Comparing National Systems of Innovation in Asia and Europe: Growth, Globalisation, Change, and Policy[1]

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1. Introduction

The concept of national systems of innovation (NSI) first emerged in the early 1990s with the seminal contributions of Lundvall (1992) and Nelson (1993). Subsequently it has attracted the attention of many innovation researchers and policy-makers (Amable 2000; Edquist 1997, 2005; Freeman 1997, 2002; Mytelka and Smith 2002; OECD 1997, 2002; Saviotti 1996) and has rapidly achieved broad international diffusion in both developed and developing countries (Correa 1998; Kaiser and Prange 2004; Liu and White 2001; Niosi 1991). However, progress in refining the SI concept has been uneven and difficult to assess, given that "no single definition has yet imposed itself" on NSI theory and research (Niosi 2002: 291). As argued previously (Edquist 2005: 201 – 203), there is a need for theoretically based empirical research to 'straighten up' the approach – a project to which comparative research on varieties of innovation systems, as well as determinants of innovation processes within them, can make particularly valuable contributions.

This article reports on the findings of a comparative study of ten 'small economy' NSIs in Europe and Asia, conducted from 2003 to 2006 under the auspices of the European Science Foundations (ESF) and participating national science councils. This study, referred to by participants as the 'Ten Country Project', was initiated some ten years after the publication of Lundvall's (1992) and Nelson's (1993) landmark anthologies on NSIs, and had the aim of contributing to further refinement and elaboration of the NSI concept. Contributors included national research teams in Denmark, Finland, Hong Kong, Ireland, (South) Korea, The Netherlands, Norway, Singapore, Sweden and Taiwan.[2]

Theoretically, the project was informed by the contrast between the 'broad' conception of NSIs championed by Lundvall (1992) and the 'narrow' approach promoted by Nelson (1993), as previously discussed by Edquist (1997, 2005). However, its aim was not simply to replicate and test existing frameworks but rather to contribute to further development by adopting a new approach. Whereas both of the original frameworks for studying NSIs were focused strongly on 'actors' within the systems, the

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[1] This article is based on the introductory and concluding chapters for the forthcoming anthology: Edquist C. and Hommen, L (Eds.). 2006 - forthcoming. *Small economy innovation systems: Comparing globalisation, change and policy in Asia and Europe*. Edward Elgar: Cheltenham, UK.

[2] We have adopted the common term countries here, but Hong Kong is not, properly speaking, a country in the sense of a nation-state. Formerly a British Crown Colony, Hong Kong was made a Special Administrative Region (SAR) of the People's Republic of China by the Sino-British Joint Declaration of 1984, and assumed that status in 1999. However, the 1984 Joint Declaration ensured preservation of Hong Kong's capitalist system and 'way of life' for 50 years, and this principle is reflected in the 'one country-two systems' framework that was subsequently enshrined in the constitution of the Hong Kong SAR.

comparative framework employed in this project instead followed Edquist's (2005) recent proposals to develop a central focus on fundamental 'activities' within systems of innovation. The project also sought to counter the criticism that NSI analyses pay too little attention to 'external' factors by explicitly taking into account processes of globalization. The comparative analysis reported in this article addresses the complex relations between growth and innovation, the issues raised by globalization, and the implications for innovation policy. A range of other issues will be addressed in the forthcoming book (Edquist and Hommen 2006) on 'small economy' national systems of innovation. It will include 10 country studies following the same table of contents, a theoretical introduction and a concluding comparative chapter.

One of the key questions that we address below concerns the validity of competing NSI concepts – the aforementioned 'broad' and 'narrow' approaches to defining NSIs. For the most part, these two frameworks have not confronted one another directly within the research literature. Instead, researchers have tended to adopt one or the other of these two basic approaches, or to elaborate variants of them, without giving much consideration to the alternative approach. Thus, Lundvall et al. (2002: 217, n.2) have discussed the further development of their 'broad' approach to NSIs without making many explicit comparisons with the 'narrow' approach, except to comment that the 'broad' approach is particularly "relevant for understanding economic growth and innovation processes in small countries". Similarly, Laredo and Mustar (2001) have applied the 'narrow' version of the NSI concept in their international survey of research and innovation policies without much consideration of its merits relative to the 'broad' alternative. It is fair to say that although the two versions of the NSI concept have enjoyed a peaceful coexistence, there has been only minimal dialogue between them. We will return to this question in the theoretical discussion that follows, as well as in our analysis and conclusions.

The remainder of this article is structured as follows. This introductory section is immediately followed by an extended theoretical discussion, which compares the 'broad' and 'narrow' NSI concepts, outlines an activities-based based framework to studying SIs and identifies key problems to be addressed in research on SIs. Subsequently, we discuss the methods used to operationalize the 'activities' approach within the Ten Countries Project. Thereafter, we categorize the ten NSIs included in the project, and develop an overview of the NSIs. We then discuss some key findings from the project and the main conclusions that can be drawn from them. Finally, we consider policy implications.

2. Theoretical and Practical Issues in Research on NSIs

In this section we outline some central theoretical and practical issues in research on NSIs. The main theoretical issue, ultimately deriving from definitional differences, concerns the character and coherence of NSIs – i.e., whether or not they are truly 'systemic' in the sense that the whole has properties distinct from those of its constituent parts. Practical issues include both the requirements of comparative research on NSIs and policy questions, particularly the debate on non-selective versus selective measures.

2.1. 'Narrow' versus 'Broad' Approaches to Studying NSIs

As discussed elsewhere (e.g., in Edquist and Chaminade 2006), the term 'national system of innovation' (NSI) was first used in published form by Freeman (1987). He defined an NSI as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies" (ibid.: 1).[3] Subsequently, Lundvall (1992) and Nelson (1993) both published major anthologies on NSIs, but used different approaches to the study of NSIs. Nelson (1993) emphasised empirical case studies more than theory development and some of the studies in his book focussed narrowly on national research and development (R&D) systems.[4] Moreover, these case studies were not designed to have the same structure and focus. In contrast, Lundvall (1992) was more theoretically oriented and sought to develop an alternative to the neo-classical economics tradition by placing interactive learning, user-producer interaction, and innovation at the centre of the analysis.

Lundvall argued that "the structure of production" and "the institutional set-up" are the two most important dimensions that "jointly define a system of innovation" (Lundvall 1992: 10). In a similar way, Nelson and Rosenberg (1993) singled out organisations supporting R&D -- i.e., they emphasised those organisations that promote the creation and dissemination of knowledge as the main sources of innovation. Organisations disseminating knowledge include firms, industrial research laboratories, research universities, and government laboratories. Lundvall's broader approach recognised, though, that such organisations are "embedded in a much wider socio-economic system in which political and cultural influences as well as economic policies help to determine the scale, direction and relative success of all innovative activities." (Freeman 2002: 195) Thus, both Nelson and Lundvall defined NSIs in terms of determinants of, or factors influencing, innovation processes.[5] However, they specified different determinants in their definitions of the concept, presumably reflecting their judgment about the most important determinants of innovation. Hence, they proposed different definitions, but used the same term, reflecting the lack of a generally accepted definition of NSIs.

Nelson and Lundvall not only offered definitions of NSIs that focussed on their components (e.g., main actors and institutions and relations among them). They also expressed fundamental differences of opinion concerning the structural integrity of NSIs. Lundvall (1992) stressed the continuing importance of NSIs, even under conditions of increasing globalization and regionalization – trends that challenge the unity and coherence of national systems. One of his main arguments for this position was that

[3] Freeman here means "organisations" in the sense of players and not "institutions" in the sense of rules. In addition, we currently use the term innovations instead of technologies – implying that we include new creations also of a non-material nature, e.g. service product innovations and organisational process innovations. Finally, it is interesting to note that in 1987 Freeman had already pointed out the "activities" carried out by the organisations – see below in this article.

