18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009
http://mssanz.org.au/modsim09

Global Green System of Innovation: Technological Wave or Policy?

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Abstract: In the tradition of technological innovation waves (modelled following Kondratieff's long waves hypothesis), the paper explores the emergence of the 6th technological wave associated with the development of new technological classes, such as renewable energy and nanotechnology. Based on 1975-2007 data from the US Patent and Trademark Office (USPTO), it analyses the emerging patterns in these two classes of sustainable technologies. The surge in activities related to nanotechnologies is in contrast with a much lower interest in inventions related to renewable energy technologies. The paper argues that left on the national and sectoral innovation systems existing around the world, it is unlikely to see a fast uptake of technologies that help mitigate or adapt to the imperatives of climate. On the other hand, the scientific evidence on the impact of CO_2 on the earth's atmosphere calls for immediate actions and would not allow enough time for the global community to ride the 6th technological wave. Urgent policy measures are needed to speed up the process of technology development and as distinct to any other period in the history of technology development, these actions need to be taken at a global scale. The paper puts forward the need for a global green system of innovation (GGSI) that represents community values and encourages sustainable behaviour.

Keywords: *Climate Change, Global Green System of Innovation (GGSI), Sustainable Development, Sustainable Technology*

1. INTRODUCTION

The patenting system which has been in existence for more than 200 years in the Western world (Marinova et al., 2005) is an example of the mechanisms that society has put in place to protect and encourage innovation. The purpose of having a patent system is on the one hand, to promote the advancement of technologies for the overall benefit of society and on the other, to reward the individual inventors with exclusive rights that allow purely economic benefits from these technological advancements. Despite numerous concerns as to whether patenting really advances innovation (e.g. Cohen et al., 2000) and what are the ethics behind it (e.g. Caulfield and Gold, 2000; Marinova and Raven, 2006), the last two decades have witnessed an unprecedented heave in patenting activities, particularly in the US (Gallini, 2002). This country is by far considered the largest and the most technologically advanced market in the world and hence particularly attractive to people and companies with new ideas. According to Gallini (2002:131), "(e)very major industrial sector has been represented in this surge in activity". Furthermore, patenting in the US by foreign inventors is highly informative of current and emerging technological trends (e.g. Marinova and McAleer, 2003) and has been extensively used since the late 1980s to describe innovation activities (e.g. Pavitt, 1988; Acs and Audretsch, 1989; Archibugi and Pianta, 1992).

A major concept in technology development which is highly related to patenting is that of technological trajectories. They are based on the notion of a technological paradigm, namely "a 'pattern' of solutions of selected technoeconomic problems based on highly selected principles derived from the natural sciences, jointly with specific rules aimed at acquiring new knowledge and safeguarding it, whenever possible, against rapid diffusion to the competitors " (Dosi, 1988: 1127). Within the technological paradigm, certain clusters of technical solutions become dominant over a period of time and guide the majority of innovative ideas (Marinova, 2008). The steam power played such a cluster role in the late 19th century; computers and digital networks are dictating the majority of technological answers nowadays.

Dosi (1982), Freeman and Perez (1988) point out that over the period of time when a certain technological paradigm is dominant, innovations tend to happen along technological trajectories which follow more or less a Bell distribution curve (see Figure 1). At the early stage of the trajectory, the number of new technologies is relatively small but as the paradigm is adopted in full force the inventions keep coming (many of them improve or replicate earlier innovations) until they reach a level of stabilisation and then slowly vanish. It is also argued that technological trajectories determine firm-level innovations (Souitaris, 2002) and they can be used to forecast future markets (as is the case with mobile phone Internet in Funk, 2005). The period when the innovative activities along the old technological paradigm start to disappear is also the time when a new technological paradigm is being born. This is manifested by the emergence of a new cluster of technologies as well as their supporting organisations, infrastructure, services, regulations and government policies.

