”Knowledge Creation Through National Innovation Systems”

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Keywords: National innovation systems, knowledge, networks, value measurement

Abstract. With increasing globalization, countries need to foster innovation in order to stay competitive on a global scale. To Western countries in particular, this is a pressing issue since they cannot compete with low cost labour provided by countries such as China and India. A key element to competitiveness in the knowledge based economy is “interconnectedness” or linkages. The nation that fosters an infrastructure of linkages (networks) among firms, universities and governments, gains competitive advantage through quicker information diffusion and product deployment. That is, nations need National Innovations Systems. This paper compares national innovation systems in Finland, Sweden and Australia, investigating the critical success factors and key ingredients of such innovation systems.

Introduction

With increasing globalization, countries need to foster innovation in order to stay competitive on a global scale. To Western countries in particular, this is a pressing issue since they cannot compete with low cost labour provided by countries such as China and India. According to the OECD, innovation is the key driver for economic growth in developed countries with at least 50 per cent of growth directly attributable to it. Furthermore, growth in the world economy will be increasingly dominated by knowledge-intensive goods and services. A key element to competitiveness in the knowledge based economy is "interconnectedness" or linkages. The nation that fosters an infrastructure of linkages (networks) among firms, universities and governments, gains competitive advantage through quicker information diffusion and product deployment. That is, nations need National Innovations Systems. This paper compares national innovation systems in Finland, Sweden and Australia, investigating the critical success factors and key ingredients of such innovation systems.

Definition

There is no single definition of national innovation systems (NIS) but a semantic core appears in most of the definitions present in innovation literature (Freeman, 1987; Lundvall, 1992; Nelson and Rosenberg, 1993; Edquist and Lundvall, 1993; Niosi et al., 1993; Patel and Pavitt, 1994; Metcalfe, 1995). The majority involve linkages, institutions (funding and R&D; private and public) and knowledge diffusion in one way or the other. For the purpose of this paper, national innovation systems (NIS) will be defined as "the network of institutions and economic structures in the public- and private-sectors rooted inside the borders of a nation state whose activities and interactions initiate, develop, import, modify and diffuse new and economically useful knowledge and technologies". The unit of analysis of innovation system does not have to be a nation but can be a region so long as there is a cultural homogeneity (Lundvall, 1992) and a critical mass.

The Role of National Innovation Systems

Nations can take deliberate action to shape the character and results of their NIS. Interrelationships between public policy makers and regulators and with other players in the economy, e.g. R&D bodies, education, technology and infrastructure institutions and private firms and financiers need to be enabled and encouraged. The challenge for policymakers is to develop policies which aim to identify relevant complementarities between firm and country-specific advantages and disadvantages. Rather than simply trying to attract foreign direct investment (FDI), policies should aim to be selective by positively discriminating towards those investors whose strategies and organisations complement national advantages.