[4] This emphasis is crystal clear from Nelson and Rosenberg (1993, p.4): "…the orientation of this project has been to carefully describe and compare, and try to understand, rather than to theorise first and then attempt to prove or calibrate the theory".

[5] Their definitions of NSIs do not include, e.g., consequences of innovation. This does not mean that innovations emerging in SIs do not have tremendously important consequences for socio-economic variables such as productivity growth and employment – on the contrary. Moreover, distinguishing between determinants and consequences does not, of course, exclude feedback mechanisms between them.

current processes of change and transformation must be understood in relation to the "old order" upon which they act – i.e., the pre-existing pattern of "interaction between institutions and economic structure … at the national level" (ibid.: 4). A further implication is that since the "old order" conditions these evolutionary processes, it is likely to be reflected (and thus partly continued) in distinctive national trajectories. In contrast, Nelson (1993) acknowledged that NSIs have tended to exhibit institutional continuity over time, but nevertheless expressed considerable scepticism about the overall coherence or consistency of NSIs in terms of industrial structure. Thus, he questioned whether "the concept of a national system [makes] sense, nowadays", given pronounced sectoral differences in "the system[s] of institutions supporting technical innovation" and the growth of strong "transnational" institutions in many fields of technology (1992: 350). A key implication of this line of reasoning is that NSIs may ultimately be largely reducible to *ensembles* of sectoral systems of innovation (SSIs).

In order to test these rival propositions of the two original approaches to studying NSIs, we require a definition of NSIs that encompasses both the 'broad' and 'narrow' definitions discussed above. A more general definition of an SI includes "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist 1997: 14). If an SI definition does not include all factors that influence innovation processes, one has to argue which potential factors should be excluded – and why. This is quite difficult since, at the present state of the art, we do not know the determinants of innovation systematically and in detail. Obviously, then, we could miss a great deal by excluding some determinants, since they might prove to be very important once the state of the art has advanced. For example, 25 years ago, it would have been natural to exclude the interactions between organisations as a determinant of innovation processes. Both the relationships among the factors listed and the actions of both firms and governments are included in the general definition above. This definition, moreover, is fundamental to the 'activities' approach to studying SIs (Edquist 2005; Edquist and Chaminade 2006) that we now turn to discuss.

2.2. An Activities-based Framework for Comparing SIs

Everyday language and the scientific literature give a common answer to the question 'What is a system?, focussing on three features (Ingelstam 2002). First, a system consists of two types of constituents: components and relations among them. The components and relations should form a coherent whole, with properties different from those of the constituents. Second, the system has a function -- i.e., it is performing or achieving something. Third, it must be possible to discriminate between the system and the rest of the world -- that is, it must be possible to identify the boundaries of the system.[6] Obviously, for empirical studies of specific systems, one must know their extension.

Making the SI approach more theory-like does not require specifying all components and all relations among them. At present, it is not a matter of transforming the SI approach into a general theory of innovation, but one of making it clearer and more consistent so that it can better serve as a basis for generating hypotheses about relations

[6] Only in exceptional cases is the system closed in the sense that it has nothing to do with the rest of the world (or because it encompasses the whole world). Like the SI approach, general systems theory might be considered an approach rather than a theory.

between specific variables within SIs (which might be rejected or supported through empirical work). Even the much more modest objective of specifying the main (rather than all) functions of SIs, their activities and components, and the key relations among the latter would represent a considerable advance. Used in this way, the SI approach can help to develop theories about relations between specific variables within SIs.

As indicated in the foregoing discussion of definitional issues, as well as in other sources (e.g., Niosi 2002: 291, Table 1), there seems to be general agreement in the literature that the main components in SIs are institutions and organisations – among which firms are often considered to be the most important organisations. However, particular definitions specify different sets of institutions and organizations and, moreover, specific set-ups of institutions and organisations vary among systems. Consequently, comparative research on SIs is doubly difficult. Even if we can bypass definitional disputes to some extent by adopting an *omnibus* definition of SIs including all determinants of innovation processes, we are left with the problem of functional equivalence -- i.e., the "many ways countries may develop … to organize what some would argue are 'functionally equivalent' activities" (Kogut 1993: 7). For example, the activity of R&D can be performed by different organisations, such as universities, public research organisations and firms. Our solution to this particular problem has been to develop a central focus on such activities.

Generally, the main or 'overall' function of SIs is to pursue innovation processes: that is, to develop and diffuse innovations. What we, from here on, call 'activities' in SIs are those factors that influence the development and diffusion of innovations. In this sense, we use the term activities as equivalent to determinants of the innovation process. Since the late 1990s, some authors have addressed issues related to specification of activities influencing the overall function of SIs (Galli and Teubal 1997; Johnson and Jacobsson 2003; Liu and White 2001; Rickne 2000). As argued elsewhere (Chaminade and Edquist 2006), we can broadly distinguish four main approaches to analysing activities in SIs.

To start with, Edquist (2005), Furman *et al*. (2002) and, though to a lesser extent, Liu and White (2001) focus on activities linked to the innovation process as such – i.e., activities needed to turn an idea into a new product or process. A second approach, represented by the work of David and Foray (1995) and Johnson and Jacobsson (2003) concentrates on activities linked to the knowledge production process – i.e., how knowledge is created, transferred, and exploited. Here there is a strong emphasis on channels and mechanisms for knowledge distribution. Third, some researchers (e.g., Borrás 2004) try to identify the activities of different organisations that have an impact in the innovation system. Finally, a fourth line of research focuses on innovation policy. The main question pursued is which activities (and organisations) in SIs can be stimulated by public intervention. The OECD (2002) and other international organisations follow this approach.

INSERT TABLE 1 ABOUT HERE.

Clearly, there is no consensus as to which activities should be included in an SI and this provides abundant opportunities for further research. In Table 1 we present a provisional list of ten priority activities that we have adopted as a basis for systematic

comparison of SIs. This list of activities is based on the literature (reflecting the research approaches mentioned above) and on our own knowledge about innovation processes and their determinant. It is structured into four thematic categories: (i) the provision of knowledge inputs to the innovation process, (ii) demand side activities, the (iii) provision of constituents of SIs, and (iv) support services for innovating firms. This list is provisional and will be subject to revision as our knowledge about determinants of innovation processes increases. In addition to a set of activities that is likely to be important in most NSIs, there are activities that are very important in some types of SIs and less important in others. For example, the creation of technical standards is critically important in some (sectoral) systems, such as mobile telecommunications.[7]

The activities-based approach to SIs suggested here does not imply that these systems are or can be consciously designed or planned. On the contrary, just as innovation processes are evolutionary, SIs evolve over time in a largely unplanned manner. Even if we knew all the determinants of innovations processes in detail (which we certainly do not now, and perhaps never will), we would not be able to control them and design or 'build' SIs on the basis of this knowledge. Centralised control over SIs is impossible and policy can only influence their spontaneous development to a limited extent.

2.3. Applications to Public Policy

Thus far, we have argued that an 'activities-based' framework enables us to address some longstanding theoretical debates concerning the character and dynamics of SIs. We have additionally argued that one of the main advantages of such a framework is to provide a basis for systematic international comparisons that can avoid the pitfalls of structurally based or actor-oriented NSI definitions. In what follows, we will advance the claim that an 'activities-based' framework is also very useful for identifying and assessing policy issues within SIs. We will argue in particular that this framework – and, more generally, the systemic approach on which it is based – is superior to the conventional 'market failure' approach to specifying and evaluating the grounds for policy intervention.

