

# Mapping Innovation Systems:

## A framework for organising quantitative empirical research on national systems of innovation\*

**Manuel Mira Godinho**

(ISEG, Lisbon and CISEP, [mgodinho@iseg.utl.pt](mailto:mgodinho@iseg.utl.pt))

**Sandro F. Mendonça**

(ISCTE, Lisbon, [sfm@iscte.pt](mailto:sfm@iscte.pt))

**Tiago Santos Pereira**

(CES, Coimbra, and CISEP, [tsp@ces.uc.pt](mailto:tsp@ces.uc.pt))

**Version 3.0. June 2004 Work in progress. Not to be quoted. Comments welcome.**

### **Abstract:**

This paper addresses the following questions: Is it possible to measure National Systems of Innovation (NSIs)? What specific technique may be used for that purpose? Can we apply that technique to both advanced and catching up economies? The paper presents the an exploratory exercise which was carried out with data from fourteen countries and it shows that satisfactory answers can be given to those questions. The method proposed does not entail the development of new indicators, but rather in the development of a method to encompass the different relevant dimensions to characterise NSIs. The main challenge for the quantitative analysis of NSIs is that such a method must be simple enough to be attractive and useful for policy-making purposes but must also be faithful to the relevance of different dimensions of a NSI and to their systemic nature. As such, the method must allow for the analysis of each NSI independently and not only in relation to ideal models. The mapping approach proposed allows for comparisons between different NSIs, in advanced and catching up economies, to detect strengths and weaknesses, to assess its temporal evolution, and to determine whether its development has been balanced or on the contrary uneven. The emphasis on intuitive data visualisation techniques makes this approach particularly useful for policy analysis.

**Key Words:** innovation, indicators, national systems of innovation

---

\* Presented at “Globelics Academy 2004 - Ph.D. School on National Systems of Innovation and Economic Development”, ISEG, Technical University of Lisbon; “Economic Policies in the New Millennium”, University of Coimbra, Portugal, 16-17 April 2004; and “Innovation Systems and Development Strategies for the Third Millennium: The First Globelics Conference”, Rio de Janeiro, BNDES, 3-6 November 2003. Comments from discussants, in particular José Cassiolato and Bengt-Åke Lundvall, and from other participants at these meetings are greatly acknowledged. Remaining limitations are the authors’ responsibility. Further comments are most welcome.

## **1. Introduction**

The purpose of this paper is to put forward a tool for mapping “national systems of innovation” (NSIs). It may be regarded as a new combination of available innovation indicators. Such mapping allows the comparison of different NSIs by visualizing in bi-dimensional space the graphic pattern of the relevant dimensions. In addition to this comparison, this tool also aims at allowing for each individual NSI to detect its weaker and stronger dimensions, to assess its evolution from one moment in time to another, and to determine whether its development has been balanced or on the contrary uneven.

The problem we are therefore dealing with in this paper is the possibility of measuring the maturity and development pattern of different NSIs, through a cartography of their relevant dimensions. The objective of this process, that combines quantification with the use of a graphical technique, is allowing for inter- and intra-NSI comparisons in a given moment and across time.

In contrast to this approach many would argue that the NSI concept might not be amenable to quantification. This is so because, along the functional dimensions which refer to the actors’ roles and the interactions connecting them, this concept has emphasized innovation as a socially embedded process, stemming from a set of intangible dimensions – scientific knowledge, technology, institutional arrangements – which are essentially qualitative in their nature.

We will however show that despite the prevalence of those intangible aspects, given certain assumptions and by using adequate sets of data the mapping and quantification of innovation systems is a feasible enterprise. A quantifying approach is necessary for the advance of the systems perspective. Following this introduction, section 2 presents a summary of the systems view in the economic analysis of the innovation process and clarify why there are good reasons for extending this perspective beyond its traditional qualitative character. In section 3 we will put forward a conceptual framework of NSI dimensions, providing indications with respect to what are the critical NSI dimensions to be retained and how they can be represented by different types of indicators. In section 4 we will map fourteen different NSIs in two points in time, providing a longitudinal comparison of NSI’s maturity and evolution. Finally in the concluding section we will point out the main limitations of this exercise, and also the many possible useful uses to which this tool for analysing NSIs can be helpful.

## **2. The NSI perspective**

In the industrial era, more than in any other, innovation is not an isolated act but, rather, an ongoing process involving a number of diversifying and interacting actors. The NSI concept has been used as a “focusing device” in bringing forward the interdependent and distributed features of innovation. The concept was developed in the late eighties and has achieved a big impact, both in innovation studies and in policy arenas. This section explores the two faces of the NSI concept: its qualitative and quantitative sides.

### *2.1 The qualitative dimensions of innovation*

In the economics of technical change the acknowledgement of the systemic nature of the innovation process represents a key claim in favour of considering the interactive

and historical nature of the innovation phenomenon. It therefore embodies a methodological option: the systems approach assumes that the appreciation of the evolution of countries' technological capabilities and performances makes these quite complex objects of analysis, one cannot understand the picture without the detail. Consequently, this stands in contrast with traditional growth accounts, which take statistical aggregates as the privileged source of empirical information. The NSI approach follows an alternative path, the awareness of concrete institutions and varieties in macroeconomic environments are at the centre stage.