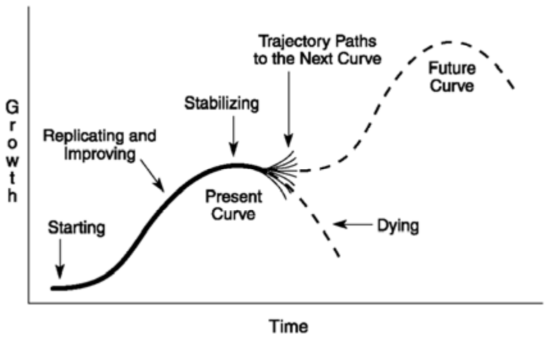

Figure 1. Technological trajectories
Source: Abraham and Knight (2001)

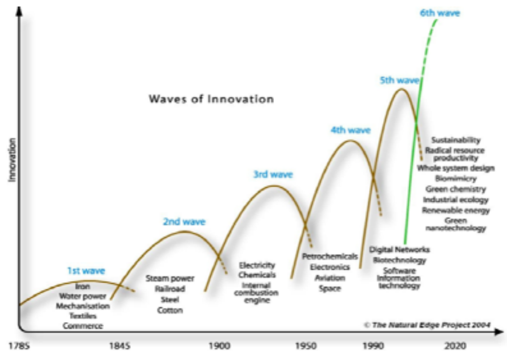

Figure 2. Innovation waves
Source: Hargroves and Smith (2005)

The history of technology shows that since the late 18th century we have experienced 5-6 such significant major technological trajectories which in the tradition of Kondratieff, economists starting with Schumpeter (1939) describe as waves of innovation (e.g. Perez, 1985; Bessant, 1991; Tylecote, 1992; Freeman and Soete, 1997; Devezas, 2006). According to Lynch (2003), each wave represents technological solutions to problems that once were thought intractable. Aligned with the dominant technologies of the wave are methods of production, socio-institutional frameworks, government policies, political and economic organisation of society (Perez, 1983; Tylecote, 1996). Despite the debate in the literature as to whether there is empirical evidence to support the hypothesis that particular clustering of basic innovations have triggered the long waves in economic development (e.g. Kleinknecht, 1990; Silverberg and Verspagen, 2003), history shows that particular groups of technologies have completely dominated economic development over extended periods of time. Even without causality being statistically proven, there is plenty of evidence that society relies on these groups of technologies and builds the appropriate structures and organisations to support them.

The current 5th wave is associated with the development and uptake of information and digital technologies as well as biotechnology and the new media (see Figure 2). These technologies foster economic activity and fuel productivity growth, provide employment opportunities and transform educational needs, they require new infrastructure, social institutions, governance, legislation and policies. The Internet has been the best manifestation for the dominance and pervasiveness of the 5th wave technologies. However while these technological clusters are still going strong, there are also important signs that the 6th wave has already begun. Many analysts associate it with the development of sustainable technologies (e.g. Hargroves and Smith, 2005; see also Figure 2).

The aim of this paper is to examine basic evidence, namely patented inventions in the US, as to whether there is clustering of innovations in several groups of what can be considered sustainable technologies. If we are already witnessing upward trends in the new technological trajectory, this would mean that society is soon to get the maximum benefits from these technological developments. If this is not the case, then the new wave of innovation would still be in its infancy.

There is however a major difference between this new technological wave and any of the previous waves in history. The triggers and reasons for technological development until now have always been linked to improving the quality of life for humans. They have been anthropocentric and have relied on human ingenuity and capacity to invent in order to satisfy human desire for better living conditions, health, social interactions, meaningful employment and recreation. There have been some restrictions and debates as to what is morally and ethically acceptable but the health of the planet Earth on which we all live has not been until now the main driving force behind technology development. The current wave is focused exactly on this issue of enormous importance.

In addition, time constraints over technology development have so far been imposed mainly by market forces and the desire to reap maximum benefits. The urgency for technological change under the new wave is triggered by the fact that the planet Earth has reached its capacity to absorb human generated pollution and needs a drastic change in the ways of production and living espoused by humanity. Can we see the new wave contributing towards such fast shifts? What else can be done to speed up the process?