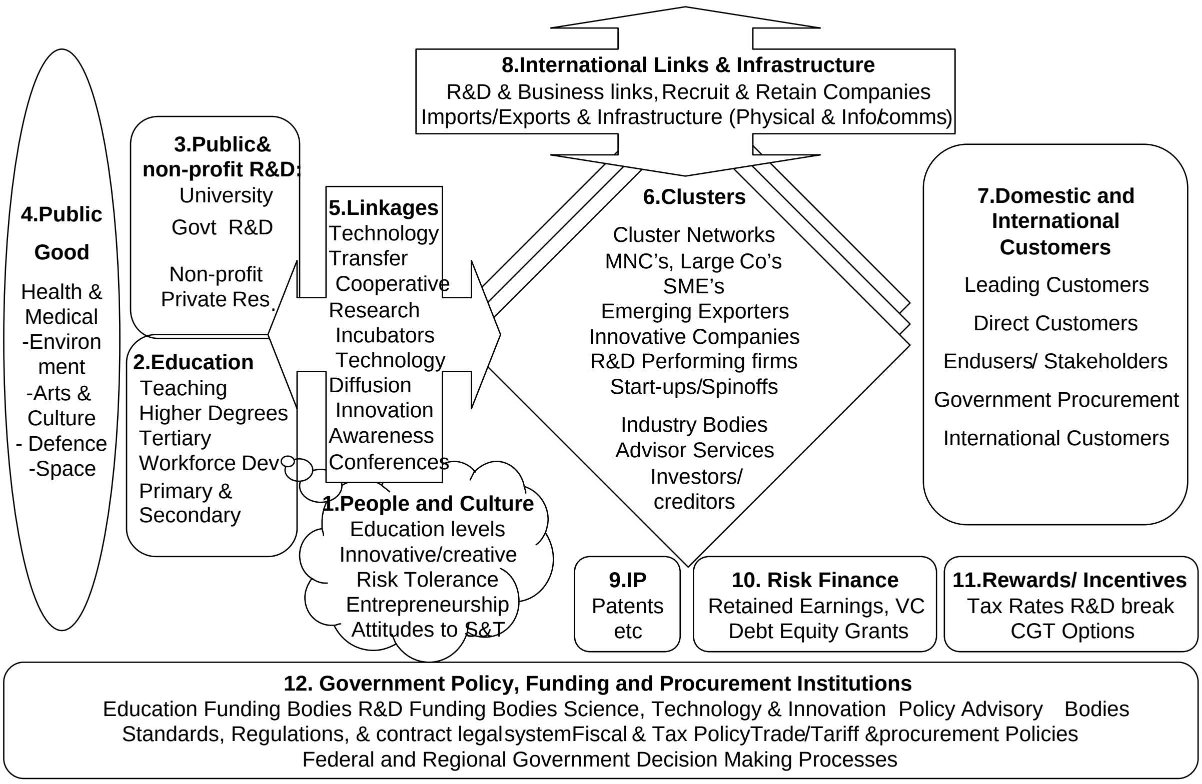

Figure 1 Constitution of national innovation systems (Roos et al. 2005)

When assuming a "systems approach" to innovation, it is not sufficient to just enumerate the institutions composing a NIS in order to understand the innovative performance of national firms (Lundvall 1992; Edquist 1997). Innovative capabilities depend on the ability to combine multiple inputs which originate in a network (system) of interdependent institutions. The relationships between elements also need to be addressed. In particular, Lundvall (1992) identifies some fundamental activities and relationships among the institutions composing a NIS. Lundvall (1992) argues that basic differences in history, language and culture are reflected in national idiosyncrasies in the following interdependent dimensions: the R&D system, the role of the public sector, interfirm relationships, the institutional set-up of the financial system, national education and training system, internal organisation of firms.

A fundamental issue in a NIS is the issue of learning and knowledge creation. Nelson and Rosenberg (1993) observe that including diffusion in the definition of a NIS is important for two reasons: (a) the diffusion of new technologies involves significant processes of local and incremental learning, and (b) the economic benefits of innovation are acquired rarely by first innovators and spillover across other firms. Lundvall (1992) emphasises that innovation is the outcome of learning processes through which economically useful knowledge is accumulated. In Lundvall's definition, learning is viewed as a complex process that involves new knowledge as well as new combinations of existing knowledge. As a consequence, learning is fundamentally an interactive and cumulative process. Learning processes, Lundvall (1992) also observes, draw upon a variety of sources of knowledge and are carried out in a variety of activities in a society. In this respect, the author distinguishes three forms of learning: i) "learning", in a strict sense, that originates in routine activities associated with the production, distribution and consumption functions of firms, in the form of learning-by-doing (Arrow 1962), learning-by-using (Rosenberg 1982), and learning-by-interacting (Lundvall 1988); ii) "searching" through more formalised learning activities carried out by firms in their departments for market analysis and R&D laboratories; and iii) "exploring" which consists of the research activities undertaken in academic or science-oriented organisations outside the private sector. All these forms of learning fall within the concept of NIS.

