Chapter 2
Systemic Innovation and Nation States

2.1 Knowledge, Technology, Innovation and Nation States

The decade of the 1980s was one where Japanese industrial competitiveness in a number of technology based industries notably computers, consumer electronics and motor vehicles came to the fore. Dosi et al. (1990) considered this example of Japanese development as the only case of economic catch-up from less developed to advanced economy status in the post World War II era. Throughout this catch-up period, corporations based in Japan expanded their technological capabilities and progressively introduced new processes and products that were at the leading edge in many industries.

With the exception of the case of Japan there was, at least until the mid 1990s, an interesting feature of research and development (R&D) indicators in particular, and innovation indicators more generally. Relevant data reveals that the relative position of many OECD countries does not vary significantly across time (Patel and Pavitt 1994). As one example, Voyer (1999) argues that Canada did not significantly increase its gross expenditure on research and development (GERD) across a 30-year period.

These observations – one country's improved competitive position (Japan), the inability of Canada to improve its expenditure on research and development and the general pattern of the difficulty for countries to shift their trajectories – strongly suggests that a company's technological capabilities are not just its own business. The progress of the major Japanese companies, in particular, had a considerable impact on researchers with an interest in technological competitiveness. The success of Japanese organisations suggested that the national milieu in which businesses were embedded is influential in their behaviour and success. As this evidence came to light in the 1980s, the concept of national innovation systems (NIS) emerged (Freeman 1987 and many since).

Two decades later, this concept is discussed or implied in the vast majority of research articles on innovation. NIS research has revealed that a country's research and education systems, its government policies on industry and innovation, and even the operation of its labour market, can all affect the ability of a firm to introduce new products and processes. Access to highly skilled personnel, appropriate infrastructure and an environment conducive to co-operatively developing research opportunities between publicly funded research laboratories and business, all play a part in the overall innovativeness of economies.

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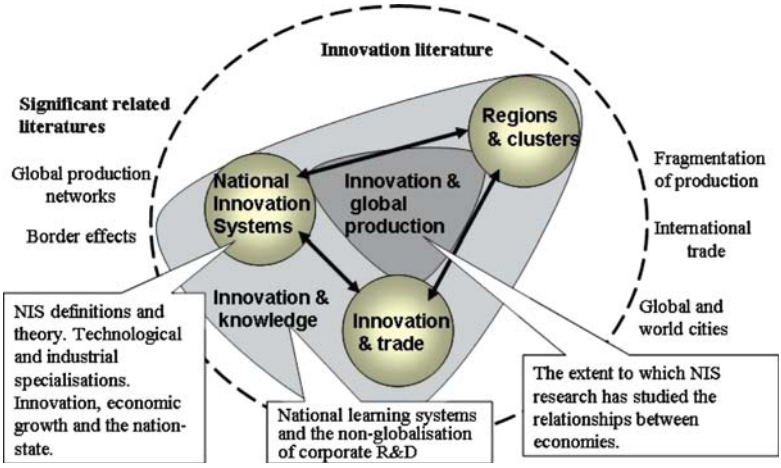

Fig. 2.1 National innovation systems in the literature

This chapter analyses the major threads of NIS research, as it is relevant to international production structures – which is not by any means the totality of the NIS literature. It evaluates the role of the 'system' in shaping technological competitiveness, promoting economic growth and the way in which knowledge production remain remarkably stabile through time. Figure 2.1 locates this chapter's contents within the overall research framework of the book.

However, the purpose of this chapter is to reveal how analysis of these subjects has been carried out largely by treating each nation essentially as independent entities. National innovation systems research has focused on determining the characteristics of particular countries that have aided or hindered economic success. As this chapter reveals, there has been little work on the linkage between the knowledge economy and the national economic interdependencies within the growing structure of global production. This chapter also shows the NIS focus on the importance of the internal dynamics of economies, to the neglect of external connections, can be seen in the very early work of Josef Schumpeter.

2.2 Technology, Competitiveness and Systems

2.2.1 Economic Growth

In the long run, what matters for human societies are economic growth (World Bank 1999), environmental sustainability (Diamond 1998 and World Commission on Environment and Development 1987) and social capital (Vinson 2004).[1] Although

[1] A revealing study of the importance of 'social cohesion' in economically disadvantaged communities in rural, regional and urban Australia. It reveals that outcomes for communities with greater social capital were better than for those with less social capital.

this triple bottom-line has been gaining more prominence in recent years, the economic wealth of nations is critical for quality of life and the health of populations. As the history of economic development is such a popular topic (Landes 1999), it is a little surprising that the understanding of the conditions that facilitate economic growth is advancing very slowly. Temple (1999, p. 112) goes so far as to say that the analysis of economic growth has often been a backwater within macroeconomics. This neglect makes it is easy to make big claims for what is known of economic growth, particularly as it relates to the role of new technology, but unfortunately less seems to be known than is claimed.

From the early 1960s, researchers from the neo-Schumpeterian tradition have been interested in the role of new knowledge and innovation in economic growth. More recently, within the neoclassical economics tradition 'new growth theory' emerged with the work of Romer (1986) who began to econometrically model the role of new knowledge creation in fostering economic growth. The OECD (2001b and OECD 2003a) has recently summarised the evidence on the empirics of economic growth.

Neo-Schumpeterian authors have approached the analysis of economic growth from a number of angles. Fagerberg points out that prior to new growth theory it was expected that capital and labour contributions would be the preponderance of factors contributing to economic growth (2001). As much as 80% of growth (p5) remained outside the models in the first attempts at growth accounting. Fagerberg argues that there are various bits of evidence supporting the significance of technology diffusion, knowledge spillovers and localisation of knowledge in economic growth. However, Temple (1999), in analysing the empirical evidence on these and other factors, is less confident that there are any clear answers. Importantly, there is a difference between national economic growth that can be influenced by many factors, such as macroeconomic management and consumer confidence related factors, and business competitiveness, which is more directly related to innovation. The OECD highlights the growth experience of Member countries and in so doing reveals the difficulties of determining the factors that encourage economic growth.