The section to follow presents the empirical patent-based evidence. This is followed by analysis of the climate change science findings and the policy environment. The final section outlines the need for a major shift in thinking about innovation towards a global model which fosters the development of green technologies that are potentially the only way to restore and preserve the health of our planet and all the species on it.

2. SUSTAINABLE TECHNOLOGIES

The nature of sustainable technologies us such that they simultaneously and synergistically include environmental considerations, market profitability and social accountability (Marinova, 2005). They require an understanding of the interactions between technology and the social, ecological, economic, cultural, political and governance systems within society. The paper explores the development of three groups of such technologies using the patenting patterns in the USA, namely renewable energy (patented solutions in solar, wind, wave, tide, geothermal, hydro and biogas energy technologies), nanotechnology and electric vehicles.

The choice of renewable energy technology is not surprising given that fossil fuels are being proven to be the main cause for the constantly increasing levels of greenhouse gas emissions in the earth’s atmosphere (IPCC, 2007). Nanotechnology on the other hand is considered inherently environmentally friendly because it has the potential to reduce the total volume of material per product function (less material waste); to reduce energy costs during the use-phase of products; allows for efficient energy conservation and storage and also includes nanoscale processes for environmental improvement, such as screening, treatment, remediation, benign manufacture, used in solar and fuel cells (Phoenix, n.d.). Despite these positive characteristics, the Centre for Responsive Nanotechnologies raises the following concerns about their sustainability (www.crnano.org/dangers.htm): there is the possibility of economic oppression from artificially inflated prices; personal risk from criminal or terrorist use; personal or social risk from abusive restrictions; social disruption from new products and lifestyles; unstable arms race; environmental damage or health risks from unregulated products; free-range self-replicators; and black market in nanotechnology. The list can be expanded to include further possible environmental damage, such as nanoscale contamination of water and air, and as with most types of technologies their development and application will depend on the policy decisions and moral value held within society. Therefore the environmentally friendly applications are also described as green nanotechnology; however the line that distinguishes them is often very blurred. By comparison, if economically viable renewable energy technology (excluding nuclear energy) is unquestionably sustainable.

Although not specifically singled out as a 6th wave innovations, electric vehicles are closely associated with developments allowing a shift towards renewable energy technologies. In fact, electric vehicles are a product of the previous innovation waves and were selling well at the start of 20th century until around 1918 when they were replaced by the gasoline powered cars (Chan, 1993). Unlike internal combustion engines, electric vehicles, which include the whole range of cars, trains, buses, trucks, boats, scooters, motorbikes and airplanes, operate on electricity that is either being stored (e.g. in a battery) or generated (e.g. fuel cells or flywheels). With the advancements in electronics, materials, battery storage and design, nowadays electric vehicles can in many ways be technically superior to their internal combustion counterparts as motor torque generation is fast, accurate and can be known precisely (Hori, 2004). However, the source of energy used to propel the vehicle could be of any source depending on the design of the vehicle. This ranges from solar cars to diesel-electronic locomotives to nuclear powered submarines. Various combinations of energy sources are also possible as evident in the case of hybrid cars. Hence, similar to nanotechnology electric vehicles can be a powerful 6th wave technology as long as they are based on the use of renewable energy.

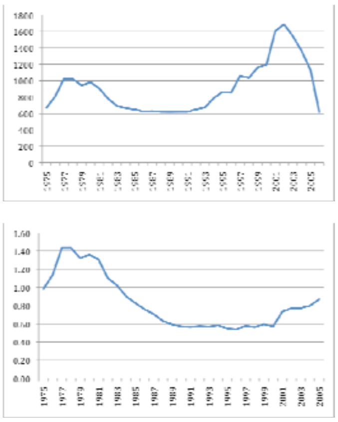
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Figure 3. Renewable energy patents, 1975–2006 (by date of application, as at 25.04.2009): a - numbers; b - relative shares (%)