Comparing the national innovation systems of Finland, Sweden and Australia

Differences in national economic performance motivate comparative studies, in order to locate the sources of these differences. Edquist and Lundvall (1993) argue that differences between countries depend on the qualitative differences in the national systems of innovation and that these differences can be understood only if we take into account the historical process of industrialisation in the countries (which we have done for Finland, Sweden and Australia). It should be noted that a comparative analysis of the Australian, Finnish and Swedish national innovation systems is constrained by the scope and quality of existing data, and indeed by space, and cannot cover a NIS comprehensively. The comparison has been carried out using external literature supported by expert interviews in all three countries.

An Innovation Index developed by the US Council on Competitiveness (Porter and Stern, 1999) paints a very contrasting picture between Australia, Finland and Sweden. Whereas both Sweden and Finland are placed within the top 6, the Index rated Australia 12th out of 17 major OECD countries. The index, based on per capita measures, are: total R&D personnel, total R&D investment, the percentage of R&D funded by private industry, the percentage of R&D performed by the university sector, spending on higher education, the strength of intellectual property protection, openness to international competition, and, finally, a nation's per capita GDP (ibid.). The report notes that Scandinavia has emerged as a new international innovation centre. This has been due to Finland (and Denmark) making major gains in innovative capacity since the mid-1980s, to join Sweden in establishing a region of world-class innovation. Australia's lack-lustre performance and potential is demonstrated by the fact that the report makes no specific mention of Australia other than including Australia in the rankings.

There are essentially four theoretical perspectives on the study of national innovation systems (Nilsson and Uhlin, 2002): policy (Freeman et. al 1982; Freeman, 1987); institutional (evolutionary economic theory) (Nelson and Winter, 1982; Nelson, 1987; Nelson and Rosenberg, 1993); structural (Porter, 1980, 1985, 1990); and an agent perspective called Triple Helix, i.e. the interaction of government, industry and universities (Etzkowitz and Leydesdorff, 1997; Leydesdorff and Etzkowitz, 1998). The perspective taken for this paper is a mix of all four although space constraint prevents us from a deeper discussion of all four perspectives. We did however use three of these perspectives as a framework when comparing the national innovation systems of Sweden, Finland and Australia.

Policy perspective

From a policy perspective, we look at government funding of R&D. Table 1 lists the publicly stated policy priorities for each of the countries studied here. In all three countries there is a strong commitment to stimulate

R&D in key areas and within sectoral priorities. There are clear structures for policy advice and formulation, and institutional structures which ensure that policies can be effectively implemented through programmes and initiatives in the R&D-performing structures within the science system. Further, all three countries have mechanisms for feeding expert advice to policy makers, although the role of this mechanism varies.

Common amongst the three countries is the desire to make the research system more responsive to the needs of industry. The mechanisms for this again vary between countries – through TEKES in Finland and NUTEK in Sweden, for example, which direct research funding and identify commercial partners and potential collaborative projects to ensure responsiveness in the research they commission. Australia, with a strong research council-based structure, tends to be more mission oriented, although similarly is attempting to become more responsive to industrial needs by incorporating industrial dissemination into the dissemination of research results. TEKES both funds research and sets priorities in line with government priorities. These are implemented through programmes and initiatives which involve the private sector.

Table 1 Summary of policy priorities, structures and implementation structures in selected countries (2001)

	Policy Priority (2001/2)	Formulation mechanism	Implementation Mechanism
Australia	Higher Education research; biotechnology; commercialising emerging technologies; cooperative research centres, major national research facilities (basic science)	Prime Minister's Science, Engineering & Innovation Council; Chief Scientist; Coordination Committee on Science and Technology	Government Departments; research councils, four scientific research organisations & three scientific service providers; universities; Industry R&D Board; programmes and agencies VC funds; increased levels of investment and R&D tax concession
Finland	Information Technology, environmental protection, energy, the Artic	Science and Technology Policy Council, TEKES, Academy of Finland	Government departments, Public funding mostly channelled through TEKES; programmes (multiannual R&D projects); Academy of Finland research programmes; macroprogrammes (universities and research institutes); national cluster programmes
Sweden	Quality of scientific research; basic research initiated by scientists, gender balance, national and international research collaboration, EU fifth framework, access to information on research and results, researcher mobility	National research Committee	Direct grants to universities and colleges, grants through research councils (one science council, and two specialised research councils (working life and social science and environment, agriculture, forestry and social planning