> Some point to the role of new technology and innovation, but if that were the only answer, then why did growth languish in Japan, which has a large and successful computer hardware industry, but soar in Australia, which has virtually no such sector at all? (2001b, p. 9)

The OECD's conclusion, while hard to fault, does not actually help very much.

> 'Consequently, policies that engage ICT, human capital, innovation and entrepreneurship in the growth process, alongside fundamental policies to control inflation and instil competition, while controlling public finances are likely to bear the most fruit over the longer term' (2001b, p. 10).

Although new technologies play a part in national economic growth, determining the value of that contribution remains a challenge. Partly, the problem with calculating the outcomes of aggregate investment in new technologies is the urgent need for improved theoretical models and tools for measuring creative destruction processes, as noted by Haltiwanger (2000). New technologies

do in time replace[2] older ones or change the relative pace at which different sectors change rates of employment or productivity. As global competition increases, the race to develop new technologies may just help countries keep pace with one another.

Since the 1970s, there have been some remarkable changes in the world economy. New technologies and innovation have become ever more important to business success. The massive increase in computing power with benefits for national productivity (Jorgenson et al. 2003), the Internet and with it the emerging possibilities of electronic commerce (OECD 1999a), the beginnings of biotechnology for both health and agriculture (Industry Canada 1998) have encouraged governments to focus on the economic potential of emerging technologies.[3] Nanotechnology is already being seen as the next 'big thing', with substantial investment in the USA (through the National Science Foundation – NSF). The European Union (EU) is also focused on this set of technologies, already devoting a chapter to measuring the level of investment in Member countries in the European Commission's 2003 indicators report. Business communities now lobby Government for innovation programs (see, e.g. Australian Industry Group 2002) and technology and knowledge is now an issue for debate by neo-classical economists. Even a bastion of economic theory and tradition, The Economist journal reflects these changes with a quarterly review of science and technology. Perhaps most surprising, governments in the world's poorest countries, such as Mozambique, have a growing interest in science, technology and business innovation (Garrett-Jones et al. 2003).

2.2.2 Innovation Aids All Sectors from Agriculture to Services

Academic interest in industrial innovation is often traced back to Joseph Schumpeter, an Austrian economist, who until recently received little attention in economics courses. In 'A Theory of Economic Development', first published in English in 1934, Schumpeter (1968) considered technological innovation not merely as the driving force of growth but as being the very essence of development (p65 ff). Schumpeter's insights are now largely supported by the results coming from a broad range of authors. Porter (1990) suggests that the ability to create new products or processes allows firms to be freed from the traditional sources of advantages such as lower labour costs and resource access, to be replaced by the advantages of skilled labour and technological infrastructure. But this change from 'comparative' to 'competitive advantages' does not make the

[2] See Christensen, Craig, and Hart (2001).

[3] The USA's Government expenditure on health research alone has grown from around US$15b in 1998 to nearly US$30b in 2004 (constant 2004 dollars) AAAS (2004b).

factors behind business development less local – it makes some factors even more localised.

By the 1960s and 1970s, Schumpeter's ideas on the innovation process were being put to the test with studies of company research and development practices and their capacity to introduce new products to the marketplace. Freeman comments on one of the path-breaking studies of the time:

> 'The SAPPHO project (Freeman, 1974 and Rothwell 1974) had already shown that good internal coupling between design, development, production and marketing functions was one of the decisive conditions for successful innovation. Many failures could be attributed to the lack of communication between the R&D, production and marketing functions as was also shown in the brilliant sociological study of Burns and Stalker (1961)' (1994, p. 472).

These early studies focussed primarily on the development of new products that were based on scientific research by firms in the manufacturing sector. While, this focus inevitably concentrated analysis on industries that require more research and development (electronics, pharmaceuticals, aerospace and motor vehicles), over time this has changed. Nelson (1993b, p. 513), for example, in his volume comparing national innovation systems demonstrates that there is a strong connection between a nation's competitive agricultural sector and the funding of agricultural research.

It has taken much longer for service businesses to be treated on their own merits, in terms of innovative capacity. Initially, services were understood for their role within the traditional areas of interest (manufacturing and new technologies). Freeman noting the significant investment by business service firms in technological change, comments:

> 'In house software development… is now characteristic of many firms in financial services, who also have a heavier investment in ICT equipment than most firms in manufacturing. At the same time, specialist software companies are proliferating and have a very dynamic role in technical change' (1994, p. 478).

There continues to be interest in how services and manufacturing interact in the innovation process (Tomlinson 1997) and there is a growing body of research on the dynamics of services innovation (see Tether and Metcalfe 2003 and Baark 2001). The SI4S[4] and RISE[5] projects have greatly improved the information on services innovation and the role of public sector research organisations. This broadening interest of innovation researchers now even extends as far as consumer preferences with a research project on 'consumption and demand' (Harvey et al. 2001). Innovation, is not just the activity of high technology manufacturing firms, it is the business of firms throughout a modern economy. Nevertheless, the important shift from the early 1970s has been the change in emphasis from the characteristics of firms to the systematic properties of innovation, typically characterised at the level of the nation state.

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[4] http://www.step.no/old/Projectarea/si4s/start.htm accessed 4 Dec 2007.

[5] http://centrim.bus.brighton.ac.uk/open/we/do/proj/rise/index.htm accessed 4 Dec 2007.

2.2.3 Innovation Embedded in Nations

In neo-classical trade theory, the standard factors of production are traditionally considered as national but knowledge is considered to be freely available (Lundvall 1998). This should lead to the global movement of production to where there are comparative advantages. However, neo-Schumpeterians have a better understanding of knowledge, highlighting that it is not easily accessible and is related to industrial structure. Therefore, they continue to retain a focus on the role of the nation state.

