Dent Associates
Science in Business

Stay Competitive, Stay Sustainable … Stay GREEN

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Knowledge Sharing Forum on Green Innovation: International Best Practice, Dusit Thani Hotel, Bangkok, Thailand - February 21, 2012.

Good Morning I appreciate this opportunity to speak with you this morning and thank you to the STI for inviting me to participate - this is very much appreciated.

Staying Competitive, Staying Sustainable and Staying GREEN is a story … a story of technology, of economics, of knowledge production, of markets and ultimately - the future role of innovation in society. In telling this story I would like to share with you this morning, the progression of ideas and concepts that have influenced my own thinking on these important issues. In doing so I hope to challenge your perspective on **innovation**, what it encompasses, who should be doing it, how it should be done and why being sustainable, - being green - gives us a real opportunity in our search for innovation - to build better relationships between researchers and industry, researchers and society, and industry and society.

I have two key opening points which are that:

- Innovation is universally understood to be the driver of economies and
- Innovation is largely associated with the development of technology

Innovation and particular technology, shapes our very existence whether it is our mobile telephones, computers, credit cards or medicines and drugs. Technology has also enabled travel on land, by sea, beneath the sea, by air and ultimately of course in space.

One of the arguments for investing in an expensive space programme is that the technologies it generates eventually flow through to every day applications in products and services such as health monitoring devices and silver foil blankets to maintain body heat for accident victims. In its long programme of building rockets for space the American National Aeronautics and Space Administration (NASA) developed the concept of Technology Readiness Levels which in the 1980s, helped manage decisions concerning the development and transitioning of technology practise.

The basic NASA scale of TRLs, as they have become known, has been modified over time through use in the space, energy and transport industry as well as the military, with most systems now recognising 9 stages of development. TRLs have the benefit of providing a common understanding of the status of a technology in its development pathway, a means of assessing and managing risk, and decision making concerning funding and implementation of technology. This has led on to the development of Systems Readiness Levels (SRLs), Innovation Readiness Levels (IRLs)

and most recently Demand Readiness Levels (DRL's).

It was just last year that Florin Paun (2011) working with ONERA, the French Space Laboratory, proposed an additional scale to Technology Readiness Levels, the introduction of Demand Readiness Levels (DRL's), to relate to the degree of maturity for the need of an innovation by the market. Importantly Paun saw the use of the two reference systems, one for "Technology Push" and the other one for "Market Pull" combining to provide essential decision making information and to predict the state of implementation and commercialisation of a technology.

I believe there is a great deal of value in Paun's approach, although there is yet scope for refining the definitions used in the DRL scale and I prefer the use of the term "Market Readiness Levels" (MRL's) as a simpler and complementary axis to Technology Readiness Levels. But what Paun's work demonstrates is that it is only as recently as last year that in technological development we really started to consider the need to relate activities to the market place. So while a great deal of effort has been invested in technological research, its funding and its management, as epitomised through the use of TRL's, there has been less emphasis given to understanding of the market into which these technologies may be integrated and taken-up. Market Readiness Levels

and their potential use provide a different, market oriented perspective on innovation and technological development. However, I emphasis that this is a very new development.

Interestingly the TRLs and DRLs describe the two routes to invention which can either be:

Technology/expertise-led or Market/demand-led. However, innovation is most commonly classified according to the work of the economist Joseph Schumpter who at the beginning of last century considered innovation to be radical (or disruptive innovation) which involved major technological change, a massive or big bang impact on the markets and potentially generating high revenues or its opposite - incremental innovation, involving as the name suggests, gradual cumulative changes, which added some additional value to existing processes, products and services but do not leverage staggering levels of revenue.

So far my talk has emphasised technological innovation, largely because this is the way that innovation and its impact on economies is most often viewed. However, there are other types of innovation besides those based on technology.

Innovations that may involve a technological element are usually referred to as product, service or process innovations. So many products and services are derived from technologies. However, there are a range of innovations that are not dependent on technology and these include: Business model innovation, organisational, market and brand positioning innovation, advertising and supply chain innovation.

However - technology based innovation predominates - and the reasons for this are that there are many benefits to technologies.

Technologies are largely science based. Government investment in science through the university structure creates additional benefits - other than just technologies - universities are educational centres, their student populations and purchasing power impacts on the local economy, and their is a perceived high value to increasing the general stock of knowledge created by university research.