The NSI concept was initially put forward as a qualitative concept for describing the technological, economic, social and institutional dimensions of innovation in advanced economies. Freeman (1987) used this concept in his discussion of the Japanese innovation system, while Lundvall (1985, 1992) and others applied it in connection to the empirical observation of the interactions and institutional framework that supported innovative activities in the small open economies of Scandinavia. From these initial applications, the concept was rapidly generalised to all the most advanced economies, being Nelson's 1993 book a good example of this. In spite of a relative turbulence in what the definition of NSI is concerned (Niosi, 2002), the major contributions are convergent in highlighting the interlinkages between firms and institutions as well as noting the path-dependent character of those relations.

The NSI approach has meanwhile developed significantly, and several other associated concepts have emerged stressing different aspects. Some of these derived concepts refer to sub-national agglomerations of dynamic competencies such as in the work of Saxenian (1994) that dealt with the local conditions in Massachusetts' Route 128 and Silicon Valley, or in the work of Cooke (1998), Braczyk (1998), Landabaso (1995) or Asheim and Gertler (2004) that refer to "regional innovation systems" in the European context. In contrast, other approaches that derive from the initial NSI concept refer to realities which are supra-national or that simply are not geographical in their nature. That is the case of the "sectoral systems of innovation" approach (Breschi and Malerba 1997, Malerba 2002), that stresses the opportunity and appropriability conditions in different sectors as key factors in determining specific cumulativeness paths, or also the case of the "technological innovation systems" approach (Carlsson et al. 1995 and 1997), that focuses on generic technologies with general application over many industries.

All these developments of the original NSI concept can be seen as evidence that research on innovation has tried to capture the manifold dimensions of innovative phenomena. However, in this paper our interest is not on how each of those derived "innovation systems" concepts sprung up from the original NSI concept. Rather we are interested in the original concept and our analysis is centred on the national level, with the objective of promoting a cartography of NSIs' development. The main question that we are addressing in the paper has to do with knowing whether it is acceptable to measure and represent NSIs' development and, if so, whether a practical and consistent technique can be put forward in order to achieve that purpose.

As it was already pointed out in the introduction, it has been argued that the NSI concept is essentially a qualitative concept not easily amenable to quantitative treatment. This argument can be understood if one considers that the initial theorisation and its several variations have tried to combine the (mainly quantitative) economic

analysis of innovation with insights into several critical intangible (qualitative) dimensions that affect innovation patterns and dynamics.

The NSI concept preceded somewhat in time many of the most recent technological developments, but it is clear that it was already put forward in connection to the central characteristics of the present competitive regime. It was not by chance that the NSI concept emerged in the late 1980s when the signs of a new techno-economic paradigm were already clear, with a set of radically new technologies starting to diffuse economy-wide (Freeman and Perez 1988, Freeman and Soete 1997, Freeman and Louçã, 2001). A key feature that has differentiated the new paradigm from the previous ones is precisely the permanence and ubiquity of innovation, which evolved from a relatively discrete and limited occurrence to a much more pervasive aspect of economic life. In the new paradigm firms must be involved, more than ever, in continuous innovation to remain competitive. In this process they have allocated a greater share of their resources to the internal production and combination of knowledge and to the external tapping of other sources, including the research organizations and their competitors (Autio et al. 1995). National governments have also been part of this process, by strengthening the S&T infrastructure (Teubal et al. 1996, Rush et al. 1996) and by trying to improve the regulatory framework and more generally the institutional conditions affecting innovation. These developments have led to what many have classified as the “knowledge based economy” (OECD 2000) or, in a relatively more dynamic interpretation, to the “learning economy” (Lundvall and Borràs 1999, Gregersen and Johnson 2001).

Summing up, innovation is central to understanding the competitive dynamics in contemporary economies. It emerges from new combinations of knowledge and depends on the institutional arrangements prevailing in each society, making it an essentially qualitative process. According to the argument we have been referring to, it is this qualitative nature of innovation that defies quantification.

## *2.2 The quantitative side of NSIs*

At least two recent developments can be considered as weakening that argument. Firstly, we might refer to the emergence and wide use of several new innovation indicators and sources. As it is known significant advancements have been made in the field of innovation measurement recently, through the implementation of a variety of new indicators. This has happened since the early 1990s when a new generation of innovation indicators has been established, adding to the classical “input” and “output” indicators. A significant part of this new generation of indicators stems from the process associated with the publication of the “Oslo Manual” (OECD 1992, Smith 1992) and to the subsequent setting up of several innovation surveys, being the most prominent the three CIS inquiries implemented by EUROSTAT in collaboration with several national statistical offices. From the studies that have been produced with these CIS-based indicators, it is clear that several dimensions of the innovation process which could not be previously studied can now be approached and understood by using quantitative data and analysis (Smith 2004, Evangelista et al. 1998). Another component of this new generation of indicators is more recent yet, and relates to the establishing by the OECD, the EU and other international organizations of statistics trying to reflect the diffusion of ICTs and other related technologies. Besides this new generation the most recent period has also witnessed to the creation and intense use, by both the academic and the policy-

making communities, of several other indicators built up from the more “classic” bibliometric, patent and R&D statistics.

The second recent development that can be seen as favouring the type of exercise we will be undertaking in the following sections relates to a demand-side effect. Policy-makers have been asking their advisers and researchers too for supplying them with summary measures of their countries’ relative innovation status. This is part of a more general benchmarking movement, and in the area of innovation the most notable result has been the production of “innovation scoreboards”.<sup>1</sup> This type of exercise has been criticized for tending to reduce the multidimensionality of innovation processes to just one simple summary measure. Such scoreboards “can provide useful information for macro level policies [...], but a scoreboard is of less value as one moves to the meso and micro level, where firms are active and where most policy actions occur” (Arundel 2003). From this and other similar criticisms that have been put forward (e.g. Pereira, 2002) we can conclude that while the simplification needs remain, excessive reductionism shall be avoided in the methodologies proposed.