While there are commonalities within the definitions of what is systemic in innovation processes within nation states, there is no agreed theory of cause and effect mechanisms. In Edquist's (1997b) view, *systems of innovation*, which encompasses a range of spatial scales (not just nation states), is a framework for investigating the development and evolution of technological capabilities, concentrations and specialisations. Edquist provides a guide to the systems of innovation perspective, emphasising it:

- Is 'holistic and interdisciplinary' – for constructing a broad understanding of the 'determinants of innovation' (1997b, p. 17);
- Is a presentation of the 'historical perspective' on geography and natural resources access, etc (1997b, p. 19);
- Focuses on the 'differences between systems and non-optimality' (1997b, p. 19) – all systems are different and defining a priori an optimal system is not sensible;
- Stresses 'interdependence and non-linearity' (1997b, p. 20) – as it is 'an approach in which interdependence and interaction between the elements in the system is one of the most important characteristics' (1997b, p. 21);
- Focuses on 'product technologies and organisational innovations' (1997b, p. 22); and
- Places institutions at the centre of analysis.

This list by Edquist breaks down into essentially two categories: the first three points position the approach to the economics of innovation and technological change vis-à-vis neo-classical economics; while the second three points identify the key issues in the study of innovation. Institutions, interdependencies and product innovations in a particular place draw upon history, culture and a set of policy interventions. This implies that the nation state is seen as a natural boundary for the actors and activities that are relevant to the creation of economically useful knowledge.

Freeman (1995) reviews a number of cases where the different way innovation systems developed was important to the broader trajectories of economic development. He argues that Japan encouraged the integration of production with research and development and technology acquisition while in the USSR these were all components that were separated from one another. In Japan, networks of users and producers developed while in the USSR these never developed. In East Asia, there was heavy investment in the education systems but in Latin America, the education systems deteriorated. In East Asia, industrial research and development expenditure increased, however, in Latin America it remained steady.

The emphasis on the nation dates back at least as far as Schumpeter. A chapter written by Schumpeter for the first edition of his 'A Theory of Economic Development' was not included in the first English translation has, comparatively recently, been translated into English and analysed. The text indicates that back in the early years of the twentieth Century Schumpeter already envisioned economic growth deriving from entrepreneurship as an endogenous process captured by nations. Matthews writes:

> 'It is this seventh chapter, lost to the world after Schumpeter's decision to drop it from his second edition (which then formed the basis of the English translation published only in 1934) […] The chapter, entitled Das Gesamthild der volkswirtschaft (the economy as a whole) provides a fascinating missing "chapter" in Schumpeter's thought, previously inaccessible to the English-speaking world. The chapter clearly written in haste late in 1911 to catch a printing deadline, sketches a highly original summation of his model of internal economic development, where transformation is generated from internal dynamics represented by entrepreneurial initiative – in contrast with the prevailing doctrines which saw change in economic circumstances, and growth, as responding to external stimuli, such as population growth, or technological innovation, or the opening up of new geographic markets' (2002, p. 2).

This emphasis on the role of domestic dynamics contrasts starkly with the literature and policy recommendations that emphasise export-oriented growth and the contribution of global economic growth to national growth performance. The IMF (2001) has had a consistent focus on encouraging developing and heavily indebted countries to support export oriented industries. In this view, continuing liberalisation of national economies will lead inevitably to a decline in the importance of the economic and social policy making of national governments. As Rangan and Lawrence argue:

> 'In the absence of border barriers, competition would be global. Corporations would rapidly shift to locations that offered lower costs. Indeed, global competition would compel them to do so, because victory would go to the firms with the lowest costs, whereas firms mired in high-cost locations would eventually be driven out of business' (1999, p. 4).

On the other hand, Schumpeter's view that domestic capabilities matter is supported by the empirical evidence presented by Rowthorn and Kozul-Wright in their analysis of globalisation. 'Domestic determinants of economic growth remain significant', even though capital investment flows are increasing, because the drivers of 'capital accumulation retain domestic roots' (1998, p. 31). Thus, those that claim globalisation is the death of the economic influence of nation states appear to have rushed to judgement. The OECD (1992) suggests that the effective structuring of a country's NIS can help a country progress rapidly and that conversely weaknesses may lead to the squandering of other resources.

2.2.4 Systems Theory

Although it took some time for implications of innovation based competitiveness theories to be applied to the full range of industries, the change to systems thinking, by comparison, was relatively quick (a point noted by Edquist (1997b, p. 3). In the

late 1980s, the concept that innovation was a systemic property of the nation state emerged with Freeman's (1987) use of the term 'National Innovation System' (NIS) with an application to the growing strength of Japanese businesses. Since then there have been many systems of innovation approaches (regional, technological, sectoral), but the national perspective remains the primary framework. The purpose of this section is to present an overview of the major strands of NIS theory and evidence as they relate to the structure and evolution of the geography of global production.

The international circumstances which encouraged the neo-Schumpeterians to analyse the role of the nation state led others to a similar interest and reinvigorated debates about the future of nations. Tyson (1992) perceived economic policy in national terms, whilst Ohmae (1995) was predicting the looming irrelevance of the nation state. Through this period of the late 1980s and the first half of the 1990s, research on economic growth returned as a core topic in economics (see for example Mankiw 1995, and the reviews in The Economist 1992a, b; 1996a, b).

The nation state has come to be at the centre of innovation studies because the ability of companies' to develop new products, processes, services and technologies does not rest solely on the resources and capabilities that can be controlled by the firm itself. NIS is a way of considering variables that are both within the influence of nation states and those which, although difficult to change are nonetheless apart of the evolutionary patterns of country development. In the former category are government interventions such as; industry policy, the higher education system, technical education, social welfare and public R&D funding (level and research fields). In the latter category are specific features of an economy such as specialised supplier businesses in particular industries, venture capital access and the way labour relates to employers (pay and non-pay conditions), all trajectories that are difficult to influence.