Universities are principal beneficiaries of public sector funding for the science and engineering base and are responsible both for the training of future scientists and engineers and, to a large extent, for the basic research that underpins the whole science system. Increasingly as well, universities are being seen as central to the whole commercialisation of science agenda. This puts a priority on the funding of university research and its commercialisation, nationally and regionally. As Millar and Senker (2000) argue, "Government policies for university research critically determine the characteristics of national stocks of knowledge and expertise" (Millar and Senker, 2000). Finland shows a decreased reliance on universities to perform R&D. This is a country with strong public-interest and mission oriented research institutes and equally strong "intermediate" institutional structures which transfer technology from the science base to industrial application. These are given equal "parity of esteem" in funding the science and engineering base. In contrast, Australia has placed increasing reliance on the university sector to perform R&D. This is largely because of reduced reliance in intramural government research laboratories. General university funding is rising in Finland and Sweden. The Australian government has committed itself for the financial years 1999 onwards to increasing spending on universities in order to reverse the relative decline between 1994 and 1998.

Triple Helix perspective

This perspective looks at how government, industry and university interact in terms of funding, skills, labour mobility and entrepreneurial climate. As suggested by Nelson and Rosenberg (1993) an important feature of a NIS is represented by the allocation and funding of R&D activities. This dimension is analysed especially in terms of the relationship between the private sector and the public sector and their specific contribution to basic and applied research. We review science funding with a view to looking at the relationships between the public and the private sector in the funding and organisation of R&D in Sweden, Finland and Australia.

Table 2 illustrates the differences in structures and format of funding in the countries for 1999. What is common to the funding structures of the countries reviewed is the increased material and political resources that have been put into science and engineering at all levels (basic, applied and developmental research) despite national budgetary pressures and/or fiscal crises. Government publications from all the countries studied indicate a high level of commitment to funding the science and engineering base on the grounds that it ultimately contributes to improving productivity.

Sweden has the highest level of R&D expenditure as a percentage of GDP at 3.80% (US Department of Commerce, 2001), but commits just 1.25% of total government expenditure to R&D. This is below the European average of 1.54% implying substantial efficiency with which private sector investment is attracted into R&D (Eurostat, 2001). In Australia and Sweden, policy makers have been keen to dedicate resources to basic research in the interests of building the knowledge base of the economy from its roots. The Australian government conducts the highest amount of R&D of all three countries covered here at 23.4% of the total. Sweden is the lowest at 3.4% which is significantly below levels in the US. Differences can be explained by the fact that in some countries' funding to public research facilities is managed through private companies rather than by government departments. Furthermore, there is a stronger practice of contracting-out of public R&D in some countries. In the case of Australia however, the experience of some Australian research organisations is that Australian industry often does not have the capability for contract research.

Table 2 Overview of different sources and modes of funding for research and development in selected countries, 1999 (Source: OECD + National documentation)

When comparing the statistics on graduate levels and their respective majors within the OECD countries, the general conclusion is that the more innovative countries have relatively more graduates. Australia produces significantly less engineering, mathematical and computing and physical graduates than Finland and Sweden but more biologists. A direct result of the skills shortage can possibly be deduced in the fact that Australia does less engineering and software R&D than comparatively more innovative countries including Finland and Sweden.