Besides its analytical purposes of understanding better the nature and dynamics of heterogeneous NSIs, we are also submitting the hypothesis of the policy relevance of our exercise. However, our goal is not to create the expectation that distances between actual NSIs and a given “optimal” NSIs can be achieved. We thus agree with Edquist (2004, pg. 7) that “[c]omparisons can be made between different real systems (over time and space), and between real systems and target systems, but not between real systems and optimal ones”. Our approach can be used as a tool for policy learning, a way to introduce a sense of panoramic awareness of the similarities and differences among different countries at different times. The mapping device we present bellow may be of interest for the design of benchmarking exercises, namely in the enlarged European Union. By drawing attention to a variety of factors that define and differentiate NSIs our approach aims at facilitating the appreciation of the role of the broader context in policy making. Arguably, the transfer of strategies without local adaptation may be counterproductive (Fagerberg, 2003). Its comparative advantage being that it points to fact that “socio-technological” congruence is not a matter of simply narrowing the gap in science and technology indicators. The congruence or maturity of NSIs is an issue of both increasing technological capabilities and social capabilities (Abramovitz 1994).

We shall add that this need for summarizing the multidimensionality of the NSI reality goes beyond the needs of policy makers operating in advanced economies. As it was pointed out before, the NSI concept was initially applied to some of the more advanced economies. But, in the sequence of the seminal contributions of Freeman and Lundvall, the research that has contributed to the NSI approach has spread also to several intermediate catching up economies more recently. These recent developments have raised the methodological problem of knowing whether the NSI concept is adequate for application to all types of economies, regardless the actual maturity of their innovative capabilities. Through the technique that will be proposed in the next section, we can experimentally explore the validity of applying the NSI concept to those economies.

### **3. A method for measuring and mapping national innovation systems**

---

<sup>1</sup> In 2000 the EU Lisbon summit decided to develop a European Innovation Scoreboard, which is an example of this approach.

In order to provide an answer to the questions raised above, we will turn next to a decomposition of NSI in terms a set of major dimensions. In the sequence we will discuss what indicators might be adequate to represent each of those major dimensions and how we can graphically depict them.

### *3.1. NSI dimensions*

Most of the graphical representations of a NSI which have been presented in the literature tend to concentrate on the actors and the linkages that typically connect them. We think however this is an oversimplification of the NSI reality. The NSI concept can be seen as a systemic model of the innovation process, growing out of the innovation theory advancements since the classic pipe-line model. This means that many of the analytical perspectives stemming from previous models of innovation, from the interactive vision of S&T-push and demand-pull factors (Freeman 1979) to the chain-link model of innovation (Kline and Rosenberg 1986), were integrated in the NSI theoretical framework.

We must therefore consider, in addition to the “process” itself in which the actors are directly involved through their own activities and interactions, the inputs and outputs of that process. In other words, one needs to consider on the one side the resources invested in innovation and on the other side the results stemming from the combination of those resources. In this case the major results from a NSI have naturally to do with the system’s innovation performance, but also, and this is a very important aspect, with diffusion, i.e. with the circulation and spreading of knowledge and new technologies among the different parts of the system.

A major theoretical point that the NSI approach brought to the analysis of the innovation process has precisely to do with this redistributive power of the innovation system (David and Foray 1995). Such power is a direct function of the collaborative arrangements and relatively stable linkages that firms set up with a diversity of actors, ranging from their suppliers (including finance providers), clients and competitors, to the R&D and intermediate organizations that produce and transfer S&T knowledge to the economy. This perspective of industrial organization can be seen as critical of the mainstream view that the central factor regulating modern economies is the competition that arises between independent firms. Competition is also an important factor in the NSI approach, but it is seen as mainly a “Schumpeterian competition” in which firms strive for the introduction of better products, improved processes, alternative supplying sources and innovative organizational arrangements (Fagerberg 2003).

In addition to the competitive action of firms, in the NSI approach other actors are also relevant in bringing about innovation. These include the universities, the public labs, a diversity of other non-profit and profit RTO organizations or the intermediate transfer agencies and brokers, among others. Institutional diversity – including the regulatory procedures, conventions and aspects that affect the attitudes and behaviours of economic agents– is therefore a critical structural property to be considered in the observation of the “completeness” of the innovation system.

Another structural dimension that needs to be considered, and that results largely from the Schumpeterian competition process referred to above, is the sectoral structure of the

economy. It has been known for long now that the sectoral characteristics of an economy affect the direction, nature and intensity of innovation (Pavitt 1984). To understand well an innovation system behaviour, we will therefore need to know how the economic activity is distributed through sectors with different R&D and knowledge intensities.

Finally, another critical aspect that deserves attention, when considering the characteristic traits of a NSI, has to do with the discussion of the frontiers of the innovation system. It has been discussed whether in an era of globalisation the “national” level of analysis retains the same relevance it had before, particularly when a great share of innovating activities is generated within large multinational firms (Patel 1995, Zanfei 2000). What comes out from empirical research in this regard is that the national level of analysis remains relevant to understand innovation, not only for small- and medium-sized firms but also for the very large firms that have retained most of their R&D activities in their home countries. However, it has also been shown that significant international technology flows are associated with the transnational activities of some of those very large firms, both through carrying out a larger share of R&D activities abroad (Meyer-Krahmer et al. 1998) or through the more classical ways of embodied technology and FDI. In any case, the external communication and openness of each NSI shall be seen as a relevant analytical dimension. Particularly for catching up economies, this link is vital for allowing the absorption of foreign knowledge and the diffusion of new technologies.