What does define an NIS? There are common themes but there are many subtly different emphases in the various definitions. The first books on this topic Lundvall (1992a) and Nelson (1993a) took quite different approaches. Nelson's book was a country-by-country description that was prone to the individual predispositions of the local authors. For example, the author of the chapter on Australia (Gregory 1993), a labour market economist, emphasised the role of human resources and the organisation of labour relations for innovation capacity. Lundvall's book, in contrast, explored the theoretical dimensions and presented empirical data on innovativeness and technological competitiveness within a thematic presentation. Lundvall remains a key promoter of the NIS perspective and the nationalism of innovation (1998, with Maskell 2000 and et al. 2002).

In trying to define NIS, Freeman suggests that it is more than just R&D but encompasses the entire way a nation is organised, commenting:

> 'most neo Schumpeterians, following Lundvall (1992) and his colleagues, stress that a 'national system of innovation' is much more than a network of institutions supporting R&D, it involves inter firm network relationships and especially user-producer linkages of all kinds (Anderson 1992a) as well as incentive and appropriability systems, labour relations and a wide range of government institutions and policies' (1994, p. 484).

Smith, in contrast, places more emphasis on the interactions between different elements of the knowledge production system (companies, labs, etc) and the facilitating institutions (the legal system). Smith also emphasises the influence of cultural factors (values and norms), arguing:

> 'the innovative performance of an economy depends not only on how the individual institutions (e.g. firms, research institutes, universities) perform in isolation, but on how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal frameworks)' (Smith 1994, p. 3).

Another definition has a greater focus on the role of government, Metcalfe suggesting:

> 'A national system of innovation is that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within which governments form and implement policies to influence the innovation process. As such, it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies' (Metcalfe 1995, p. 463).

The OECD (1999c) combines many of the variables in these and other definitions of NIS in a diagram of the operations of a national system, but neither the diagram nor the book, in which it appeared, goes beyond generalities. However, The OECD is not alone in attempting to create 'maps' of the innovation system. The Australian Government has recently published its guide to Australian innovation (Science and Innovation Mapping Taskforce 2003). The report states that 'For the first time, we have been able to present a detailed overview of our science and innovation system in Australia' (2003, p. i), but it presents little that is different from other indicator publications that have been published in Australia for sometime (see for example Department of Industry, Technology and Commerce 1987). Furthermore, its analysis is commonplace in other countries (National Science Board 2002 and European Commission 2003).

What becomes clear, however, from these attempts at defining and mapping innovation systems is that we are far from a macro-innovation theory of economies, in the same way that macro-economics purports to depict the interactions that occur within modern economies. It may not even be desirable to progress towards such a theory. Instead, NIS is a body of research which adopts a number of different viewpoints and methodologies which nevertheless all progress the general proposition that political geographies still matter for the innovativeness of businesses located within their borders. Dosi (1999) provides a much needed classification system of the various research approaches to analysing the influences on innovation which are 'national'. Dosi categorises both the major processes driving systems of innovation as well as the diverse meta views on the operational features of national systems (with appropriate author attribution).

Processes in national innovation systems:

1. Production systems.
2. Innovation system operations.
3. Knowledge accumulation.

Dosi's typology of analytical lenses on national significance for innovativeness:

1. National innovation institutions & policies [R&D funding and universities, etc] (Nelson)
2. User-producer relations (Lundvall)
3. Technological accumulation (Patel & Pavitt)
4. National institutions [Financial markets, labour markets and training institutions] (Soskice)

From these two lists, three categories are important for the analysis in this book.

1. Technological accumulation (see Sect. 2.5 of this chapter). Knowledge and technology creation are viewed as important engines of long-term economic growth (Nelson 1990) but, like natural resources, they are accumulated unevenly across nations. Similar to other resources, history plays a part in exploitation and the rate at which countries develop knowledge resources is fundamentally shaped by the operation of national institutions. Knowledge typically accumulates along pathways. Investment in science and technological capabilities in one generation is usually consistent with previous investment decisions. This is because knowledge production relies on self-reinforcing mechanisms including physical capital (infrastructure in the form of existing laboratories or expensive scientific equipment) and human capital (training of personnel). Knowledge also tends to be 'sticky' (Dosi 1999) to given locations both because it is accumulating and as most knowledge is uncodified – it does not diffuse easily. Such tacit knowledge is held in the minds of people and is passed on by either learning by doing or word of mouth. Increased knowledge accumulation is thus likely to foster increased diversity rather than convergence amongst the world's economies and is one of the prime reasons for any understanding of globalisation retaining a focus on specific locations.
2. Production systems (see Sect. 2.3.2 of this chapter). Systems of innovation research contributes to improving the understanding of production specialisations, trajectories and industrial location at the national and the sub-national level.[6] NIS analyses have focussed on examinations of industry competitiveness (Fagerberg 1998), business R&D (Patel and Pavitt 2000 and Gassman and von Zedtwitz 1998), patenting patterns (Archibugi and Pianta 1992) and export growth (Dalum 1992 and Laursen 1998a, b). Although the framework of innovation systems extends beyond industrial activity, it is necessary to focus on corporations, industries, sectors and whole value chains. It is through these actors and activities that technologies come to market.
3. User-producer relations (see Chaps. 3 and 5). One of the most important findings of innovation research is that the interaction of the producers and users of industrial

[6]See chapter 3 for a discussion of geography based analyses including; development blocks, regions and clusters.

components and services can create an environment for new products to emerge. The communication of needs (users) and possibilities (producers) opens the way to the creative processes and the incentives for investing in research and/or product development. Thus, 'user-producer relations' are seen as one of the key characteristics of business innovation (von Hippel 1988, DeBresson 1996 and Edquist 1997b). In some cases the intensity and nature of relations has been seen as an attribute of nation states (Lundvall 1992a).