Labour mobility among research organisations (universities and other research institutions) and the business sector, as well as among firms, together with informal contacts within innovation systems, is one of the most powerful mechanisms for transmitting tacit knowledge. It concerns scientists, technicians, engineers, and skilled workers but also business executives, since their mobility is a very effective way of propagating best managerial practices. Analysis of the impact of labour market allocation and mobility on countries' innovation capacity is severely constrained by the lack of appropriate data. Nordic countries are however unique in their access to labour-registry data and have pioneered research on linkages related to human resources in innovation systems. A study by Sweden's NUTEK on the employment patterns of graduates in natural sciences and engineering showed that the qualifications and allocation of human resources provide a better explanation of a country's technological strength than R&D expenditure statistics. The same study concluded that mobility of PhDs was a very weak means of knowledge transfer. Universities are the largest employers of PhDs in engineering and natural sciences, and the PhDs tend to remain in universities (in Sweden, within a seven-year period only 16% moved to another type of institution).

An essential driver in a NIS is naturally entrepreneurs (Schumpeter, 1934) and venture capital. Whilst Australia's venture capital market is immature, it has grown quickly in recent years and continues to do so. However, the amount invested in the early stage of the venture capital market is small compared to international levels. Investment in the early stages of the venture capital market in the United States is 100 times that in Australia. Furthermore, the number of deals is greater and the deal size is, on average, ten times larger than in Australia. In comparison to the Nordic countries (Figure 2), Finland fares better than Australia although the levels invested in Sweden are lower than the Australian figure.

	Aus	Can	Fin	Fra	D	J	Sw	UK	US
R&D Performer									
Business Enterprise	**45.1**	**59.8**	**71.1**	**63.1**	**70.0**	**70.7**	**75.1**	**67.8**	**75.7**
Government	**23.4**	**12.0**	**11.1**	**17.9**	**13.7**	**9.9**	**3.4**	**10.7**	**7.2**
Higher Education	**29.4**	**26.9**	**17.8**	**17.6**	**16.3**	**14.8**	**21.4**	**20.0**	**14.1**
Private non-Profit	**2.1**	**1.2**	**0.7**	**1.5**	**0.7**	**4.6**	**0.1**	**1.4**	**2.9**
Source of Funding									
Business Enterprise	**39.7**	**44.7**	**66.9**	**53.5**	**65.1**	**72.2**	**67.8**	**49.4**	**66.8**
Government	**47.8**	**31.2**	**29.2**	**37.3**	**32.3**	**19.5**	**24.5**	**27.9**	**29.2**
Abroad	**2.5**	**16.7**	**3.0**	**7.4**	**2.3**	**0.4**	**3.5**	**17.6**	**-**
Other national sources	**4.7**	**7.4**	**0.9**	**1.8**	**0.3**	**7.9**	**4.2**	**5.1**	**4.0**