Technologies can also be protected by patents allowing industry to maximise investment and gain greatest commercial value from their exploitation. And lastly as we have seen technologies can be disruptive innovation, leading to market domination with new products and services generating great wealth. However, technologies are not alone in their disruptive capacity - the impact and value of non-technological innovations and the transforming nature of non technological innovations such as new business models, supply chain re-organisation can also be disruptive. You only have to think about budget airlines, use of design in branding or on-line shopping to understand the importance of non-technological disruptive innovation.

Conclusions so far:

- Routes to invention may be technology/experise-led or market-led
- There are a whole range of different types of innovations that have economic value
- Technology has dominated our approach to innovation because this is seen to be more likely to lead to disruptive - big bang - products and services
- Non-technological business models, brands and supply chains also have proved to be disruptive creating - big-bang – product and service opportunities

Economic growth

Scientists are largely unaware that they owe the continued investment made by successive governments into the science and research base to the American economist Robert Solow, the 1987 Nobel Laureate in economics. In the 1950's Solow formulated a theory of economic growth that emphasised the importance of technology. He argued that technology is the main factor responsible for growing an economy over the long term. Since scientific research underpins the development of technology, the work of researchers is seen to be crucial for economic growth. However, recent analyses would suggest that the link between economic growth and formal scientific research might be more tenuous than previously thought and, while this may be perceived by some as a threat to the science base, it might better be viewed as a whole new opportunity for the University sector in widening the skills and disciplines involved in innovation.

The overwhelming consensus is that long term economic growth is dependent on technological innovation, and this is most commonly expressed in terms of the investment made in research and development (R&D). This belief is supported by some empirical evidence and simple regression models such as those that positively relate cross national Gross Domestic Expenditure on R&D (GERD) and the level of development measured by the GDP per capita. However, there are many factors that are omitted in regression analyses of this kind and so, even though they are sometimes highly correlated, this is not necessarily indicative of a causative relationship; R&D indicators could just be acting as a proxy for a range of other influencing factors.

Robert Solow's research in 1956 on growth accounting, was based on models called Exogenous Growth Models and these led him to the conclusion that labour productivity and capital deepening accounted for as little as one eighth of the growth in the US economy between 1909-1949, the residual - the majority of growth, he attributed to technical change. On the basis of this work governments around the world invested heavily in universities and research institutes to promote technological development.

However, there were some economists who were concerned that technological change appeared to contribute far too much to economic growth - but it was not really until the 1980s that economists turned to the use of endogenous growth theory in order to be able to challenge the basic premise.

Endogenous growth theory holds that economic growth is primarily the result of factors over which some control may be exerted through government policy. Hence, government can use policy measures to influence R&D and long-term growth, and from which there may also be externalities or spill-over effects that have a positive impact on the wider economy. For example, investment in university R&D in order to develop technologies, also facilitates improvement in education and hence, the quality of labour, as well as contributing to the overall stock of knowledge with wider benefits for society.

Using endogenous growth models Diego Comin in the US in 2004 demonstrated that less than 15% of economic growth in the USA could be attributed to investment in scientific R&D. More recently between 2007-10 Argentino Passoa demonstrated that R&D investment in OECD countries contributed less than innovation in marketing, design, organisational change and new production facilities. These models went on to show that successful companies were those that invested more in R&D than those that didn't. And across all companies, volatility (variability of success) was dependent on the availability of non-technological innovations.

From a government perspective these studies present a scenario whereby it might be possible to achieve a larger positive impact on economic growth through supporting policies that encourage research that will lead to non-technological innovations rather than traditional science-based technological innovation through conventional R&D. In addition, developing policies that encourage individual companies to invest in R&D will also have a significant impact.

Conclusions so far:

- Routes to invention may be technology/expertise-led or market-led
- There are a whole range of different types of innovations that have economic value
- Technology has dominated our approach to innovation because this can lead to disruptive - big bang - products and services
- Both technological and non-technological innovations are crucial for economic growth
- Non-technological innovations contribute more to the general aggregate of economic growth than technological innovation

Knowledge Production Systems

From the perspective of a government dependent on innovation to drive economic growth, a knowledge production system based on the following principles and attributes would seem ideal:

1. a problem-based approach delivering innovative solutions and applications of assured economic value and impact within a relevant definable time frame
2. operating freely across, and applicable to, any and all fields of human endeavour for which there can be derived a measurable economic or social benefit
3. engaging with and utilising the broadest range of skills, know-how and experience from all available practitioners
4. flexible, responsive and able to deliver to, and for, a wide range of economic conditions and circumstances i.e. offering resilience
5. wholly transparent, accessible and accountable to society

Such an ideal knowledge production system differs quite markedly from that currently existing in many parts of the world - including the UK.