### *3.2. Methodological steps in the NSI mapping exercise*

From the discussion above we draw eight major dimensions as being representative of the NSI multidimensionality. Table 1 presents the list of dimensions. Being as a compromise between lessons drawn from the innovation systems literature and the availability of relevant indicators, this may be regarded as a methodological device akin the appreciative mode of theorising proposed by Nelson and Winter (1982). Our mapping exercise is an example of a style of socio-economic inquiry that attempts to outline and interpret “stylised facts ” and dynamic regularities in order to confront the new findings with the results of past research.

Anchoring the eight dimensions in the innovation systems’ approach is not, however, a straightforward undertaking. This reflects the absence of a “generally accepted definition of a national system of innovation” (Edquist 2004 pg. 4). In particular, it is not always clear what is meant by a system’s components, relations between components and the activities carried out within the boundaries of the NSI’s, which determine the rate, direction, and consequences of the innovation processes. At the general level we agree with Edquist (2004 pg. 16) that the overall function in NSIs is to enable and further innovation processes, i.e., to develop, diffuse and use innovations. Therefore, satisfactory account of the determinants of activities in NSIs must be multi-causal.

The second column of table 1 presents the theoretical roots of our choices. The eight dimensions represent the basic building blocks of our approach and are organised in three main categories. The first four dimensions represents factors that support and direct learning. The next two dimensions reflect the ability to cope knowledge-based

relationships. Finally, the last two account for the effectiveness in exploiting the economic opportunities of useful new technologies.

*Table 1.*

<b>Dimensions</b>	<b>Activities or functions</b>
Institutional diversity and development	Institutional set-up
Economic structure	Economic set-up
Resource base	Research set-up
The actors and their behaviours	Organisational set-up
Interactivity and linkages	Inward relational capabilities
External communication	Outward relational capabilities
Innovation	Innovation activities
Diffusion	Adoption activities

Table 2 below identifies the indicators that operationalise each of those dimensions. The table also provides information about the sources and other details related to each indicator.

We sought in this exercise to retain a diversity of indicators, based on different types of variables (stock and flows, monetary and physical), in order to provide information about the eight dimensions. In these indicators' selection we tried to consider not only those that represent the actual innovation capabilities and performances, but also those who might provide a dynamic outlook of the innovative potential (e.g.: scientific publications, new scientists and engineers leaving higher education).

We are aware that many of the selected indicators do not constitute ideal solutions for portraying the different dimensions of a NSI. However, in this exercise we had to act pragmatically, choosing the indicators according to their accessibility, reliability and adequate coverage of the period to be observed. The identification of this period was also limited by data availability. We therefore retained "1996" and "2000" as the two moments of observation, with many of the indicators providing information for one-plus or one-less year in relation to those two dates. In some cases we were even forced to consider other years outside those limits, being a common situation for a few variables the use of the same figures both in the initial and latter moments.