As discussed elsewhere (e.g., Edquist 1997; Edquist 2001), market failure in mainstream economic theory implies a comparison between conditions in the real world and an ideal or optimal economic system. However, innovation processes are path dependent over time, and it is not clear which path will be taken as they have evolutionary characteristics. We do not know whether the potentially optimal path is being exploited. Moreover, the system never achieves equilibrium. For these reasons, the notion of optimality is irrelevant in an innovation context. It follows that we cannot specify an ideal or optimal system of innovation and, therefore, comparisons between an existing system and an optimal system are not possible, and – as a corollary – it is not meaningful to talk about optimal policies. Thereby, the notion of market failure loses its meaning and applicability.

Instead of market failure, researchers following a systemic approach often speak of systemic problems.[8] In contrast to the conventional approach outlined above, the main focus of the systemic approach is the complex interactions that take place among the

[7] The activities in this sectoral system of innovation are discussed in Edquist (2003).

[8] This means that the systemic approach decreases the degree of rigour and formality. It specifies 'problems' on an empirical basis and in a pragmatic way – not by referring to a formal model.

different organisations and institutions that constitute the system of innovation. From this perspective, policy makers need to intervene in those areas where the system is not functioning well. The rationale for innovation policy should therefore be based on 'systemic' failures or problems rather than on 'market' failures (Chaminade and Edquist, 2006; Edquist 2001; Edquist and Chaminade 2006). A variety of systemic problems are mentioned in the relevant literature (Smith 2000; Woolthuis et al. 2005), referring to deficiencies in infrastructure and organisational capabilities, evolutionary obstacles rooted in risk and uncertainty, institutional hurdles (both regulatory and cultural) faced by innovative actors, and barriers (cognitive and other) to effective networking. These various kinds of problems commonly point to institutional and organizational issues that can not be conceptualized or addressed exclusively in terms of the (ideal) operation of market mechanisms. Instead, they identify bottlenecks, discontinuities, gaps and inconsistencies that reflect "the contextually specific nature of innovation processes" (Smith 2002: 1477).

As argued elsewhere (Edquist and Chaminade 2006), the 'activities' framework for analysing SIs proposed above can fruitfully be used for innovation policy purposes, since the activities that influence innovation processes in SIs provide a useful point of entry into policy analysis. Thereafter, one can identify the organisations performing the activities and examine the relations among them. Often, there is not a one-to-one relation between organisations and activities, since a certain kind of organisation can perform more than one activity and many activities can involve more than one category of organisation. With respect to innovation policy, we can analyse the division of labour between private and public organisations with regard to the performance of each of the activities in innovation systems and determine whether this division of labour is justified or not. Key questions regarding the grounds for policy intervention are, first, whether there exists a systemic problem not spontaneously solved by private actors and market forces (i.e., firms and markets fail to achieve given public policy objectives) and, second, whether government bodies or public agencies have the ability to solve or mitigate the problem (Edquist 2001). The policy discussion at each point should focus on changes in the division of labour between the private and the public spheres and on changes in those activities already carried out by the public agencies. This includes not only adding new public policy activities but also – and not least importantly -- terminating others.

As noted above, one of the main differences between conventional (or mainstream economics) and systemic approaches to innovation policy is that the conventional approach begins by trying to define an ideal or optimal market model, whereas the systemic approach focuses on interactions among the constituents of an innovation system, and compares existing systems with each other. These two approaches tend to define problems very differently, and they also recommend different overall strategies for problem-solving. One of the main differences between the two approaches is therefore reflected in current debates on non-selective *versus* selective innovation policies. In this respect, current understandings of innovation policy are divided into two main camps. A non-interventionist "*laissez-faire* version … [which] signals that the focus should be on 'framework conditions' rather than specific sectors or technologies" competes with a "'systemic' version … [for which] a fundamental aspect … becomes the reviewing and redesigning of the linkages between the parts of the [innovation] system" (Lundvall and Borrás 2005: 611). From the systemic perspective, innovation policy – like most other

public policy -- is naturally selective, since even policies that try to avoid 'picking winners' by addressing market operations in general tend in practice to favour certain sectors, often preserving "the existing structure of production" and already established technological trajectories (Edquist 2001: 224 – 225).

The question then becomes in which *direction* or in which *respects* the innovation policy is – or should be – selective? Most large firms in established sectors of production pursue lobbying intended to make public actors support their own sectors and firms. New and nascent sectors normally do not include strong actors and can therefore not pursue lobbying in an effective way. However, public innovation policy intervention is generally more justifiable in new sectors or in new operations in established sectors, since "problems" that are not solved or mitigated by private organisations are more frequent in these contexts. This argument can be supported in the following way:

- Private organisations and markets have the greatest problems in handling *new* activities where uncertainty and risk are largest. In such operations there is a strong risk that firms will underinvest in R&D, or abstain from development activities since it is unclear if there is a market for the potential new products. Publicly financed R&D, public technology procurement, or incubation activities can mitigate such problems.
- There is empirical evidence that suggests that large-scale and radical technological shifts rarely take place without the support of public intervention – not even in the USA (as opposed to incremental innovation in established sectors). Carlsson and Jacobsson (1997) have shown this for technological breakthroughs in electronics, semiconductors, and genetic engineering in the United States and Sweden. Mowery (2005) has shown that publicly funded R&D in combination with public technology procurement has played a crucial role in developing new high-tech SSIs in the United States (and thereby in the world). Examples are computer hardware, computer software, large aircrafts, biotechnology and the Internet
- A small intervention at an early stage in an innovation process can have a very large effect. The NMT 450 mobile telephony standard is an example. A large intervention at a mature stage often has a very small effect. (An example was the Swedish public support to the shipyard industry in the 1970s and 1980s. The support for NMT 450 was a couple of hundred man-years and led to the emergence of a global industry, where Nordic firms are leading. The support to the shipyard industry absorbed 0.5 percent of the Swedish GDP over a 10-year period, but did not have any lasting results. The difficult thing is to "pick and support winners", but avoid "supporting losers" (in terms of sectors, technologies, and products). Still, this is the challenge for innovation policy – as well as for firm strategy.

Thus, lobbyism often seems to work for an innovation policy that should not be pursued. Instead the support should be channelled to operations and sectors where risk and uncertainty are largest. Innovation policy should play the role of a midwife – not provide support towards the end of life. This requires that policy-makers and politicians have a sophisticated analysis at their disposal, as well as a high degree of integrity, to counter-balance lobbyism.

Arguably, changing the structure of production and altering technological trajectories are among the most formidable policy challenges facing NSIs, given that when uncertainty and risk are high, the danger that markets will under-perform relative to public policy objectives is particularly great. For example, private actors might under-invest in basic R&D (Arrow 1962) or they might not invest at all in activities of great social return but low individual return (e.g., some drugs). High uncertainty might also prevent the emergence of innovations.

3. Comparing NSIs in the Ten Countries Project

In the literature on SIs, there has been an ongoing tension between, on one hand, demands for a more structured conceptual framework that would facilitate systematic comparisons and, on the other hand, insistence on recognizing the unique character of individual SIs. The first position is well represented, for example, in various contributions on 'benchmarking' by Niosi and colleagues (Niosi 2002; Niosi et al. 1993; Niosi and Bellon 1994), and it has also been adopted by the OECD (1997). The second position has been championed by, among others, Miettenin (2002) who argues for a more contextually oriented approach to describing SIs, based on the principles of historicity, industrial specificity and geographical specificity. The NSI literature has not yet fully satisfied either set of expectations, as NSI proponents admit (Lundvall 1999).