The cooperation seen in user-producer relations runs counter to the assumptions of market competition and arms length open contracting that exists in neo-classical economics. Far from simply emerging from the operation of markets, competition and inventive businesses, the development of technology evolves from an interaction between the different actors (see Hofer and Polt 1998) and can even be observed at the system level (DeBresson 1996). Unfortunately, there has been very little analysis of cross border user-producer relationships. Although DeBresson et al. (1998) imply a positive role for international linkages; they could not provide information on the scale or spatial structure of the extra-territorial links. The issue of linkages between businesses across borders is quite different to the topic of international R&D spillovers which has been of some interest to researchers but which have been perceived as small (i.e. see van Pottelsberghe 1998). Due to its relevance for developing an understanding of the extension of innovation systems across borders, the topic of user-producer relations research is returned to throughout this thesis. The next two sections further develop the reasons for considering nations as the appropriate spatial scale at which to analyse innovative activities.

2.3 The Historical and Continuing Importance of Nations

Neo-Schumpeterians, to date, have seen competitiveness predominantly in national terms. It is thus necessary to map this existing thinking on the role of nations before being able to highlight the weaknesses of the approach and the need to look at the interdependencies between systems.

2.3.1 Learning Nations

The ability of countries, through their businesses and populations, to learn, to access current knowledge and to understand how to transform existing data into new knowledge is crucial to social and economic progress. Although nations have developed many traditions in the funding and organisation of their education systems, some features are arguably fundamentally 'national'. Qualification standards are often a national responsibility and intra-national labour mobility is rarely hindered, whereas movement across international borders is more restricted.

Accessing human capital and knowledge have been critically important for economic success since at least the beginning of the industrial revolution, even earlier according to Smith (2000). In the view of Landes (1999) access to codified knowledge is no guarantee of being able to successfully adopt technologies, noting that during the industrial revolution even with 'sample products and equipment' or 'blueprints and explicit instructions, some know-how can be learned only by experience' (1998, p. 278). Not surprisingly, European countries designed policies, during the industrial revolution, that not only built their own capability but aimed at acquiring new ones through, initially, hiring British workers; 'foreign governments paid people to come and helped them set up in business' (Landes 1999, p. 279). Landes comments that some of these workers were:

> anonymously ordinary, most British expatriates were workmen drawn by wages that ran twice and three times higher than home. (British wages were ordinarily considerably higher than those across the channel, but these experienced craftsman and mechanics were scarce commodities in follower countries) (1998, p. 280).

Whilst the measures taken by follower countries were partially successful, it was the eventual development of formal technical education systems, first in France and then copied across Europe that powered success. Germany developed the approach to its fullest extent at that time. It formed a network of trade schools and technical high schools as well as changing the universities to conduct teaching and research in chemistry and engineering (Landes 1999, p. 283). The German universities became centres of technological diffusion because they focussed on both theory and applications of science. In contrast, the approach in Britain still relied upon 'learning by doing – the strategy had driven the Industrial Revolution' but failed as 'the frontiers of technological possibility and inquiry moved outward, exploration went beyond the lessons of sensory experience' (1999, p. 283). The education system helped Germany take the lead in the chemicals industry, in which Britain had previously had an obvious competitive and comparative advantage (Landes 1999).

The change in the structure and content of the education system in Germany led directly to significant changes in the economic fortunes of nations and accords with Lundvall's strong emphasis on the learning capabilities of nations. He notes 'Innovation appears now, not primarily as a single event, but rather as a process' (1992b, p. 9). Thus it is:

> argue[d] that most important forms of learning may fundamentally be regarded as interactive processes, and that together with the economic structure and the institutional set up form the framework for, and strongly affect processes of interactive learning, sometimes resulting in innovations (1992b, p. 9).

For Lundvall a national framework is necessary for understanding this learning process for the development and diffusion of knowledge, which is critical to the creation of innovations and competitiveness (see also 1998, with Maskell 2000 and et al. 2001). Consistent with this perspective, are the conclusions that universities and publicly funded research needs to be seen primarily as an investment in the development of human capital rather than investment in new technology

(Salter et al. 2000). Although new technologies may or may not emerge, it is *talent not technology*,[7] which has the greater economic benefit. The investment payoffs include (amongst others) 'increasing the stock of useful knowledge', 'training skilled graduates' and 'creating new scientific instrumentation and methodologies' (2000, p. 59).

2.3.1.1 Knowledge Accumulation

Increasing knowledge creation in a given field tends to be dependent on previous investment in knowledge creation. The idea of cumulative causation in traditional economics has been discussed for the better part of a century (see Toner 1999) and its application to endogenous growth theory has been intensively debated over the last decade. The emphasis historically has been on increasing economies of scale, increasing specialisation and the central importance of manufacturing. It is, however, the cumulative causation of investment in knowledge that has gained very wide acceptance with the neo-Schumpeterian community. Investment in knowledge is path dependent and generates positive feed back effects.

Capability and capacity with one field of knowledge enables future research within that same field but it is difficult to change scientific fields. Each field of knowledge requires existing training expertise, scientific infrastructure and relationships with researchers across the world facilitating access to tacit and codified knowledge. Cohen and Levinthal (1990) were the first to suggest that there are 'two faces of R&D'. Business expenditure on research and development both generates new knowledge and, more importantly, it assists the company in attempts to access the greater part of knowledge that is external to the business. Without conducting its own R&D, companies will be largely ignorant of the leading edge and be unable to absorb new technologies. Cohen and Levinthal also argue 'accumulating absorptive capacity in one period will permit its more efficient accumulation in the next' (1990, p. 136). Dowrick, quoted by the Industry Commission (1995) in its wide-ranging inquiry into the importance of R&D to Australia's competitiveness and the role of R&D policy, notes that R&D investment also has positive feedbacks and spillovers:

> Crucially, the larger the stock of knowledge, the easier it is to increase it. Better educated and more knowledgeable people learn faster and develop new ideas more easily' … 'The second channel is R&D spillovers, which involves the notion of transfers of knowledge among firms for which no payment is made (1995, p. 153).