Table 2. Variables used in mapping NSI dimensions and evolution

Code	Variable Name (V2-V46) NSI Dimensions (G1 -G8)	Year (1996)	Source	Page	Year (2000)	Source	Page	Notes
G1	<i>Resource base</i>							
V2	R&D financed by government/GDP (%)	1995	1	293	2001	1	293	
V3	R&D financed by industry/GDP (%)	1995	1	293	2001	1	293	
V4	Venture capital Investment/GDP	1997	3	55	2001	4	154	
V5	Researchers per 10,000 labour force	1995-96	1	312	1999-00	1	312	
V6	Population 25-64 y.o. with tertiary education	1996	3	120	2000	6(+1)	(311)	
G2	<i>Actors' behaviour</i>							
V7	BERD/GDP (%)	1997	2	236	2001	1	297	
V8	HERD/GDP (%)	1997	2	236	2001	1	297	
V9	Flows of graduates in S&E	1998	2	225	2000	6		(1)
V11	PhDs in S&E per 1000 in the age group 25-34	2000	4	188	2000	4	188	=
V12	Life-long learning	2000	5		2001	6		=
V13	Scientific publications per million inhabitants	1996	1	317	2000	1	317	=
G3	<i>Interactions and linkages</i>							
V14	Business funding of gov. and univ. R&D (%)	1997	3	136	1997	3	136	=
V15	R&D arrangements between firms and gov. or univ. org. (%)	1994-96	3	136	1994-96	3	136	=
V16	SMEs in cooperation to innovate (%)	1996	5		1996	5		=
V17	Average n° of scientific articles in EPO patents	1992-96	4	421	1992-96	4	421	=
G4	<i>Institutional diversity and development</i>							
V18	Density of R&D matrix							(2)
V19	BERD/GERD (%)	1995	1	295	2001	1	295	
V4	Venture capital Investment/GDP	1997	3	55	2001	4	154	=
V16	SMEs in cooperation to innovate (%)	1996	5		1996	5		=
G5	<i>External communication ("absorption")</i>							
V21	TBP payments/GDP	1997	3	171	2001	1	320	
V22	Domestic ownership of foreign inventions	1993-95	2	251	1993-95	2	251	=
V23	R&D financed by foreign sources/GERD (%)	1997	2	231	2001	1	292	
V24	R&D expenditures by foreign affiliates/BERD (%)	1995-97	2	307	1997-99	2(+4)	307(123)	
V25	Scientific publications with a foreign co-author (%)	1995	3	164	1995	3	164	=
V26	Patents with foreign co-inventors (%)	1993-95	3	164	1993-95	3	164	=
V27	High-tech imports/GDP (%)	1998	7	69	1998	7	69	=
V28	FDI inflows/GDP (%)	1995	1	325	2000	1	325	
G6	<i>Economic Structure</i>							
V29	Share in R&D expenditures of top 500 companies/GDP (%)	2000	4	139	2000	4	139	=
V31	High tech-industries in business sector value-added (%)	1995-97	2	220	1999-00	1	286	
V32	Knowledge-intensive services in business sector value-added (%)	1995-97	2	220	1999-00	1	286	
V33	High-tech exports/GDP (%)	1998	7	69	1998	7	69	=
G7	<i>Innovation</i>							
V34	USPTO patents granted/population	1996	2	256	1999	2	256	
V35	High tech EPO patents/population	1999	5		2000	6		
V36	Revealed comparative advantage in high tech exports	1998	7	69	1998	7	69	=
V37	New to market products in total sales	1996	5		1996	5		=
G8	<i>Diffusion</i>							
V38	ICT expenditures/GDP (%)	1996	2	221	2000-01	6		
V39	Cell-phones per 100 inhabitants	1996	3	118	2000	9	186-7	
V41	Internet hosts per 1,000 inhabitants	1997	1	327	2000	1	327	
V42	Personal computers per million inhabitants	1996	8		2000	8		
V43	Gross fixed capital formation/GDP (%)	1998	1	285	1998	1	285	=
	OTHER VARIABLES (Auxiliary)							
V44	Innovation expenditures as a % of turnover	1996	5		1996	5		=
V45	Population 2000	2000	9	162-3	2000	9	162-3	=
V46	GDP 2000	2000	9	190-1	2000	9	190-1	=

Sources: 1. OECD, STI Outlook 2002; 2. OECD, STI Outlook 2000; 3. OECD, STI Scoreboard 1999; 4. Third European Report on S&T Indicators 2003; 5. European Innovation Scoreboard 2001; 6. European Innovation Scoreboard 2002; 7. EUROSTAT, Key Figures 2000, Towards a ERA; 8. Dados F&G 2004; 9. UNDP, Human Development Report 2002.

Notes: (1) Year 1 and Year 2 in different bases: Y1 - Flows of graduates in S&E/total employment (%); Y2 - New S&E graduates per thousand 20-29 years old; (2) Not included in the calculations; = Means that the same information was used for "Year 1" and "Year 2"; Bold is used for variables which were included in more than one dimension.

The 38 relevant variables listed above were transformed using a conventional standardization procedure. We normalize indicators as follows:

$$\frac{\text{actual value} - \text{mean value}}{\text{standard deviation}}$$

The next step was the aggregation of the variables in each group. Similar weights were used for the variables. A possible variation in future replications of this exercise would be the selection of different weights for the variables according to the importance ascribed to them in the innovation dynamics. Given the procedure highlighted above we reached eight composite indicators, one for each of the NSI dimensions presented before.<sup>2</sup>

For several variables information only existed for part of the countries in the sample. The most remarkable case in this respect is the CIS indicators, which only exist for the European economies. In all these cases and for each of the eight dimensions, the composite measure was calculated for the country whose data was missing on the basis of only  $n-1$  (or  $n-m$ , more generally) indicators.

In what regards country selection we tried to gather information covering both the advanced economies (large and small) and the catching up economies, all of them with a diversity of geographical origins (Americas, Asia, Europe). On the whole, 14 countries were included in this exercise.

Information visualisation is often a neglected aspect of academic communication. However, from the point of social science users such as policy makers, seeing information could allow clearer interpretation of trends, more effective identification of anomalies and faster decision-making. With so many institutions generating huge quantities of data, images constitute a easy way to absorb information. Techniques for capturing vast amounts of information in one picture is are likely to be in great demand from individuals for which time and attention are the scarcest of resources. In the context of the present exercise, having gathered, processed, summarised and critically observed all the necessary information, we were able to represent the results for each dimension along eight axes, using the so-called radar-type charts. Each axis in the chart varies between - 2 and 2, with zero being the value of the standardized mean. We will turn now in the next section to the results of the exercise.

#### **4. Mapping NSIs: assessing their patterns, size and evolution**

The main results are presented in figures 1 and 2, which display information for all the 14 countries in the sample respectively in years 1996 and 2000. The charts provide the mapping of each NSI along the eight dimensions we have been discussing.

The figures are illustrative of the relatively stronger and weaker points of each system. For example, the observation of the “institutional diversity ” axis shows that this is a strong aspect of the US NSI, while for Mexico this is clearly a weak aspect. The US advantage has certainly to do with a very dynamic risk and venture capital industry.

---

<sup>2</sup> In what regards the use of composite indicators, the notes in Eurostat (2002) and European Commission (2003), respectively on pages 80 and 433, clarify some methodological aspects.

