabilities and infrastructure will be required for the different roles and there will be different requirements for how this supporting infrastructure is provided and in how it can be accessed;
- different funding models may be appropriate for different roles;
- there will be different issues around intellectual property rights and their management;
- differing models of technology transfer and knowledge diffusion may apply for different roles;
- measures for impact and return on investment will vary according to role; and
- different groups of stakeholders will be associated with each role.

Later versions of this paper will elaborate upon these points and seek to draw out their policy implications.