In the Ten Countries Project, we tried to strike a balance between these opposing views of how to study NSIs. On one hand, we paid close attention to basic statistics (on, e.g., educational attainment of the labour force, industrial structure, and globalisation) and performance indicators for growth, scientific activity (publication), patenting, and innovation. CIS II data was used extensively in descriptions of the European NSIs, and parallel data sets were used for their Asian counterparts. In addition to work on indicators, we also followed a common format for describing the ten NSIs, based largely on the 'activities' framework presented above, as well as including sections on 'globalisation' and the economic consequences of innovation for economic growth. On the other hand, however, we required each national study to take the NSI's historical background into full account, and we also asked for an assessment of the NSI's particular strengths and weaknesses, as well as its past accomplishments and future challenges in innovation policy. Perhaps most importantly, we encouraged contributors to identify for each NSI a central issue, problem, or paradox that illuminated its essential character – and these provide central themes in each of the country chapters.

In operationalising the 'activities' framework presented in the foregoing section, we were determined to avoid 'naïve benchmarking' – i.e., ranking the performance of countries on a set of indicators, while disregarding entirely the 'systemic' element in the systems of innovation concept (Lundvall and Tomlinson 2002). Instead, we followed what has been called a 'case-based' approach to making international comparisons. This approach develops a central focus on contexts and patterns, in order to provide a basis for generating causal analyses (Ragin 1987). Essentially, the analysis first draws out patterns from within cases, and then compares these patterns. To use somewhat different terminology, 'cross-case' analysis is preceded – and informed – by 'within-case' analysis, and both types of analysis focus on causal relationships.

Prior to focussing on the identification and comparison of patterns, we systematically mapped national contexts. We began with a detailed overview of economic performance over time, focussing on growth profiles, the processes and mechanisms by which economic growth had been achieved, and the linkages between growth and innovation. We also addressed globalization and its implications for innovation as another important contextual dimension. Subsequently, we examined the performance of NSIs. We used comparative patenting data indicating historical changes in revealed technological advantage (RTA) to distinguish between countries that had diversified their technological profiles, and countries that had not. Thus, our mapping of national contexts yielded two key dichotomies – 'fast' vs. 'slow' growth and 'broadening' vs. 'deepening' technology profiles -- to describe broad patterns of change over time. By combining these dichotomies into a four-fold matrix, we were able to classify the ten countries into four main groups, as will later be discussed in relation to Table 2, below.

To identify and compare patterns, we grouped our ten activities into four broad categories: 'knowledge inputs' (R&D and competence building), 'demand-side activities' (market creation and articulation of quality requirements), 'constituents of innovation systems' (generation of organizations, networks, and institutions), and 'support for innovating firms' (incubation, financing and consultancy services). We further combined these four categories into two main axes of activity: one corresponded to 'knowledge inputs' vs. 'demand-side activities', and the other to 'constituents' vs. 'support for innovating firms'. These procedures provided a compass that could be used to chart the occurrence of problems of inconsistency – imbalance, mismatch, or tension – in two main dimensions of activity that are fundamental for systems of innovation. The first dimension features the problematic of supply vs. demand that is conventional to standard economics and fundamental to the policy discourse of 'market failure'. The second is associated with the evolutionary economics problematic of diversity creation and the alternative discourse on institutional and organisational 'system failure'. By mapping the occurrence of what we have called innovation policy 'problems' in relation to these two axes, and by investigating their causes in terms of relationships among activities on both axes, we identified patterns that lent themselves to comparative analysis.

4. Grouping NSIs by Growth and Technology Development

In this section, we discuss how we arrived at an initial grouping of the ten NSIs, based on performance indicators compiled for the Ten Countries Project – particularly indicators for growth and technology development. First, we discuss the countries' growth profiles. Subsequently, we address their records with respect to technology development. Finally, we present a four-fold classification of the ten NSIs.

4.1. Patterns of Growth

Our study was especially concerned with the patterns of growth for these countries during more recent decades, and it is therefore appropriate here to characterize the countries according to their growth patterns over the past 30 years – i.e., from 1975 to 2005. Patterns of economic growth related to the ten NSIs are shown in Figure 1, below. The figure, which depicts growth in GDP per capita over the 1975 – 2005 period,

shows a clear separation between two groups of countries, with regard to their growth patterns.

We can thus distinguish between a first group of five countries marked by 'slow growth' and a second group of five countries that have exhibited 'fast growth'. The first, 'slow growth' group includes the countries of Denmark, Finland, the Netherlands, Norway, and Sweden. The second, 'fast growth' group includes the countries of Hong Kong, Ireland, Korea, Singapore and Taiwan. This grouping of the ten countries is neither surprising nor controversial, corresponding as it does to the well-known distinction between 'catching up' economies and those that are either 'falling behind' or risk doing so (Abramowitz 1986, 1994). In fairness to the first group of 'slow growth' countries, though, they generally appear to have been holding and in some cases improving their positions in recent years, rather than losing ground.

Our findings concerning the ten countries' growth patterns do not bring into question accepted explanations of differential rates of economic growth, though they may provide more support for some theories than for others. For example, the fact that all of the fast growth countries, despite their long histories, have undergone profound 'regime change' during the 20th century, through upheavals such as revolution, civil war, and de-colonization, may support the thesis that economic growth is best promoted by the removal of inhibitory political institutions protecting the vested interests of traditional ruling elites (Jones 2003).The various national studies served to highlight, with respect to 'fast growth' countries, that entry into the same 'growth sector' (the electronics and ICT industries) can be achieved by very different means. With regard to 'slow growth' countries, the national studies showed that slow growth can be coupled with very different sectoral specializations and technological trajectories.

INSERT FIGURE 1 ABOUT HERE.

4.2. Technology Development

With respect to technology development, a clear division can be made amongst the ten countries in terms of change in the direction of inventive activity over time. This division, moreover, cuts across the previously discussed categories of 'fast growth' and 'slow growth' countries.

To capture the direction of inventive activity over time, we constructed statistical profiles indicating historical change in patterns of revealed technological advantage (RTA), measured in terms of patenting activity occurring during the period from 1980 to 2001 (Bitard et al. 2006: Figure 3.2).[9] These 'technology profiles' covered eight of the ten countries, excluding only Hong Kong and Singapore. They were examined in terms of whether or not patenting activity over the whole period had maintained the same

[9] These profiles were originally produced as an addendum to the following 'indicator report' for the project: Wang, K. Tsai, M.-T., Luo, I Y.-L., Balaguer, A., Hung, S.-C., Wu, F.-S., Hsu, M.-Y., and Chu, Y.-Y. 2003. Intensities of scientific performance: Publication and citation at a macro and sectoral level of nine countries. Working Paper. Science and Technology Information Centre – National Science Council. Taipei, Republic of China.

pattern of specialization as indicated for the first sub-period, from 1980 to 1986, or developed new areas of specialization in more recent sub-periods.

On this basis, we were able to divide the national technology profiles into two distinct groups. One on hand, there is a group of countries that have significantly 'broadened' their technological profiles: Finland, Norway, Sweden, and Taiwan. Although they are not covered by the 'technology profiles', other evidence from the country reports indicate that Hong Kong and Singapore should also be included in this group, due to their recent initiatives to develop domestic biotechnology industries. On the other hand, there is a group of countries that have either maintained their earlier patterns of specialization or narrowed them: Denmark, Ireland, the Netherlands, and South Korea.

4.3. Patterns of Change over Time in NSIs

By combining the distinction between countries that had either 'broadened' or 'maintained/narrowed' their technological profiles with the previously discussed distinction between 'fast growth' and 'slow growth' countries, we were able to sort the ten NSIs into four main groups. These groups are shown in Table 2, below.

INSERT TABLE 2 ABOUT HERE

Grouping the NSIs according to these two sets of categories enabled us to specify four distinctive patterns of recent historical change among the countries. The summary account of the national studies that follows in the next section is organised according to this scheme.