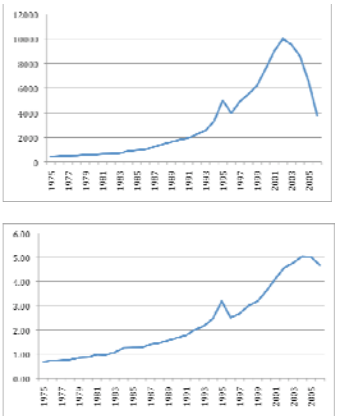
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Figure 4. Nanopatents, 1975–2006 (by date of application, as at 25.04.2009): a - numbers; b - relative shares (%)

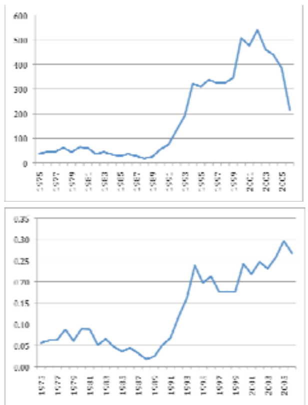
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Figure 5. Electric vehicles related patents, 1975–2006 (by date of application, as at 25.04.2009): a - numbers; b - relative shares (%)

The other groups of 6th wave technologies, namely green chemistry, industrial ecology, biomimicry (and more recently, ecomimicry, see Marshall, 2007), require similarly conceptual shifts from the way we have been using and treating the natural environment to applications that are more sustainable. At this stage, they are difficult to capture through patent counts. In fact, a keyword search of the US Patent and Trademark Office reveals only 84 green chemistry patents registered (the first one lodged in 1997), seven in biomimicry (the first one in 2000) and two in industrial ecology (in 2004 and 2007).

Despite the many concerns about the patenting system (e.g. Edgerton, 2006) and many recommendations for its improvement (e.g. Merrill and Levin, 2004), it remains one of the best sources (if not the best source) of information available about new technology development. Its growing importance within society is manifested with the larger and larger numbers of new applications and consequently new patents issued The Patent and Trademark Office in the US (USPTO) alone receives more than 300,000 of patent applications per year (Merrill and Levin, 2004). Patent information has been extensively used to describe innovation activities and new trends in technology (Pavitt, 1988; Acs and Audretsch, 1989; Archibugi and Pianta, 1992).

This paper uses patent data from the USPTO for the 1975-2006 period (by date of patent application) retrieved on the basis of key words, to describe trends in patenting technology related to renewable energy (excluding nuclear energy), nanotechnology and electric vehicles. The renewable energy patents cover technical solutions in solar, wind, wave, tide, geothermal, hydro and biogas technologies.

A patent is identified as belonging to the class of renewable energy if the key words (or truncated key word expressions) related to the range of renewable energy technologies are found in the patent's title, abstract, description or claims. Similarly, a patent is identified as covering nanotechnology if a truncated key word expression containing "nano" (but not nanosecond or nano.) is found in the patent's title, abstract, description or claims; and related to electric vehicles respectively with a key word expression containing electric vehicle, car or automobile.

The analysis of patent trends as presented in the US market (see Figures 3, 4 and 5) shows that there is evidence for the 6th wave to be associated with the raise of nanotechnologies, however the uptake of renewable energy is very slow. As the potential applications of nanotechnology are across all sectors, there is not enough evidence yet for a green, i.e. environmentally friendly, 6th technological wave to be occurring. There is also a recent surge in patenting related to electric vehicles but the relative numbers are still very low. From all countries, Japan is performing the best and is dominating all of the three technological groups. In many ways the patent system is one of the fundamental mechanisms that support the market economy. The evidence presented here points to the fact that the market economy is failing to endorse the new wave and if left to it alone would take dozens of years before it reaches the intensity of inventiveness required for it to become the dominant technological behaviour. In other words, the market is not supporting the new wave.