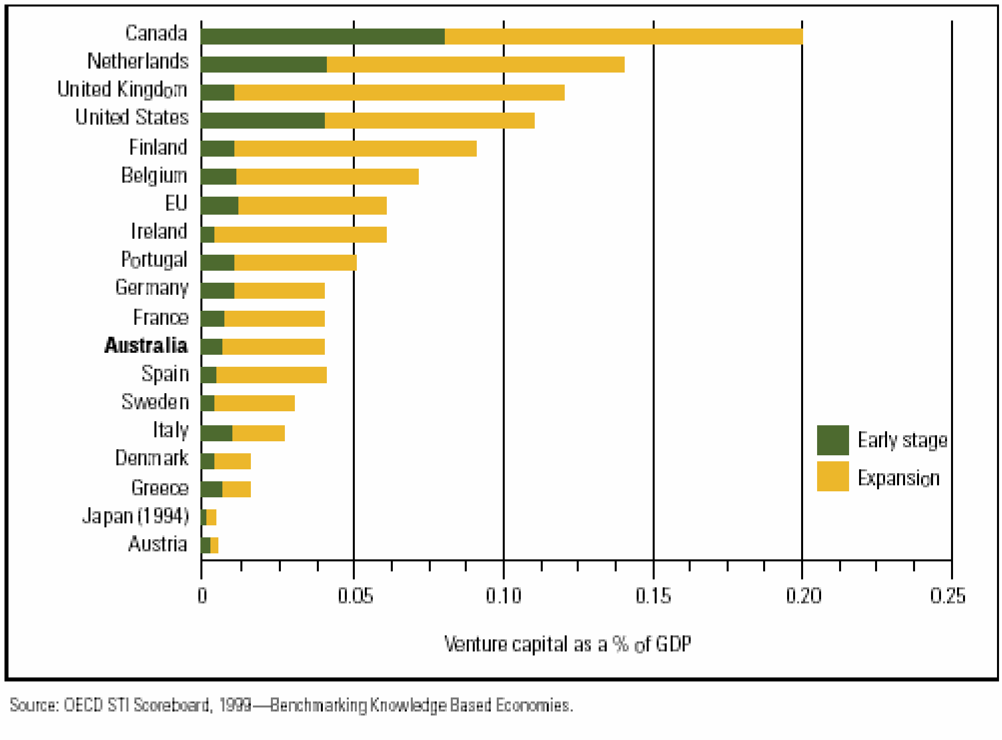

Figure 2 Comparative venture capital markets

Structural perspective

"Clustering" of countries with similar technological specialisation shows strong similarities between smaller, mainly resource-based economies (although to a lesser degree in the 1990s than in the 1980s) as well as some similarities among the larger European countries. It also reveals the unique specialisation patterns of Japan and the United States. At the same time, structural change is reflected in the changing composition of country "clusters" over time. Important structural changes can be observed for Denmark and Spain, and for Finland and Ireland.

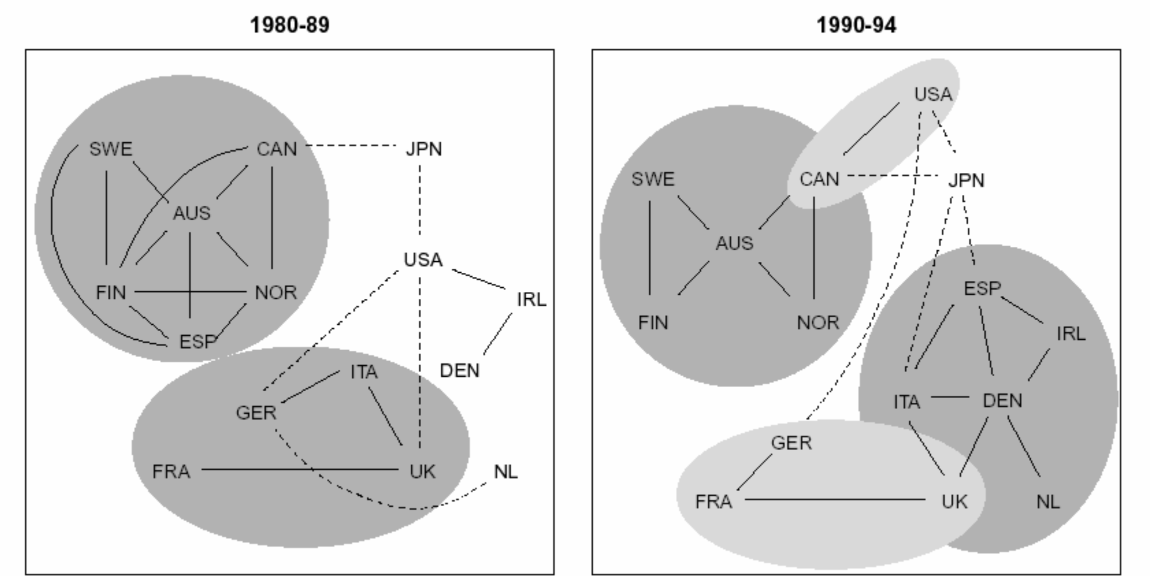

Figure 3 Technological (dis)similarities among groups of countries[1] based on patenting. (Source: OECD)

The differences in the scientific and technological specialisation of OECD economies are partly reflected in patterns of export specialisation. Although science and technology are not equally important to all sectors of the economy, strong technological performance may be reflected in strong export performance. The strong patent performance of Australia, Denmark and the Netherlands in food products is reflected in their export performance, the strong innovative performance of Belgium, Denmark and Switzerland in pharmaceuticals, and the relatively strong patent performance of Japan, the Netherlands, the United Kingdom and the United States in office and computing equipment. These patterns do not always hold, however, and more detailed work – for instance, in the form of cluster analysis – is required to substantiate these findings.