5. Patterns of Activity in NSIs

In the following section, we provide brief accounts of the patterns of activity characteristic of the four groups into which the ten NSIs were divided, as discussed above. We are unable to provide detailed and comprehensive accounts of all ten cases, and therefore rely on brief summaries of the national studies prepared for the Ten Countries Project. For each cell of the four-fold matrix illustrated in Table 2, we describe and analyze the pattern of activity within NSIs, referring to two main axes of activity: 'knowledge inputs' - 'demand-side activities', and 'constituents' - 'support for innovating firms'. Due to space limitations, the discussion here does not address all the NSIs equally but focuses on selected cases. Sweden is treated as a leading example of a 'slow growth' country that has broadened its technological profile, and Taiwan as its 'fast growth' counterpart. Among countries that have instead deepened their technological profiles, The Netherlands represents 'slow growth' countries and Korea 'fast growth' countries.

5.1. Technology Broadening and Slow Growth: Sweden, Norway and Finland

Sweden, like Finland and Norway, has successfully broadened its technological profile under – and in response to -- conditions of slow growth. Of all these countries, however, Sweden may have made the least progress in technological diversification. Recent and fairly dramatic Swedish advances in Telecommunications and other fields such as Medical Electronics actually extend earlier specialization patterns and only appear to be 'new' from a longer-term perspective. In contrast, Finland's breakthrough in Telecommunications is much more recent, as is Norway's rapid progress in Medical Electronics. Of all three countries, however, Sweden retains the broadest overall profile.

Sweden has experienced an ongoing imbalance between the supply of and demand for innovations or innovation inputs, particularly R&D. The 'Swedish paradox' refers essentially to low pay-off in terms of new products from very large investments in R&D and innovation. This problem can be attributed to several causes: globalization resulting in commercialization of Swedish innovations abroad, ineffective technology transfer from research organizations to commercial application by firms, and a sectoral allocation of R&D investment favouring industries with low innovation intensity. The dominance of incumbent large firms (MNCs) is a common thread in all these lines of explanation.

Sweden's extensive support for innovating firms and entrepreneurial start-ups has resulted in only modest rates of new firm creation and only moderate success in strengthening specialization in fast growing 'high tech' industries. New firm creation and inter-firm networking remain dominated by large firms, and institutional arrangements (in e.g., labour markets and taxation) also sustain the dominance of large firms, many of them based in industries with low innovation intensity. There is considerable lack of fit between 'constituents' and 'support', such that the ultimate beneficiaries of the latter appear to be those least in need. The overall pattern of evolution in Sweden is one of gradual tradition from an innovation system dominated by large mechanical engineering firms to one in which science-based and information-intensive sectors will feature more prominently, but large incumbent firms are unlikely to be displaced by new entrants.

Similar dynamics can be observed in the other two countries. Norway exhibits little entrepreneurship in science-based and information-intensive sectors. Thus, extensive provision of support for innovating firms has brought poor results, due to the restrictive investment climate and structural rigidity bred by the dominance of large firms in the resource-extraction and transportation services sectors. In Finland, public-sector support for innovation, networking arrangements, and institutional reforms have been geared mainly to the successful development and internationalization of large firms such as Nokia. Entrepreneurial small firms have been much less well provided for.

5.2. Technology Broadening and Fast Growth Taiwan (Singapore and Hong Kong)

Taiwan is our leading example of a country that has broadened its technology profile under conditions of - or leading to - rapid economic growth. Indeed, it may be the only verifiable example, given the lack of corresponding data on the apparently similar cases of Singapore and Hong Kong. In Taiwan, broadening has occurred primarily through dramatically increased patenting in the field of Semiconductors and Electronics.

As in the Swedish case, though, Taiwan has been active in this field for some time, and it is only from a very long-term perspective that it constitutes a 'new' specialization.

Taiwan's rising rate of investment in R&D has been characterized by the fast growth of business expenditure on R&D and a dramatic increase in patenting. Similarly, the strong expansion of Taiwanese post-secondary education has increasingly focused on ICT-related scientific, engineering and technical skills. Balance between supply and demand has obtained, since these developments have been driven by the upgrading of firms in high-tech manufacturing sectors. These firms excel in production for high tech markets, drawing their competitive advantage from manufacturing and process innovation skills.

As it reaches the limits of factory automation and the adoption of advanced production techniques as a competitive strategy, though, Taiwan now confronts mismatches on the 'constituents-support' axis. These issues reflect the need of existing firms to diversify, through product innovation based on independent scientific and engineering capabilities. For Taiwanese firms to break out of the trajectory that they have established for themselves as technology followers and 'second movers', it has become necessary to reform existing institutions for protection of intellectual property and develop forms of R&D collaboration that facilitate appropriation of innovation.

Similar patterns emerge in the cases of Singapore and Hong Kong, both of which have recently diversified their pattern of innovative activity by investing in the emerging field of biotechnology. In Singapore, recent increases in indigenous R&D within targeted fields of science and technology have not been matched by the commercialization of indigenous intellectual property in corresponding sectors -- especially on the part of entrepreneurial high-tech start-up firms. Historically Singapore has concentrated on developing labour force competencies and skills, and its main R&D inputs have come from technology-intensive foreign MNCs with local operations. Singapore has successfully reconfigured public and private innovation capabilities several times over the past decades, through institutional reforms and changes in the provision of support to innovating firms. However, there has been little recent private-sector response to the current build-up of support services targeting entrepreneurial high-tech SMES. Prospects for developing indigenous R&D and innovation capability remain uncertain, and technological entrepreneurship in strategic sectors remains low, due to cultural factors (risk aversion), gaps in institutions and organizations (a lack of mechanisms 'bridging' R&D and seed investment) and the conservatism natural to a small domestic market. In Hong Kong, support for innovating firms largely reinforces the dominant producer services trajectory by developing consultancy services and financing ICT projects, but incubation targets the nascent biotechnology industry. This divided focus indicates possible future tension and conflict between established and emerging industries. All three cases reveal the difficulties of diversification in the face of path dependency.

5.3. Technology Maintaining and Slow Growth: The Netherlands and Denmark

In the Netherlands, unlike Sweden, there has been no significant broadening of the country's technological profile in recent years, and both advances and retreats in patenting have occurred only in areas of specialization that were established at an early point. Recently, the strongest advances have occurred in the fields of Food and Tobacco, Biotechnology, and Medical Electronics, all of which were already areas of strength for

the Netherlands in the early- to mid-1980s. A similar pattern obtains in Denmark, perhaps most notably in the fields of Food and Tobacco and Biotechnology.

In the Netherlands, despite very high performance with respect to knowledge inputs, innovative activity has levelled off and private sector R&D has begun to decline, at least in relative terms, implying diminishing demand for these inputs. A pattern of sectoral specialization that de-emphasizes manufacturing, together with globalization effects, makes it difficult to improve system performance simply by increasing knowledge inputs. Instead, balancing supply and demand requires the Netherlands to gear inputs to emerging growth sectors.

The problems encountered in the Netherlands include low levels of entrepreneurship and inadequate interaction between universities and other public research organizations and private sector actors, reflected in low levels of knowledge transfer and research commercialization. The overall pattern is one of an impasse bred by 'lock-in' to institutional and organizational arrangements that serve incumbent firms in declining (or de-industrializing) sectors better than 'new entrants' in emerging sectors. The Netherlands NSI appears to be a 'dual system'. The universities, most research institutes, and many public research organizations cater primarily to large incumbent firms, well established but declining industries, and 'relatively old' technological fields. In contrast, only a few organizations provide inputs to new firms, industries, and technologies. Also, creation of new firms, industries, and technological innovation platforms is often poorly coordinated with corresponding forms of support, some of which are inadequately funded.