There are many ways of improving an organisation's knowledge base including research, learning by doing, reverse engineering, imitation and the purchase of equipment (Dosi and Castaldi 2002) but all encourage specialisation and trajectories. Patel and Pavitt (1998) argue that technology development by nations is both

[7] This is also the title of their report.

uneven and divergent and earlier (1994) they suggested that while national technological specialisation trajectories are not predetermined, the incentives structure and the available resources do create likely evolutionary patterns. Dosi and Castaldi (2002) find evidence in the literature to support the argument that, globally, countries have diverging technological capabilities. However, this trend is less pronounced for countries within the OECD group. Interestingly, economic growth patterns reveal that the advanced economies are converging with each other but largely diverging from the rest of the world (see, e.g. Dowrick and DeLong 2001).

2.3.1.2 The Non-Globalisation of Corporate R&D

Knowledge (as opposed to information) is not only cumulative, but is also geographically 'sticky' (in Dosi's 1999 words). Such stickiness derives from several dimensions including the cumulative nature of knowledge specialisations (as above) and the limited geographic spillover of tacit knowledge (discussed below in Sect. 3.4.3[8]).

In terms of the role of nations, it might be expected that as production activities are internationalised, multinational corporations may wish to internationalise their research efforts. Neo-Schumpeterian research has, however, not found strong evidence for the decentralisation of R&D centres away from being geographically near the home bases of multinational corporations. Patel (1997) found that firms tend to keep their R&D activities in their home country, although there is a trend towards increasing the amount of R&D that is located abroad (see for example OECD 2008b). While generally supporting this existing view of the involvement of multinationals in R&D, Carlsson suggests that 'innovation systems may have become more leaky over time. The role of tacit knowledge and the spatial limits of knowledge spillovers have caused firms to locate R&D facilities where new knowledge is being created' (2003, p. 21). There is a significant literature on the knowledge production and absorption-activities of multi-national enterprises[9] and international knowledge spillovers.[10] This line of research is not pursued in depth in the present thesis, as the purpose here is not to map the extent to which knowledge flows, but to begin to develop an understanding of how local knowledge contributes to local specialisations within internationally extended value chains.

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[8] In chapter 3 (below) it is shown that the limited spatial spillover of tacit knowledge is a key argument for industrial agglomeration.

[9] Readers interested in R&D location and internationalisation can start with Paoli and Guercini (1997), Gassman, and von Zedtwitz (1998a) and OECD (1998a).

[10] On the role of FDI and international knowledge spillovers – see Van Pottelsberge De La Potterie (1998) and Verspagen and Schoenmakers (2000) on the spillover of knowledge in patents.

2.3.2 Production System Specialisation and Trajectories

As noted above knowledge specialisations accumulate in trajectories and it can also be shown that knowledge and industrial specialisations trajectories co-evolve. It has already been pointed out that in the early stages of the industrial revolution the development of formal training systems aided Germany's ability to gain the predominant share of the European industrial chemicals sector. Landes describes this shift as one of the most rapid industrial transitions in history (1998). This link between learning and industry is not, however, just an interesting facet of the birth of the modern age. A statistically significant association between scientific performance and economic specialisation for science based, scale intensive[11] and some resource-based industries has been found by Laursen and Salter (2001, p. 18).

With this connection in mind, Wixted (2005, p. 35) charts the national configuration of manufacturing value added and manufacturing exports (2005, p. 36) for OECD countries for 1994. The first chart reveals that Germany, Japan and Korea are countries with a strong manufacturing presence in a number of industries. In contrast to the first chart, the second demonstrates that many countries have export specialisations in the same industries. The transport, non-electrical (industrial) machinery, electrical machinery as well as food and textiles all appear as having overseas sales above 2% of GDP for a number of countries. As most East Asian economies are not represented in the database, export strengths in electronics do not feature prominently. This cross-country profile of export specialisation is consistent with the World Trade Organization (2003) list (in order) of the most globally traded industries; transport and machinery equipment, office and telecom equipment, mining commodities, chemicals, automotive and agricultural products.

How these country specialisation patterns emerge and how they evolve has been of interest to neo-Schumpeterians, although the processes leading to increased levels of cross border economic activity in these industries is of less interest. Evidence on structural stability of the specialisation of economies is a key piece of evidence in debates over the nationally bound conditions for knowledge creation and innovation which are the basis for arguing for NIS. In particular, the speed of change can be used as a measure of the scale of economic movement and the continuing importance of both the nation state and knowledge production for industry. Slow change, for example, is used as evidence that 'globalisation' processes are limited by endogenous factors of knowledge accumulation.