Knowledge is often divided into two categories "Academic" and "Applied" where

"Academic" knowledge may be considered as authoritative, objective, and universal knowledge which is abstract, rigorous, timeless – and difficult . It is knowledge that goes beyond the here-and-now knowledge of everyday experience to a higher plane of understanding. Academic knowledge generated through basic scientific research is usually driven by the desire to answer specific scientific questions. This basic research - variously called "fundamental", "pure" and "blue skies" research, is highly regarded and is epitomised by the mantra of "scientific excellence" a belief in the delivery of knowledge for sciences-sake in order to enhance and build upon the stock of global scientific knowledge. Scientists careers in different disciplines are advanced by peer esteem through the publication of scientific work in respected, highly cited journals and essentially this is the force that drives additions to the scientific knowledge stock. The information is openly available to the world's scientists to scrutinise, use and build upon, the ability to answer scientific questions with scientifically useful answers. The direction the research takes is not guided by any process other than the need to be leading edge, high quality science, recognised and supported through peer-reviewed publications and grant awards. In marked contrast to "Academic" knowledge there is "Applied" knowledge.

“Applied” knowledge is usually considered to be practical knowledge that is produced by putting academic knowledge into practice. It is gained through experience, by trying things out until they work in real-world situations, which may include incremental change through worker experience, trial and error, and practical knowledge of how to get things done.

The direction the work takes is determined by what works, as judged by those it most affects.

These differences between “Academic” knowledge and “Applied” knowledge are representative of the attributes of two modes of knowledge production - so called Mode 1 and Mode 2 knowledge production; terms first coined by Gibbons *et al.* (1994) in a book called the *New Production of Knowledge*, in order to describe the shifts occurring internationally in knowledge production. Mode 1 knowledge refers to that largely generated in an academic context, based on disciplines of research (e.g. Food Science and Technology, Endrochrinology, Neurobiology, Pharmacology) carried out in our universities and research centres and measured for its effectiveness through peer review and citation indices. In contrast to Mode 1 (but potentially also embodying it), Mode 2 knowledge is generated in the context of application. Of course Mode 1 knowledge can also result in practical applications, but these are always separated from the actual knowledge production in space and time. This gap requires so-called knowledge transfer. Other attributes of Mode 2 Knowledge Production include its transdisciplinarity, heterogeneity, reflexivity and novel means of of quality control.

For the moment I wish you to take note here that social accountability is important in Mode 2 Knowledge Production and then I would want to just talk a bit more about two other key aspects of Mode 2 Transdisciplinarity and Novel Quality Control.

Transdisciplinarity refers to the mobilisation of a range of perspectives and practical methodologies to solve problems. Transdisciplinarity goes beyond what we normally think of as interdisciplinarity, in the sense that the interaction here is much more transitory and dynamic. Once a consensus is attained, disciplinary parts become less relevant and even unrecognisable as research results diffuse to context of the problem and its practitioners. This is partly achieved because Mode 2 Knowledge is produced in a heterogenious array of organisations including not only the traditional universities, institutes and industrial laboratories, but also contract research organisations and charitable organisations, think-tanks, high-tech spin-out companies and consultancies as well as through individual inventors and entrepreneurs. Trends suggest that such organisations may be linked through networks of communication, and research is conducted in mutual interaction related to a particular problem. Movement away from traditional knowledge production institutions with their monopoly on knowledge and its generation, towards a wider range of protagonists who may be more integrated and accountable to society, should ensure knowledge production that is sensitive to its impact in society - which is built-in from the start.

Traditional quality control in knowledge production is achieved through discipline-based peer review systems. Peer review is used in the assessment of scientific papers for publication and for deciding on grant funding for scientific projects. In Mode 2 the trends are that these systems of review may be supplemented by additional criteria of economic, political, social or cultural nature. Due to the wider set of quality criteria, ‘good science’ has a wider meaning, since this is no longer limited to the judgement of disciplinary peers. However, this does not imply that Mode 2 research is generally of a lower standard.