Denmark, like the Netherlands, has maintained essentially the same technological profile over the past two or more decades. Its current transition towards a more mixed mode of innovation combining a science and technology driven mode with the traditional mode based on doing, using, and interacting has so far not entailed any major disruptions. Against this background, recent policy appears to have led in a potentially disruptive direction that may actually become problematic, depending on the strength and focus of initiatives to bring about structural change through efforts to strengthen high technology sectors by promoting university-industry interaction and the creation of science-based firms and industries. However, policy makers could argue that Denmark's flagging growth rate makes it imperative to step up these efforts and thereby break with tradition.

5.4. Technology Maintaining and Fast Growth: Korea and Ireland

Korea stands out among the 'fast growth' countries as an example of technology deepening that has also involved a narrowing of the country's technological profile over time. Korea's profile in the 1980-86 sub-period was much broader than in the 1994 – 2001 sub-period. Similar changes have occurred in Ireland, but not to the same degree.

Korea, like Taiwan, has a history of developing the technological capabilities of its own large firms. Similar to other 'catching up' economies, Korea has matched supply- and demand-side activities by utilizing imported technology to support a strong specialization in rapidly growing export markets, especially for 'high tech' products. Increasing globalization of both production and R&D by major Korean firms has meant, however, that efforts to upgrade domestic knowledge inputs will have to be coordinated with initiatives to strengthen the absorptive capacity and innovative capabilities of small domestic suppliers to these large firms.

Liberalization and efforts to promote a more entrepreneurial economy in Korea have been fairly recent developments. Despite regulatory reforms and the reorganization or creation of support functions suitable to new venture businesses, the economy continues to be dominated by large conglomerates. The *chaebols* have adapted poorly to liberalization and continue to constrain innovation networks, in particular. Thus, a mismatch of organizations and institutions frustrates support for innovating firms. Generally, the Korean NSI is experiencing a difficult transition from large firm dominance and top-down government steering to entrepreneurship, open competition, and more interactive partnerships between government and industrial actors. In both the 'old' and the 'new' versions of the Korean NSI, small domestic firms have tended to be disadvantaged, but the latter benefits new venture businesses while threatening more traditional SMEs.

A similar problem arises in Ireland, albeit in relation to foreign, rather than domestic MNCs. In activities related to 'constituents' and 'support', the Irish NSI has, on one hand, bolstered inward investment by embedding foreign MNCs within local or regional clusters of inter-related firms, and, on the other, promoted the formation of new firms, the development of innovative capabilities, and effective innovation networks within indigenous industries. Success in the latter type of effort appears to have depended greatly on the degree to which there has been a significant overlap with the former type. The predominance of foreign MNCs has ensured high overall consistency in Ireland's NSI, such that its main strengths are based on alignments of different kinds of activities that support this industrial order. Thus, e.g., foreign MNCs based in Ireland constitute important sources of demand for indigenous firms, whose innovation and growth performance has been improved by vertical linkage with them. Small indigenous firms in traditional industries outside this virtuous circle remain the NSI's weakest components.

6. Comparative Analysis

In this section we relate the foregoing overview of the ten NSIs to the theoretical and practical issues that we raised at the outset (in Section 2). The main theoretical issue, related to the different perspectives advanced by 'broad' and 'narrow' definitions of NSIs, concerned the character and coherence of NSIs – i.e., the question of whether or not they exhibit truly 'systemic' properties, even in the context of increasing globalization. Practical issues included both the requirements of comparative research on NSIs and policy questions, particularly the debate on non-selective versus selective measures. The discussion below focuses on primarily on policy issues. However, it also seeks to demonstrate the utility of an 'activities' approach for comparative research on SIs.

6.1. NSI Coherence under Globalisation

We begin by returning to our original point of departure, the concept of NSIs. As noted at the outset, there has been ongoing, albeit understated, rivalry between 'broad' and 'narrow' conceptions of NSIs. In addition to defining NSIs differently, they expressed fundamental differences of opinion concerning the integrity of NSIs. Representing the broad approach, Lundvall (1992) argued that NSIs would continue to pursue distinctive national trajectories, even under the homogenizing influence of globalization processes.

The narrow approach implicitly questioned this position, based on Nelson's (1992) view that NSIs could largely be reduced to *ensembles* of sectoral systems of innovation (SSIs).

On these questions, evidence from the ten countries investigated in this project generally favours the 'broad' perspective on NSIs, rather than the 'narrow' one. The national studies have shown that although economic growth can be based on different patterns of sectoral specialization and trajectories of technology development, most countries have moved, or attempted to move, in the direction of greater specialization in rapidly expanding 'high technology' sectors, in order to achieve or maintain high rates of economic growth.[10] However, examination of the countries that have been most successful in this endeavour – i.e., the 'fast growth' countries – reveals that their respective entries into (in almost all cases) the same 'high-tech' sector (i.e., electronics) have been accomplished through very different strategies and mechanisms. Some, like Korea and Taiwan, have focused on developing domestic firms capable of competing in the global market, whereas others, like Ireland and (until recently) Singapore, have focused mainly on attracting foreign MNCs and promoting 'innovation by invitation'.

Further, the evidence on globalization effects reveals a growing diversity in the technological trajectories that both 'fast growth' and 'slow growth' countries have chosen to pursue, even within the same sectors. In ICT manufacturing, for example, Sweden has increasingly become a centre for R&D, whereas Taiwan has mastered and refined sophisticated production technologies and Hong Kong has focused on co-ordination, adding high-value-added services to regionally based international production networks. Both Denmark and The Netherlands have developed strengths in biotechnology, but while the former has benefited from international collaboration, the latter has experienced diminishing returns. Rather than converging, the NSIs in our study have established distinctive roles within an increasingly differentiated international division of labour. Moreover, these roles tend to be consistent *across* sectors, as demonstrated by the cases of countries as widely different as Sweden and Hong Kong. Thus there is considerable evidence to indicate that globalization does not erode NSIs or render them incoherent.

6.2. An 'Activities-based' Perspective on Policy in NSIs: Problems and Strategies

We now turn to policy issues, which we initially discussed in Section 2. Following our more general argument that our proposed 'activities' framework facilitates the comparative study of NSIs by circumventing the problem of 'functional equivalence', we argued more specifically that this framework provides an especially useful point of entry into policy analysis. Following this approach, we can identify the organisations performing the activities and examine the relations among them, focussing on the division of labour between private and public organisations and trying to determine whether it is justified or not. This kind of analysis, we explained, requires the specification of policy 'problems' and the assessment of organisational problem-solving capabilities. Further, we pointed out that conventional (or mainstream economics) and systemic approaches to innovation policy differ not only in how they define policy problems – i.e., 'market failures' in the former approach and 'system failures' in the latter – but also in their strategies for solving such problems. The conventional mainstream economics approach recommends 'non-selective' strategies that address framework

[10] Here, specialization is measured in terms of change in production structure, not in terms of patenting.

conditions, whereas the systemic approach promotes more 'selective' strategies focused on particular linkages within a given NSI.

Our discussion of analytical procedures in Section 3 outlined how the occurrence of policy problems could be mapped onto two main axes or dimensions of essential activities in NSIs: The first axis of 'knowledge inputs' and 'demand-side' activities highlights problems of supply and demand, which can be conceptualized as 'market failures'. The second axis of 'constituents' and 'support for innovating firms' features institutional and organizational problems that can be thought of as 'system failures. We used this scheme to identify and compare the occurrence of policy problems in NSIs

For most of the countries in our study, the most intractable problems of innovation policy took the form of issues arising on the axis of activities concerned with the 'constituents' of innovation systems and the provision of 'support for innovating firms'. This is perhaps unsurprising, given that market forces – or public interventions aimed at clearly identifiable market failures -- can be expected to achieve or restore balance along the other main axis of 'knowledge inputs' and 'demand-side' activities. Mainstream economists have been fairly successful in identifying specific policy instruments that can be used to address 'market failures', whereas proponents of the alternative, systemic approach have not made similar progress in specifying instruments to address 'system failures' (Mytelka and Smith 2002).