The evidence, in fact, is that industrial structures do evolve relatively slowly. Archibugi and Michie (1998) note that manufacturing specialisations change 'very slowly' with it being difficult to 'move from an established competitive advantage in one industry to another' (1998, p. 11). These authors draw attention to the underlying

[11] These classifications of industries are also used in the current analysis and discussed in chapter six, and the link between science and scale based activities is interesting in the light of the research presented there.

technological competencies of industries, linking industry development to the cumulative processes of knowledge progress. Industrial employment structure is shown by Metcalf et al. (2002) to change, at a fairly constant rate, but industrial structure as measured through production output shares exhibit a degree of continuity over approximately 20 years. Output shares appear to resist change for a period of time and then change can occur quite rapidly – relative to the initial conditions. At the level of manufacturing sector sub-branches, Wolff argues that the industrial specialisation of OECD countries changes very slowly, commenting:

> 'The finding of little change in the degree of specialization among manufacturing industries may appear somewhat surprising in light of the evidence that aggregate measures of factor endowment (such as capital-labour ratio for the whole economy) have become similar in these advanced economies. On the other hand, the result is consistent with the finding that dispersion of productivity at the industry level remains high, and that there has been no strong trend toward cross-country convergence of industry-level productivity since mid 1970s. It appears countries are maintaining specializations in different industries; in this way convergence of aggregate productivity can be consistent with continuing divergence of industry-level productivity and a continuing high dispersion in production patterns' (2000, p. 200).

Curiously, therefore, despite a convergence of factor endowments across advanced economies, industry specialisations are not converging. Even so-called low technology industries are resistant to wholesale movement. Dosi et al. (1994) suggest that textiles and clothing have often been the starting rung for industrialisation for developing economies and, by implication, is more easily internationalised. However, low technology industries have, in a number of cases, not moved offshore as expected. In an article titled 'the strange life of low tech America' (1998, pp. 81–82), The Economist, in almost surprised tones, explores the continuing success of some very low cost, low technology activities in the USA. Amongst the various explanations of this success are the prevalence of trade protection barriers, the benefits of being close to markets for these industries, and the accumulation of skills which are necessary for industry competitiveness together with unexpected levels of ongoing product development in these industries.

Such trends point to the importance of local sources knowledge and innovation, and it is argued by some that these sources are likely to remain predominantly national without large movements across the borders of developed countries (see Ernst 2000). This 'spatial stickiness' (Ernst 2000, p. 2) of knowledge and innovation facilitates countries developing measures that maintain their technological superiority and could be behind the increased movement of goods and services, as there is a growing need to integrate technologies that have not been developed 'in country'.

2.4 Nations in a Changing World: Weaknesses of NIS

The evidence presented so far in this chapter provides strong grounds for continuing to believe that political nation states remain economically important domains of the world economy. Particular characteristics of the processes that lead to the generation

of new knowledge, together with the dynamics of technology diffusion, appear to preference national spaces over a borderless world. This does not, however, imply that the national system of innovation approach is without serious problems, particularly in relation to exploring the current changes in the global architecture of production. These are explored in the section below.

2.4.1 NIS and National Geography

The seemingly unquestioning acceptance of national borders within the NIS framework ignores the differences generated by the scale and structure of countries. In the United States, the national Government funds, by global standards, a very large defence and medical research[12] program. Thus, the USA's Federal Government clearly has had a very strong long-term impact on the dynamics of the US innovation system. At the same time, California by itself is the world's 6th largest economy. California has benefited from federal research funds and from the opening up of new urban spaces during the twentieth century – in a movement of population from east to west (see Saxenian 1994). Today, California has substantial clusters in manufacturing and services with a major share of world demand for ICT equipment.[13] It thus appears that California has benefited both from being included within the overarching political structure of a large nation state (itself the world's largest economy) and from regional spatial agglomeration processes.

The NIS approach seems to both suffer from, and to continue a confusion caused by the lack of long-term statistics at the sub-national level.[14] The nation state is the dominant statistical feature of our understanding of global economics. International trade data is generally collected at the level of the nation state and not regions. Other data, such as industry value added or research expenditure for some countries, also becomes problematic below that of the national level. This availability of data biases analysis towards nation states. So whilst the emphasis of the NIS approach is on the uneven development paths of nations, even Freeman (2002, p. 209) points out that uneven development exists within countries. Therefore an interesting possibility it that the irregularities in development of long-term specialisation

[12] AAAS (2004b).

[13] The latest estimates reveal that the USA has a significant share of the world market for ICT (European) Information Technology Observatory (EITO) 2004 estimates that the USA has 32 per cent of the world market and all of Europe (including the East) has 30 per cent of the world market. Analysis of Bureau of Economic Analysis data suggests that California represents approximately 17 per cent of the USA's value added in electronic and electrical equipment.

[14] Classifications of 'regions' still suffer from problems – see Casellas and Galley 'The EU Nomenclature of Territorial Units for Statistics, referred to by the French acronym NUTS, is very heterogeneous in character. Tiny islands, cities, large rural regions and entire countries are considered to be comparable units for analysis' (1999: 551).

patterns (knowledge accumulation and industry) seen in NIS studies may well be present at the level of regions (states or, provinces) but these issues are little analysed due to data deficiencies (see Chap. 3, for discussion).

2.4.2 NIS Politically Defined

Freeman's view that the 'phenomena of forging ahead, catch-up and falling behind in nineteenth and twentieth centuries can most plausibly be explained in terms of national systems' needs to be tempered as such a generalisation ignores the changes to the power, borders and nature of those nations (2002, p. 209). As Elam writes:

> While technologies have been successfully portrayed as fluid and always in the making, nation-states have been largely accepted as fixed, stable and ready made. What has escaped attention is that just like technologies, nation-states are also being continually envisioned, designed, launched, remodelled, renamed, disassembled and scrapped. By failing to take adequate account of the historical contingency of modern nation states, research on national systems of innovation has been handicapped in its attempts to grasp contemporary phenomena such as globalisation and European integration (1997, p. 157).