Figure 1

### Mapping NISs' Dimensions, 1996

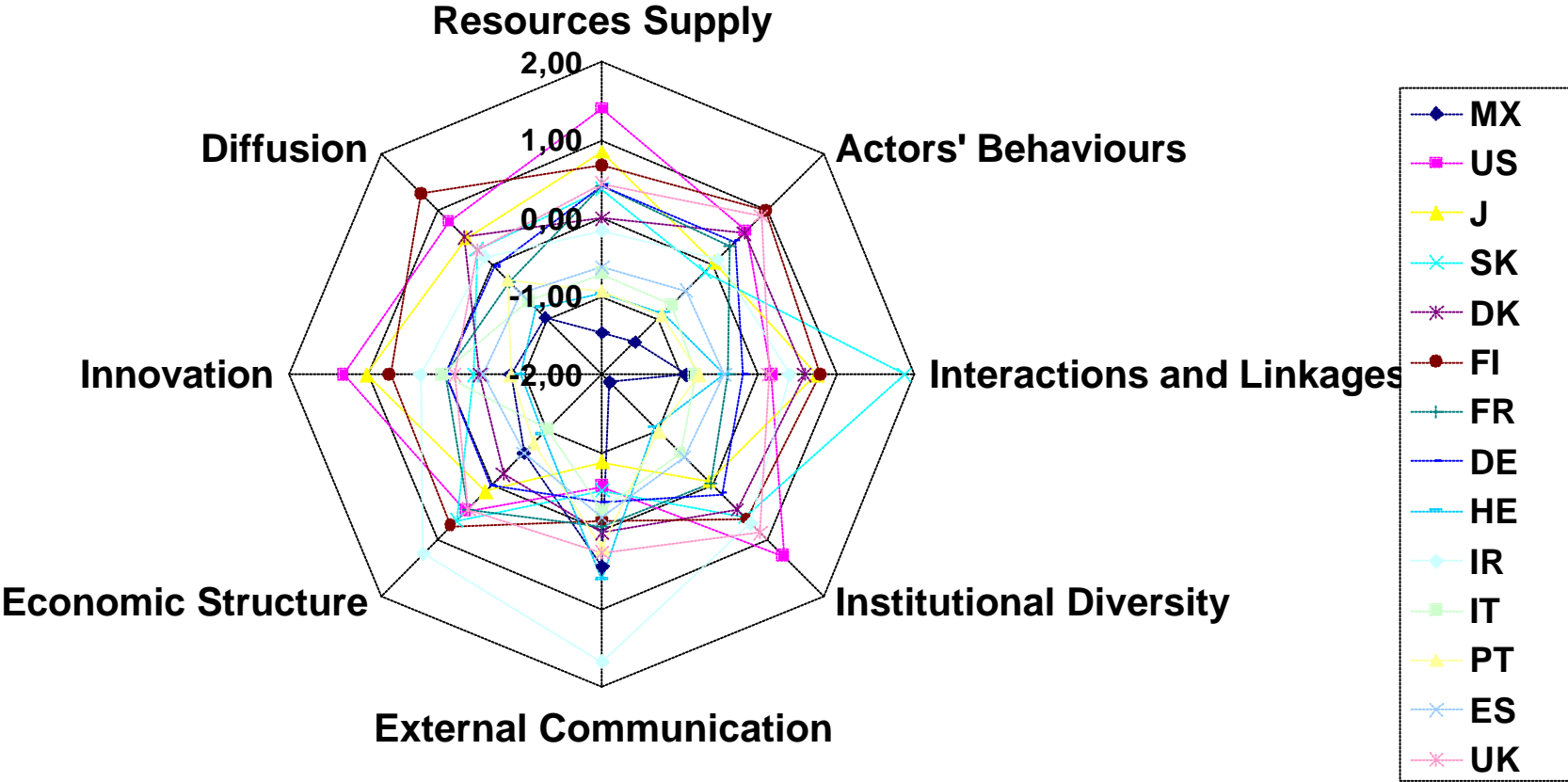
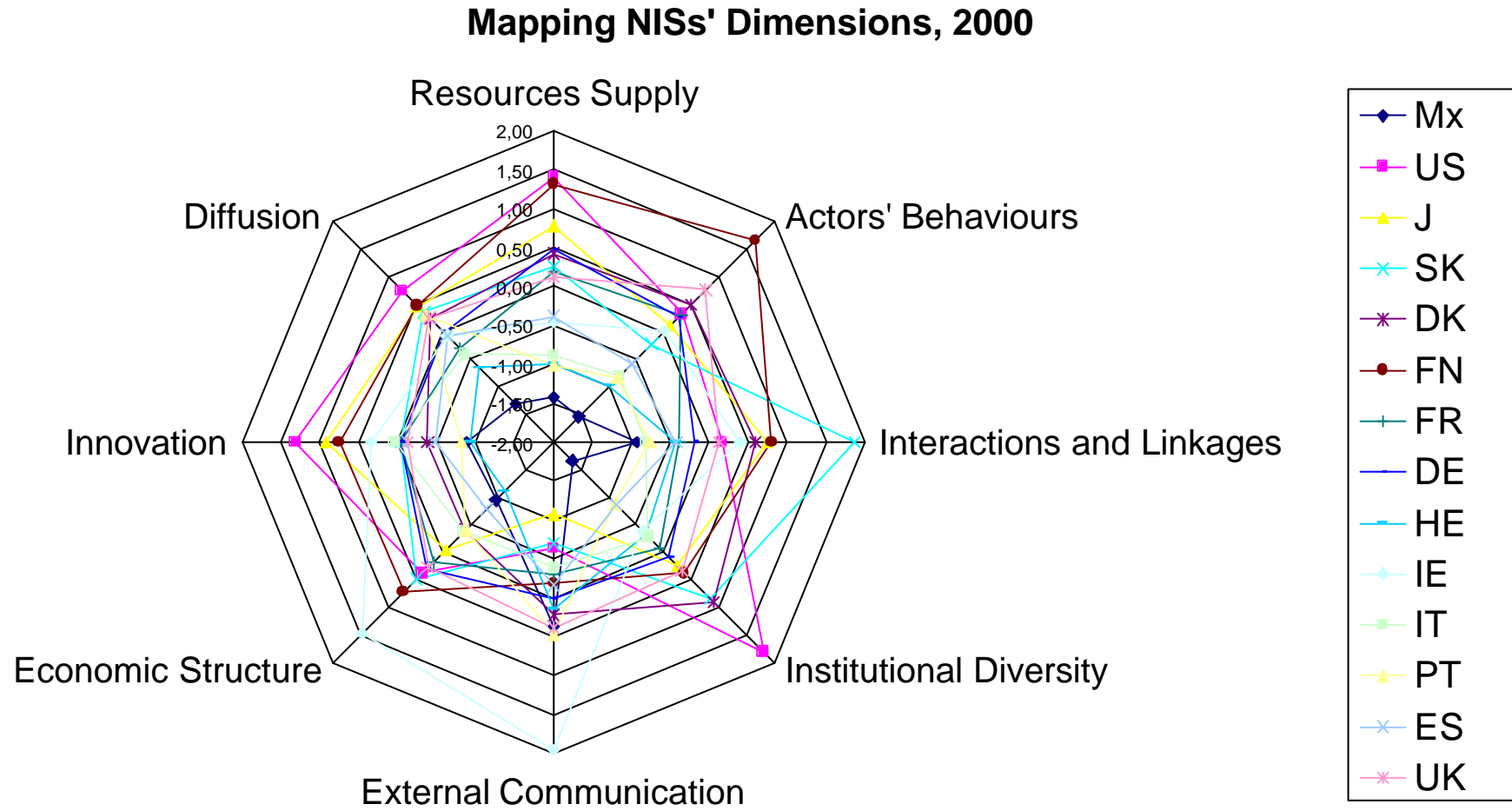