A perhaps more surprising observation is that in those countries where serious mismatches or inconsistencies do arise on the axis of 'knowledge inputs' and 'demand-side' activities, they can be traced to causal factors associated with the axis of 'constituents' and 'support for innovating firms'. This finding indicates that the main challenge facing NSIs is that of creating diversity – i.e., escaping 'lock-in' into well-established production specializations and technological trajectories by launching new alternatives. In contrast, the more familiar problems of providing adequate factor inputs and ensuring competitive 'framework conditions' appear to be issues whose solution is much easier. These considerations lead, in turn, to arguments for selective innovation policies, which in contrast to 'framework' policies, are more closely associated with 'system failures'.

Returning to the most problematic cases among the 'slow growth' countries, the evidence from both Sweden and the Netherlands supports a critique of non-selective policies. Historically, Swedish innovation policies have reinforced the dominance of large firms and industries characterized by low innovation intensity, and have also supported high levels of investment in education and R&D. More recent policies have emphasized providing support to start-up firms in science-based sectors, but other 'non-selective' reforms have promoted the globalization of Sweden's major industrial firms while maintaining their dominant position within the national economy. New firms and new industries have therefore developed slowly, on terms favourable to incumbent actors. In the Netherlands, past and present policies, directed towards increased competition, on one hand, and higher levels of public-private interaction, on the other, seem too broadly framed to accomplish a fundamental reorientation of the NSI. The main question concerning interaction in the Netherlands NSI, e.g., is arguably not one of 'how much'? but rather 'what kind'? Non-selective policies that overlook such issues are liable simply to reproduce the existing system and perhaps also erode its main strengths.

Strong support for the necessity of selective policies – and also clear indications of the problems entailed in developing and implementing them – emerges from the most problematic cases among 'fast growth countries. Korea exemplifies the limitations of policies addressing 'the market' in general. Liberalization was a necessary response to the financial crisis of the 1990s, and involved the introduction of reforms that were both wide-ranging and comprehensive. However, Korean policy-makers apparently underestimated the difficulties of implementation, as evidenced, e.g., by the relative underdevelopment of new arrangements for financing innovation. Further, continuing problems with the output and organization of both public education and public sector R&D indicate that the extent and pace of reform have not been sufficient and may need to be redoubled in certain areas. The Taiwanese case illustrates the difficulty of designing selective policies. Historically, Taiwan's innovation policies have succeeded in fostering competitive OEM/ODM firms in ICT manufacturing. Many aspects of the NSI have been geared to this effort – e.g., the public sector's role in building competences in strategic areas through a variety of mechanisms for technology diffusion and learning. However, the past achievements of Taiwanese innovation policy have also contributed to current problems of lock-in, and policymakers now face the challenges of developing stronger indigenous R&D capabilities and strengthening the IPRs of domestic firms.

The cases cited above are not exceptional, insofar as similar findings occur in other national studies. For instance, the Norwegian case supports the same conclusions as the studies of Sweden and the Netherlands, and the Singaporean case develops insights similar to those articulated in relation to Taiwan. In Norway, past innovation policies were directed towards breaking out of the existing pattern of industrial and technological specialization by focusing on selected science-based and information-intensive industries, and corresponding research fields. However, these policies were not supported by accompanying reforms in areas such as taxation, and they were also undermined by an economic downturn during the early 1990s. More recent innovation policy has shifted towards a non-selective approach that implicitly favours established sectors and incumbent firms, especially in terms of support for R&D. In the case of Singapore, innovation policies have evolved with the NSI, typically leading its development. However, the achievements of past policies for 'MNC-leveraging economic development' may have reduced policymakers' scope of action in recent efforts to build up indigenous innovation capabilities. Although the policy shift towards investment in R&D has had a positive impact on R&D intensity and innovative performance, policies geared towards promoting high-tech entrepreneurship have not enjoyed similar success thus far.

7. Conclusions

The findings discussed in the foregoing section point to the fundamental importance of path-dependent processes of co-evolution – i.e., "mutual expansion of complementary social institutions" via coalescence around "national specificities in organizing principles" (Dosi and Kogut 1993: 253, 258) -- in the ongoing development of NSIs. The innovation studies literature has mainly discussed co-evolution in terms of interaction among the variables of technology, industrial structure, institutions, and demand (Nelson 1994; Metcalfe 1998), but has lately sought to develop more finely-grained accounts of how various elements of a system of innovation develop over time through mutual adaptation (Malerba 2004: 30). Arguably, the 'activities' approach that we

have followed in describing and analyzing the 'small economy' NSIs in the Ten Countries Project is particularly well suited to this purpose. Unlike other approaches to the study of innovation systems, which typically focus on elements, actors, and structures, the activities approach directs attention towards the fundamental mechanisms and processes by which systems of innovation are constituted and change over time, given that "social systems [must] temporalize their elements as action-events" (Luhmann 1995: 293).

We do not claim to have produced a definitive account of co-evolution in NSIs within the Ten Countries Project, but merely to have indicated its fundamental importance. As we shall now discuss, that importance is nowhere more evident than in relation to the design of innovation policy. At the system level, innovation policy informed by an evolutionary perspective entails attempting to assess, influence, and lead (i.e., co-ordinate) complex processes of change and development, rather than trying to "impose predetermined outcomes" with a focus on individual innovations (Metcalfe 1995: 31). On one hand, as we have argued, this requires a selective approach; on the other, it demands grasping the dynamics of co-evolution and key complementarities among different aspects of an NSI.

In all ten of the NSIs covered by this study, policymakers have, without exception, proclaimed the adoption of the 'systems of innovation' approach as a framework and guide for future innovation policy. As already noted, however, there are widely differing views within the policy-making community on what 'innovation policy' consists of, and the same might also be said of the systems of innovation approach, which is often used "more as a label than an analytical tool" (Edquist 2005: 202). Certainly, there are often wide discrepancies in policy between the rhetorical and practical expressions of a systems of innovation approach. This point is strikingly demonstrated by the case of Norway. Norway currently faces "the issue of deciding between a broad approach *versus* a more targeted approach" (Grønning et al. 2006: Section 7.3). Implicitly, the 'broad' approach appears to invoke the systems of innovation concept in calling for a 'holistic' policy framework. However, it remains vague as to specific policy measures, expresses an underlying philosophy of 'general upgrading', avoids setting priorities, and reverts at least partially to a linear view of the innovation process. All of this is highly incompatible with a systems of innovation approach, as demonstrated by the Norwegian study (ibid.), which incorporates a critical analysis informed by a systemic perspective that proposes a much more 'targeted' kind of innovation policy for Norway.

In developing a 'performative' perspective on organizational change, Feldman (2003: 749) has argued that "it is difficult to bring about change in organizational routines when the change is inconsistent with broader understandings about how the organization operates as these understandings are produced and reproduced by other performances in the organization". The activities-based approach applied in this comparative study of national systems of innovation leads to similar conclusions about the importance of achieving consistency at the system level. The success of specific policy measures aimed at changing particular activities, or sets of activities, within a system of innovation usually depends on simultaneous adjustments to complementary or related sets of activities within the system. The discussion in the foregoing section has cited numerous examples to this effect, and here we confine ourselves to just one more. In Denmark, where 'low-tech' activities predominate and a large population of SMEs has only weak networking linkages with the universities, "policies aiming at bringing the national

system 'to the very top' in this dimension might not necessarily strengthen the system as a whole"; other technology transfer strategies "such as life-long learning" may be more effective in strengthening the innovative capabilities of many firms and sectors (Christensen, et al. 2006: Section 7). More generally, the Danish study shows that policies aimed at promoting a transition to a 'science-based' mode of innovation are unlikely to succeed in Denmark without taking into account the wider socio-economic setting and other factors contributing to the successful operation of the Danish model.