3. POLICY ENVIRONMENT

In order to encourage such innovative behaviour, many governments have particular policies and institutions (including enterprises, universities and research institutes) in place which in their complexity are known as national innovation systems. This is particularly the case in Japan (Freeman, 1988). According to Scott-Kemmis (2004:1), the national innovation system describes the levels of "investment in innovation, the roles of the public and private sectors, the industries and technology fields of greatest importance and the rates of change in those patterns, the level of cooperation among organisations, the modes of financing innovation, attitudes to risk taking, the regulation of the labour market and the role of large and small firms". However, what is needed in the current climate change imperatives are not just national systems of innovation but super-national policies and innovation systems that can encourage the uptake of the green technologies.

The scientific evidence provided by the Fourth Assessment Report of the IPCC (2007) shows record warm temperatures on Earth together with increased incidents of weather calamities. Similarly, a faster raising sea level is being observed in recent years. The expectations are for these trends to continue. Other long-term detected phenomena include "changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones" (IPCC, 2007:5). The report also points the finger at humankind as the main culprit for these changes: "Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" (IPCC, 2007:8).

The 2006 Stern Review in the UK which examined the economics of climate change demonstrated that it will be cheaper for society to act on reducing greenhouse gas emissions now rather then postpone this to future generations. Despite the evidence from science and economics, we are yet to see serious changes. The Australian 2008 Garnaut Report characterises the current international political environment where measures for arresting climate change need to be taken as captured in a "diabolical" problem that can only be resolved through collaboration.

Such cooperation has started to appear in sections of the market (as witnessed in the patent trends) and in government (as manifested in the Carbon Reduction Trading Scheme in Australia and the $150 billion climate change package introduced by the new US administration) but this will not be enough to trigger the new technological wave. There is a need for a global innovation system in which all countries, including China, India, Brazil and Russia, endorse a vision for a greener world. The developing world should not be seen as the problem as there is ample evidence that these countries are on the right track in their efforts to integrate economic prosperity with social advancement and protection of the natural environment. Under the constant pressure for energy demand from its fast growing economy, China is likely to soon turn into renewable options at a mach greater scale. Although still centralised, China's innovation system is very much geared towards practical applications with fast economic outcomes. India is already a global research and development centre for major international corporations. The government has played a major role and in most cases singularly in the development of India's innovation system and it is hoped that this huge potential will soon translate into important renewable energy solutions.

A global green system of innovation (GGSI) for climate change response would require reassessment as to how things are being done currently and a move towards a faster development and application of sustainable technologies. A move towards such a global innovation system is already happening with the recently released United Nations Environmental Program's report "A Global Green New Deal" which sees a recovery from the current global crises of food, fuel and finances by taking up this opportunity to reduce carbon dependency (Barbier, 2009). The report also suggests a list of international actions that can help make the Global Green New Deal a reality.

4. CONCLUSIONS

The empirical evidence from patenting related to renewable energy and electric vehicles technologies in the US shows that the 6th wave of innovation is only in its infancy. Nanotechnologies (which have the potential to be sustainable) are surfacing as the main trigger of the new technological wave. They however cannot cause the change of behaviour and direction that is required to respond to the urgency and imperatives of the anthropogenically induced climate change as energy technologies are the ones that are mainly responsible for the large greenhouse emissions. Left to the individual countries' innovation systems, as it has been the case until now, the world will be facing with the impossible solution of a "diabolical" problem with no precedence in human history. Cooperation can be the only way to resolve the inherent conflicts and weaknesses of the market and governance.

In order for such collaboration to happen, a super-national or even global climate change innovation system is needed which will combine the power of science, research and development with the financial institutions across societies and attitudes towards risk. It will generate the skills and labour force that can implement this new vision across all sectors of society in individual countries, including industry, government and education. The determining factor for climate change innovation to be endorsed globally and become the new 6th wave of innovation is for community to adopt a vision for a sustainable world. This will translate into changes in values and everyday practices as well as in a surge of activities in relation to patenting human inventiveness to support the transition towards a more sustainable future.

ACKNOWLEDGMENT

The author wishes to acknowledge the financial support of the Australian Research Council.

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