Figure 2



The observation of the information in figures 1 and 2 allows one to infer for each NSI both its relative “size” and discuss its uneven vs. balanced nature. NSI size, or total NSI dimension, was calculated as the area within the line representing each country, with a value of 0 being given to point  $-2$  in the centre of the charts.<sup>3</sup> The values provided by this measurement method can be seen as an alternative to the summary measures provided by the innovation scoreboards we mentioned before. The discussion of the unevenness of the system can be done by simply observing the charts, to see whether the country has a regular shape with all eight dimensions showing similar distances to the centre of the chart, or in alternative it can be calculated as the standard deviation of the country’s values in each of the eight axes. The results for both these calculation procedures are displayed in tables 3 and 4 below.

Table 3 shows interesting information as regards the hierarchy of NSI size, with Ireland and South Korea ranking quite well, but with Italy ranking less well than what could be expected. This situation certainly has to do with the fact that indicators for the industrial structure were taken into the analysis, favouring the two countries mentioned in the first place. But it might well also do with the consideration both in the “resources supply” and the “actors’ behaviours” dimensions of certain indicators of innovative potential, related to the stock and flows of advanced human resources into the economy. Observing both charts, it is clear that Italy fares well in the “innovation” axis but less so in all the other seven dimensions.

With respect to the unevenness vs. balanced nature of the NSIs, some countries like Germany or France show a regular graphical pattern, with all the eight dimensions of their NSIs displaying about the same size. Interestingly, some of the nations with relatively “larger” NSIs, like the US and Japan, show “uneven” systems. This is a result that should be observed with caution, since this “unevenness” is relative and it is endogenous to the exercise itself: we are comparing each country’s values with a figure that can not be necessarily seen (by the simple fact that it is the sample’s mean) as being the “right” or balanced value. In any case, and perhaps not surprisingly, it shall be pointed out that the figures in table 4 also stress the “unevenness” of the Irish and Korean systems.

In the sequence of tables 3 and 4 we present four additional figures, for years 1996 and 2000, in which we divided the 14 countries’ sample into two groups (“leading” and “following” NSI). These figures are presented for the sake of facilitating observation, which may be more difficult when all the countries are charted together as in figures 1 and 2.

---

<sup>3</sup> This was done for practical reasons. The NSI area must be calculated only with positive values. For this we added 2 to the actual value displayed along each axis, with the figures now varying in the interval between 0 and 4 (while in the charts they vary in the interval from  $-2$  to 2).