Of course, achieving perfect consistency within systems of innovation should never be regarded as an end in itself, since that would be tantamount to the pursuit of inertia. Our study abounds with examples of countries that have excelled in specialising in certain sectors, technologies, forms of business organisation, and modes of innovation, to the extent that further incremental progress along these well-established trajectories would be for them the path of least resistance, attended by little or no disruption at the system level. However, as these same examples indicate, this kind of balance or harmony within a system of innovation may actually be cause for alarm, since it is symptomatic of 'lock-in' to pathways whose potential for generating economic welfare may soon be exhausted. Taiwan may have achieved world-class mastery in ICT manufacturing, but now faces strong competitive pressures to develop the innovative capabilities of Taiwanese firms in the areas of product innovation, design, marketing and distribution. Finland may have accomplished a successful large firm-led entry into a key high-technology sector, but remains highly vulnerable in terms of both excessive dependency on electronics and the preponderance of one large, multi-national firm. In both NSIs, change is imperative.

Rather than minimizing systemic change, the proper task of innovation policy should be to channel it in the most potentially rewarding directions. Innovation systems, like other systems, evolve by resolving problems of inconsistency – systemic tensions, mismatches, or imbalances -- and innovation policy directed towards achieving fundamental systemic change often requires introducing such problems into the system of innovation, usually through specific policy measures aimed at altering particular aspects, or sets of activities, within the system. However, policy-makers should not be so naïve as to expect that these initiatives are liable to succeed in the absence of accompanying adjustments to complementary or related aspects, or areas of activity. This kind of balancing act, moreover, may be easier to accomplish at the earlier stages of system development. As systems evolve over time towards greater complexity, they may afford policy-makers progressively less room for manoeuvre with regard to any given area of activity.

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Table 1
Key activities in systems of innovation

I. Provision of knowledge inputs to the innovation process

1. *Provision of R&D* and, thus, creation of new knowledge, primarily in engineering, medicine and natural sciences.

2. *Competence building*: educating and training the labour force for innovation and R&D activities.

II. Demand-side activities

3. *Formation of new product markets*.

4. *Articulation of quality requirements* emanating from the demand side with regard to new products.

III. Provision of constituents for SIs

5. *Creating and changing organisations* needed for developing new fields of innovation. Examples include enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms; and creating new research organisations, policy agencies, etc.

6. *Networking through markets and other mechanisms*, including interactive learning between different organisations (potentially) involved in the innovation processes. This implies integrating new knowledge elements developed in different spheres of the SI and coming from outside with elements already available in the innovating firms.

7. *Creating and changing institutions* – e.g., patent laws, tax laws, environment and safety regulations, R&D investment routines, etc. – that influence innovating organisations and innovation processes by providing incentives for and removing obstacles to innovation.

IV. Support services for innovating firms

8. *Incubation activities* such as providing access to facilities and administrative support for innovating efforts.

9. *Finance of innovation processes* and other activities that can facilitate commercialisation of knowledge and its adoption.

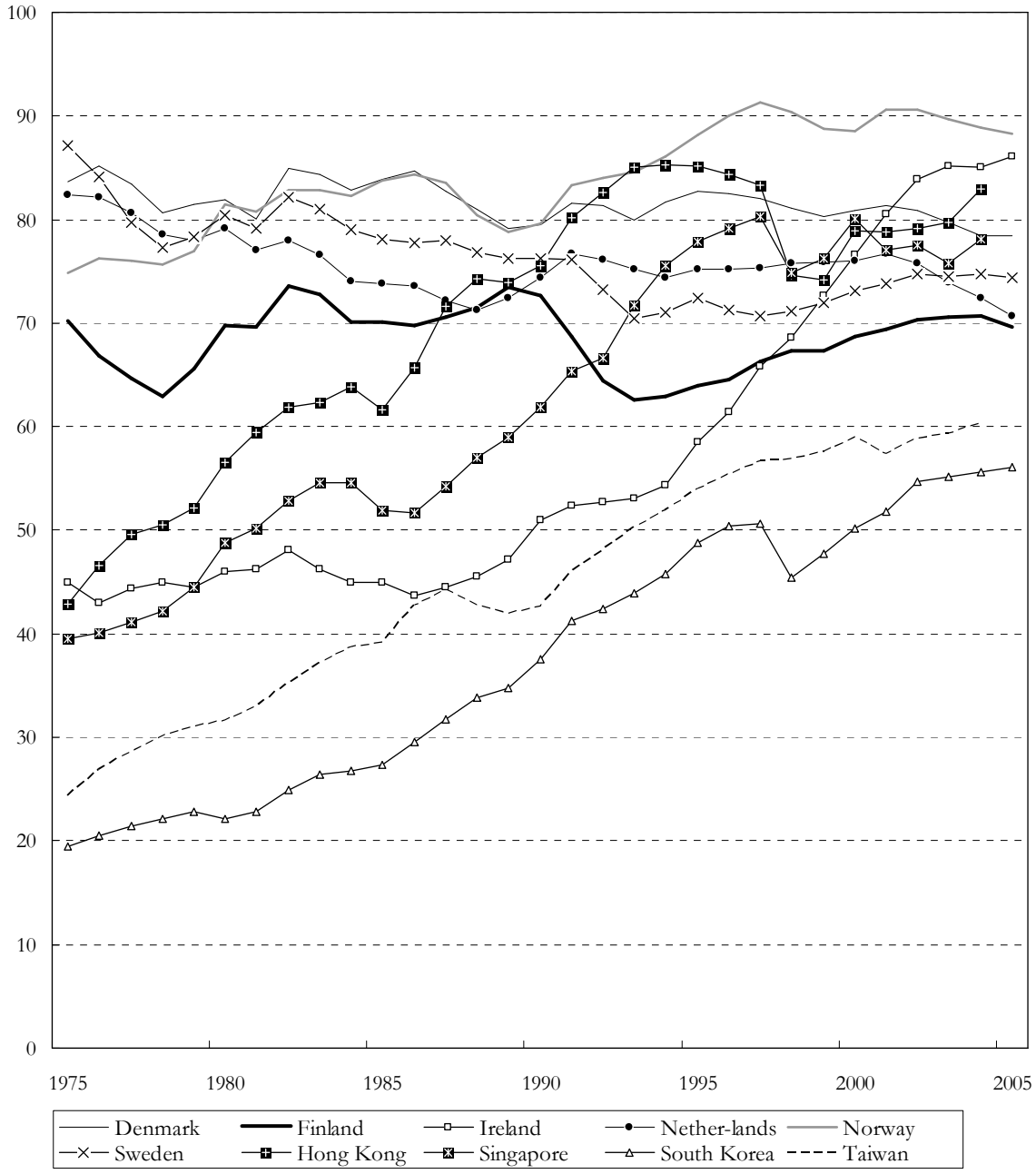
10. *Provision of consultancy services* relevant for innovation processes, e.g., technology transfer, commercial information, and legal advice.

Source: Edquist (2005)

Table 2
Patterns of Recent Historical Change in 10 National Systems of Innovation

Direction of Innovative Activity (1980 - 2001)	**Economic Growth Rate (1975 – 2005)**	
	Slow	**Fast**
Broadened	Finland Norway Sweden	Taiwan (Hong Kong?) (Singapore ?)
Maintained or Narrowed	Denmark The Netherlands	Ireland Korea

Figure 1
GDP per capita 1990 GK $, USA = 100. 10 European and Asian Countries.[a]



[a] The term 1990 GK $ refers to "1990 US dollars converted at 'Geary-Khamis' purchasing power parities".

Source: Groningen Growth and Development Centre and The Conference Board, *Total Economy Database*, January 2006, available at: http://www.ggdc.net.