Mode 2 is close to an Ideal Knowledge Production System: Firstly Mode 2 is a problem-based approach and if the problem is set so as to generate solutions of potential economic or social value, then the science base could be directed to deliver to that need. Mode 2 addresses the concept of transdisciplinarity - engaging across all aspects of human endeavour (science and the humanities) as well as utilising all available skills and know-how from any source (formal scientific research institutions to more informal bodies e.g consultancy companies) to ensure that solutions are generated. The need for transparency, accessibility and accountability to society is built into Mode 2.

Such an approach however, does require a major change in emphasis so that the science becomes less of a driver of innovation relative to the market. This is largely because by taking a problem-solving approach one has to know what the problems actually are, and to identify these there is a need to look to the market. For each sector there would be a need to identify market gaps and opportunities, in each case defining the parameters of the gap and the specifications of the solution.

Vast financial resources are spent on scientific research and the development of technologies but next to nothing is spent on research to understand the markets, the gaps and the opportunities to which the technologies are meant (at some distant point in time) to apply, and this would need to change in the adoption of an explicit Mode 2 Knowledge Production system.

Conclusions So Far:

- Routes to invention may be technology/expertise-led or market-led generating innovations which have economic and social value
- In the search for disruptive innovation and large impact technology based products and services has meant non-technological innovations tend to be ignored
- Non-technological innovations contribute more to the general aggregate of economic growth than technological innovation
- Principles of an ideal knowledge production system can be defined based on the economic and social needs of a nation
- Knowledge may be academic (with Mode 1 Knowledge Production) or applied (with Mode 2 Knowledge

Production)

- The Characteristics of Mode 2 more closely fits an ideal knowledge production system
- Mode 2 requires a major change in emphasis with wider engagement of society with science and its institutions, including peer review, which means "the Market" (people, society and its needs) will have a greater role in determining priorities and targeting of innovation.

Markets

Understanding markets is all about understanding the people, the industry, the products and services, their manufacturers, suppliers, distributors and sellers, how they organise themselves and how they advertise, market, sell and deliver to consumers. In understanding all of this, it becomes easy to see how the market if properly researched can set the scientific and technological agenda, how the approach to solving the problems will involve a diverse range of organisations, how it will be transdisciplinary in approach, how social accountability is built in from the start and how quality control will be dependent on delivery of solutions meeting the exacting standards of all players. Thus the market comes into play in innovation, in the same way markets drive other areas of life - in fact one wonders why science and technology has been exempt from this all pervading rationale to date. With an explicit commitment to Mode 2 Knowledge Production through government science and innovation policy, the way would be cleared to place the market at the centre of innovation, and ultimately, the potential economic benefits that would accrue from such an approach.

Markets tend to be thought of as the province of business and are often viewed in terms of just potential customers and business competitors.

On this basis market research is undertaken by business to provide key information to identify and analyze the market need, market size and competition from a business perspective.

I would like to talk about something slightly different which is "Market Research for Innovation" - which is the study of a market sector and any gaps, opportunities and trends within it for use in the prioritisation and targeting research activities to create innovations of commercial and societal value.

Generally at present we think of science generating innovations which through technology transfer offices of universities are transferred to industry who adapt the technology to meet market needs. The system can often fail because a technology may be an excellent technology but if there is no market for it then it is a wasted technology. If a "Market Research for Innovation" capability is established as a conduit between the University or research institute and industry this can serve the interests of both parties. Universities will have more information about the nature of gaps and opportunities in the market place, the type of solution required which can guide their research. Industry will benefit from market intelligence and technologies or other business solutions, which are more closely geared to their market requirements.

Market Research Techniques

Market research techniques are about understanding the people, the industry, the products and services, their manufacturers, suppliers distributors, sellers - their organisation, advertising techniques, marketing methods, selling techniques and means of deliver to customers was once difficult to achieve but now with advances in the:

- International standardisation of data collection and benchmarking
- Availability of extensive public and private data sources
- Publication of company information on websites
- Computational, profiling and analytical techniques

It is much much easier.

These advances have enabled sophisticated market research techniques to be developed to inform target opportunities and priorities for innovation and these include: technology tracking, patent landscaping, market-led innovation gap analysis, activity specific market transaction analysis - providing information not available even five years ago.