Performance Measurement of National Innovation Systems

With NIS, as ever with complex social phenomena, the issue of measurement is one that triggers a lot of debate. Any company or other organisation which funds or undertakes research will have asked at some time whether they give or receive value for money (Garnett et al., 2006). Unfortunately, we cannot elaborate on that matter within the space constraints of this paper other than to give an example of how a method for measuring the impact and value was used to evaluate of one element of National Innovation Systems, namely that of universities. In a recent study in Australia (ibid), an advanced conjoint measurement system was assessed to determine whether it could give a comprehensive, transparent and agreeable assessment of a university's research value as seen the stakeholders who sponsor research there. The Conjoint Value Hierarchy (CVH) (Pike and Roos, 2004; Roos et al. 2006) was employed in the study for its academic rigour being founded upon axiology (Frondizi, 1971; Rescher 1969) and multi-attribute value theory (Keeney et al., 1993) and operationalised using measurement theory (e.g. Scott and Suppes, 1958; Suppes and Zinnes, 1963;). A total of 29 stakeholders took part in the study and the study presents aggregated results from these stakeholders. The scope and utility of the output shows that the CVH can be used as an auditable, reliable, transparent and usable measurement system that does not place excessive burdens on the university user (Garnett et al., 2006).

It would naturally be of interest for further research to delve deeper into how to measure the effectiveness and value of a NIS as a totality and build on previous bench marking studies. Other than conventional economic, although complex in this context, models, a potential approach is to examine the impact of NIS on intellectual capital on a national level (see e.g. Bounfour and Edvinsson, 2005).

Conclusions

This paper has briefly reviewed the workings of national innovation systems and their contribution to knowledge creation through comparing the national innovation systems of Sweden, Finland and Australia. The responsibility for improving a nation's level of innovation, with the consequent benefits it brings to global competitiveness, jobs and enhanced productivity, is a task that governments share with private enterprise and all the other players engaged in economic endeavours. The development of successful national innovation systems by Finland and Sweden demonstrates how vital it is to give priority to innovation and technology policy as a key driver of a country's economic growth. It is also vital that investment in innovation and technology policy is applied optimally to all elements, from industry clusters and incubators to research capability and educational institutions to marketing, finance and technology transfer infrastructure.

Further, policies on innovation and technology must be focused on deliberate and coherent actions that capitalise and build on the nation's advantages and specific circumstances to create self-sustaining innovation capabilities in its firms that provide them with an enhanced ability to compete internationally. Within this framework and focus, nations can make the choices about where to allocate resources in a way which most potently enhances their industrial capability, their economic prosperity and their social wellbeing.

As concluding remarks, it seems appropriate to list what seem to be the key characteristics of successful national innovation systems:

- Recognition of the need for and cohesive, deliberate action by governments to invest optimally in each of the elements of the innovation system, and in the way the structure works together as a whole. Too often, innovation policies focus on single components only, such as research and development investment or access to venture capital.

[1] Dotted lines indicate a significant negative correlation (dissimilarity) between the patterns of revealed technological advantage (RTA) of countries; straight lines indicate significant correlation (strong similarity) (at a 5% significance level).

- An economy which is flexible and adaptable, with a commitment to reform and a global focus.
- The existence of demanding sophisticated leading-edge customers.
- A high level of networking among innovators, and the existence of robust industry clusters.
- Improved linkages between science and industry, enabled by government.
- An increasingly diversified base of research and development performers.
- High business and government expenditure on research and development.
- A supportive financial system.
- Above average rate of investment in education, research and innovation.

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