Borders and constitutional political power evolve over time and may change more quickly and more often than those in the EITC field appear to acknowledge. The powers of the European Union have been in a constant state of flux since its birth in the post World War II period, as Table 6.8 makes clear. Each change and each enlargement of the European Union alters the dynamics of development and the process of change is unlikely to stop in the near future with ongoing negotiations for a written constitution and the enlargement process is envisioned to continue beyond the 10 countries that joined in 2004. The 10 new 2004 members plus the two 2007 new members of the EU will alter the dynamics of the pre-2004 economies in ways that are not entirely clear (see Gorzelak and Jalowiecki 2002). Recent research suggests that supra-state structures can play a role in promoting innovation and development[15] through a re-distribution of funds to lagging regions and even assists in determining nation state borders.[16] Although their impact is less, multilateral agreements on trade and intellectual property[17] can influence the commercialisation of innovation and the catch-up processes.

Only a few authors seriously suggest systems of innovation can extend beyond national borders. Even fewer studies can be identified that actually conduct supra-national research. The OECD identifies the concept of worldwide systems but notes that 'national characteristics and frameworks always play a role in shaping

[15] See for example the discussions in Cappelen, Fagerberg and Verspagen 1999 and 2000 on the effect of European Union structural funds for promoting regional development.

[16] The Economist (2003c) *When small is beautiful* (p103) argues that the trend in recent examples of nation-state formation is towards smaller rather than larger borders. Crucially, however, it suggests that this might be due to supra-state structures such as the European Union that offer free trade zones across borders and other benefits of Federalism.

[17] See for example Turpin (2000) for an interesting discussion of IPR in Asia Pacific countries.

them' (1999c, p. 23). However, despite the acknowledgement, the study does not actually identify any specific research that fits such a category.

Elsewhere the term 'supra-national systems of innovation' has emerged. It is used by Bergman, Charles and den Hertog (2001, p. 9) and by Edquist (1997b and 2001). Few references are provided, however, it is typical to conceive of the supra-nation system as the entirety of a distinctive political system or jurisdiction. As Edquist indicates, 'one may – in Europe – distinguish between a supranational system at the European Community level, the national level, and the regional/local level' (1997b, p. 16). The examples of both Caracostas and Soete (1997) and Gregersen and Johnson (1997) both support the principle that innovation systems researchers have a tendency to think in terms of politically defined structures as the starting unit of analysis before focusing on the working dimensions of the 'system'. The latter commenting that the 'European system of innovation only exists, so far, in a rather narrow sense' (1997, p. 489). Rather than focusing on potential cross-border functional sub-systems, they were testing for the rather more nebulous idea of generalised European integration.

Such a perspective excludes the possibility that there might be supra-national systems that encompass, for example, the Scandinavian countries (noting that Norway is not a member of the EU) or that Germany and France might have close ties without the need for all the countries in the EU to have ties with each other in a European System. Such unity is unlikely to occur even within a single country's borders. The political definition of systems also excludes analysis of cross-country economic links, which change structure depending upon the sector.

Therefore, promoters of the NIS perspective over-emphasise the position of countries within the global economy. There are too few analyses of the causes and drivers of technological fragmentation (see Pavitt 2003a, b,[18] and Chaps. 6–9) – where technological products are integrated from across the world. Instead policy recommendations such as those suggested by Archibugi and Iammarino (1999) are designed to strengthen individual countries (Table 2.1).

Table 2.1 A response to globalisation: widening national technology portfolios

Categories	Targets		Instruments
International exploitation of national innovations	Inward flows	Achieving lower foreign dependency and filling technology gaps, increasing learning.	Incentives to infant industries. Promoting collaborations between national firms and leading firms in the field. Incentives to selected FDI in the country.

Source: Archibugi and Iammarino (1999, p. 327). This is a row from Table 7: Public policies targets and instruments for the globalisation of innovation.

[18]Pavitt in a series of articles on globalisation discusses the shift of manufacturers in advanced economies from owning factories to focusing on design and product integration. Pavitt foresees a likely shift of manufacturing to developing economies but does not discuss the possibility that components or complementary products sourcing may move across (the) border, but be built in developed economies.

Given the evidence, already presented in this chapter regarding the difficulties of shifting technological or industrial specialisations, the advice here to 'fill technological gaps', is surprising. The technological complexity of products is increasing and thus the ability of countries to specialise in all the components for a given product would appear to be decreasing.

2.4.3 NIS, Borders and Economic Space

Carlsson puts it so simply 'in view of the fact that most studies of innovation systems focus on national innovation systems, it is not surprising that little direct evidence is found that innovation systems are becoming global' (2003, p. 20). Carlsson could uncover only a few analyses of the internationalisation at the spatial scale of systems. The analysis presented here is in agreement with Carlsson's assessment of the literature. However, to simply expand the definition to larger but, nevertheless, politically defined territories such as the European Union also seems to be a dead end analytically.

Many of the findings of the national innovations systems literature appear to be strongly substantiated by empirical evidence. What is strongly disagreed with here is the lack of attention that has been given to explaining the increasing prevalence of economic links and embodied knowledge flows (and innovation flows?) that are crossing national borders. The big question for those that promote NIS over other approaches is, if, as Edquist (1997b) notes, interdependency is central to the very essence of innovation theory, then why are interdependencies bounded by national borders? Niosi and Bellon (1994) is the only major exception that could be identified for this study. They identified a trend of increasing interconnectedness in the development of national systems of innovation as companies and scientists interact and move across borders.

Too frequently, data results of cross border innovation patterns are presented as a general preference for national systems or proximity without the means to look for specific spatial structures in the data that might represent functional systems of innovation that extend internationally at important levels of scale.

Although the nation state is an enduring politico-economic phenomenon, to construct the analysis of the massive changes in political and economic power that is occurring with the rise of East Asia and China, while existing economies remain prosperous, purely around nation state entities ignores critical dimensions of the interdependencies between countries. It is argued throughout this analysis that there are clear theoretical, empirical and methodological reasons to choose an analytical tool that allows the strengths of linkages between two places to define the spatial cores of interacting systems. Analysis should retain a spatial and therefore a systems perspective as is argued in the next chapter, which explores the research on sub-national systems (clusters and regions, etc.).

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