What this means is that it is now possible to collect vast amounts of data cost effectively and with available computational techniques to drill down to understand the minutae of activities in the markets. By way of example a UK company with whom I work closely, called K-Matrix, is unique in its ability to access over 10 thousand company templates for performance profiling, 100,000 different data sources and over one million business case studies - from which they can triangulate for any one of thousands of business activities in order to determine transaction volumes and value. My company Dent Associates, has complementary expertise with even more detailed datasets allowing us to identify existing gaps in markets against cross-sectorial templates.

Each gap identified can generate Market Opportunities which are solutions with commercial value that can be:

- a technological solution leading to a new product, service or process
- a new business model
- a novel means of delivery
- a re-organisation of a supply chain
- a new brand and so on and so forth.

This is all based on the ability to create a template of business activity which is developed much like a biological taxonomic system. There are different levels of complexity in each of the 8 levels of the taxonomic template, including 8 Business Forms, 5 Business Processes, 24 Business Models, use of the thousands of categories in the Standard Industrial Classification (SIC) Codes of Products, 7 Primary categories of Service and 90+ sub-categories, 18 Promotional & Marketing Models and Processes, 30 Advertising Models and Techniques and 4 Primary categories of Supply Chain

Benefits of Market-led Innovation

The benefits of market research for innovation is that:

- Any technologies developed based on its outputs enter a pre-defined market gap (increasing success in, and speed to, market),
- An identified problem is matched with the most effective solution whether technological or non technological
- It can engage a wider range of individuals, inventors, innovators and institutions
- The market research for innovation can bridge the gap between academia and industry

Conclusions So Far:

- A more balanced research approach between technological and non- technological innovation will contribute most to economic growth
- Knowledge Production Systems affect the type of knowledge generated and an "ideal" knowledge production system based on a nation's needs is possible
- Wider engagement of society with science and its institutions, and a lead from "the Market" in defining priorities and targeting of opportunities for innovation is also possible
- The latest Market Research Techniques inform the development of new technological or non-technological solutions for industry and society

So given all of this, what is its relevance to the sustainability agenda and to green economics?

Sir John Beddington the UK Government Chief Scientific Adviser argues that we have a "Perfect Storm" brewing in the combination of World Population Growth, Climatic Stress, and the need to preserve the environment while addressing water shortages, reduction in land available, increasing urbanisation, and food security.

Green Innovation has to address the issues of:

- Generation of renewable energy and more efficient use
- Sustainable management and use of water
- Waste management and recycling
- Reduction of greenhouse gases
- Sustainable food production

I believe the characteristics of the Perfect Storm make it likely that change will be possible in the way we innovate, produce knowledge and direct our research through more market oriented approaches because:

- The problems impact upon everyone in everyday life
- Problems impact on every single business
- Solutions need not be technical or technology based
- Green Innovation is open to every individual, inventor, scientist, entrepreneur and business
- The need for green innovation is not going away and will continue to grow with time

Hence we need to redefine and create a new practical relationship between:

- industry and society,
- society and science,
- science and industry
- and the market and the nature of innovation - a new paradigm

The relationship between Industry and society will change because the "Perfect Storm" is going to affect everyone on an equal basis, whether as an employer, employee, a consumer - we are all affected and we can all act to do something about it, both in our workplace and in our homes. Addressing issues of sustainability will allow businesses to reduce their costs, making them more competitive. A new focus on the development of sustainable products for the consumer will create business opportunities based on product maintenance, repair, recycling, refurbishment and manufacture on demand for a much wider range of products.

The relationship between Society and Science will change because of the nature of sustainable energy use, water use and waste management - we are all intimately aware of the problems and with all of our individual creativity, solutions will come from many different sources. Our scientific community will need to be open to this and embrace participatory engagement of society in science and innovation. The science of sustainability must not be something done in isolation by an elite few, but will become something in which everyone participates and contributes. There will inevitably be a greater movement towards involvement of the public in determining the direction of science and innovation and assessment of its value and impact to society.

The relationship between Science and Industry will change because of the need to find common cause and means of communication in delivering solutions that impact positively on society. This can be achieved through putting the market for innovation at the centre of their relationship. Through this relationship innovation will be better directed to the quicker delivery of technological and non- technological innovations relevant to the market and consumers needs.

Stay Competitive, Stay Sustainable ... Stay GREEN

Nations wishing to stay competitive and to stay sustainable need to embrace being Green - because it represents a new paradigm for innovation that will benefit science, industry and society - and ultimately our children's children.

Thank you.

Acknowledgements

Dr Brian Pettit, Chilworth Consultants UK
Professor Mike Theodorou, Durham University