Table 3. “NSI size” - Estimated values

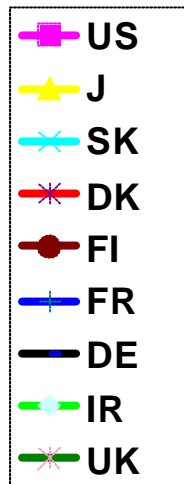
1996		2000	
Finland	20,70	Finland	21,22
US	20,35	US	20,47
Ireland	18,39	Ireland	16,41
UK	16,26	South Korea	15,67
South Korea	15,49	Japan	14,56
Japan	14,77	UK	14,51
Denmark	13,49	Denmark	14,46
Germany	11,87	Germany	12,67
France	11,84	France	10,73
Spain	6,59	Spain	6,63
Italy	5,61	Italy	6,47
Portugal	5,11	Portugal	6,43
Greece	5,01	Greece	5,08
Mexico	3,14	Mexico	2,59

Table 4. “NSI Evenness”

1996		2000	
Spain	0,14	Germany	0,22
Germany	0,27	France	0,26
France	0,32	UK	0,26
Italy	0,33	Spain	0,27
UK	0,34	Italy	0,32
Denmark	0,39	Greece	0,43
Finland	0,40	Denmark	0,46
Portugal	0,42	Finland	0,57
Greece	0,55	Portugal	0,57
Ireland	0,62	Mexico	0,64
Japan	0,62	Japan	0,64
US	0,67	South Korea	0,77
Mexico	0,70	US	0,79
South Korea	0,74	Ireland	0,87

Note: The “evenness” of a NSI was estimated for each country (and for each year 1996 and 2000) as the standard deviation of the country’s values in the eight NSI dimensions. A value closer to zero means that the country has about the same relative “size” in each of the eight axes/dimensions. In contrast, a value closer to 1 means the country has an uneven system, with some of the eight dimensions scoring much better (or worse) than the others.

Figure .



## Leading NISs 1996

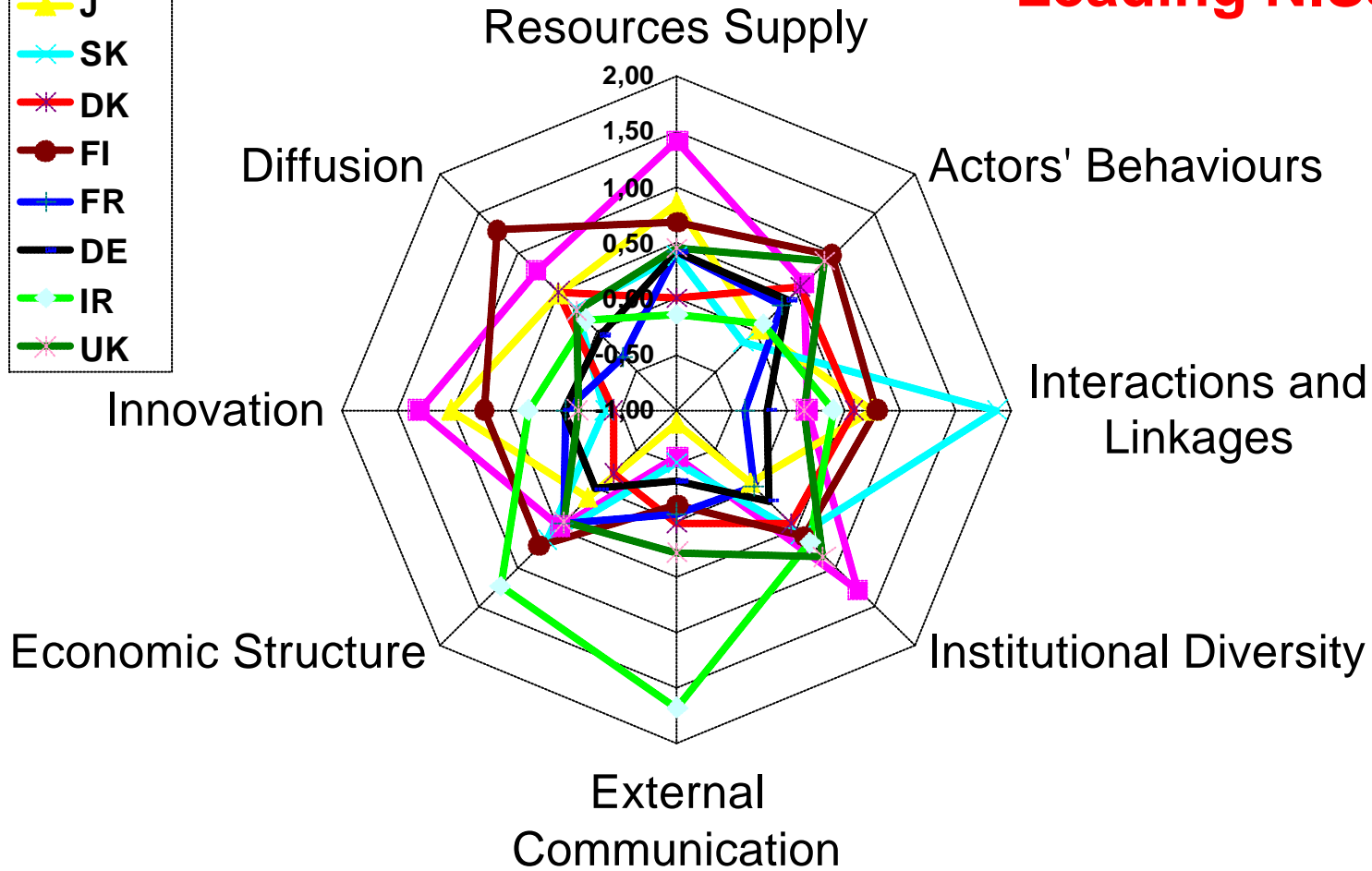
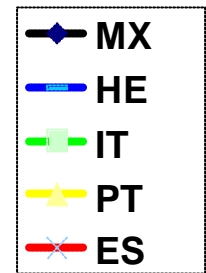


Figure 4.



## Followers 1996

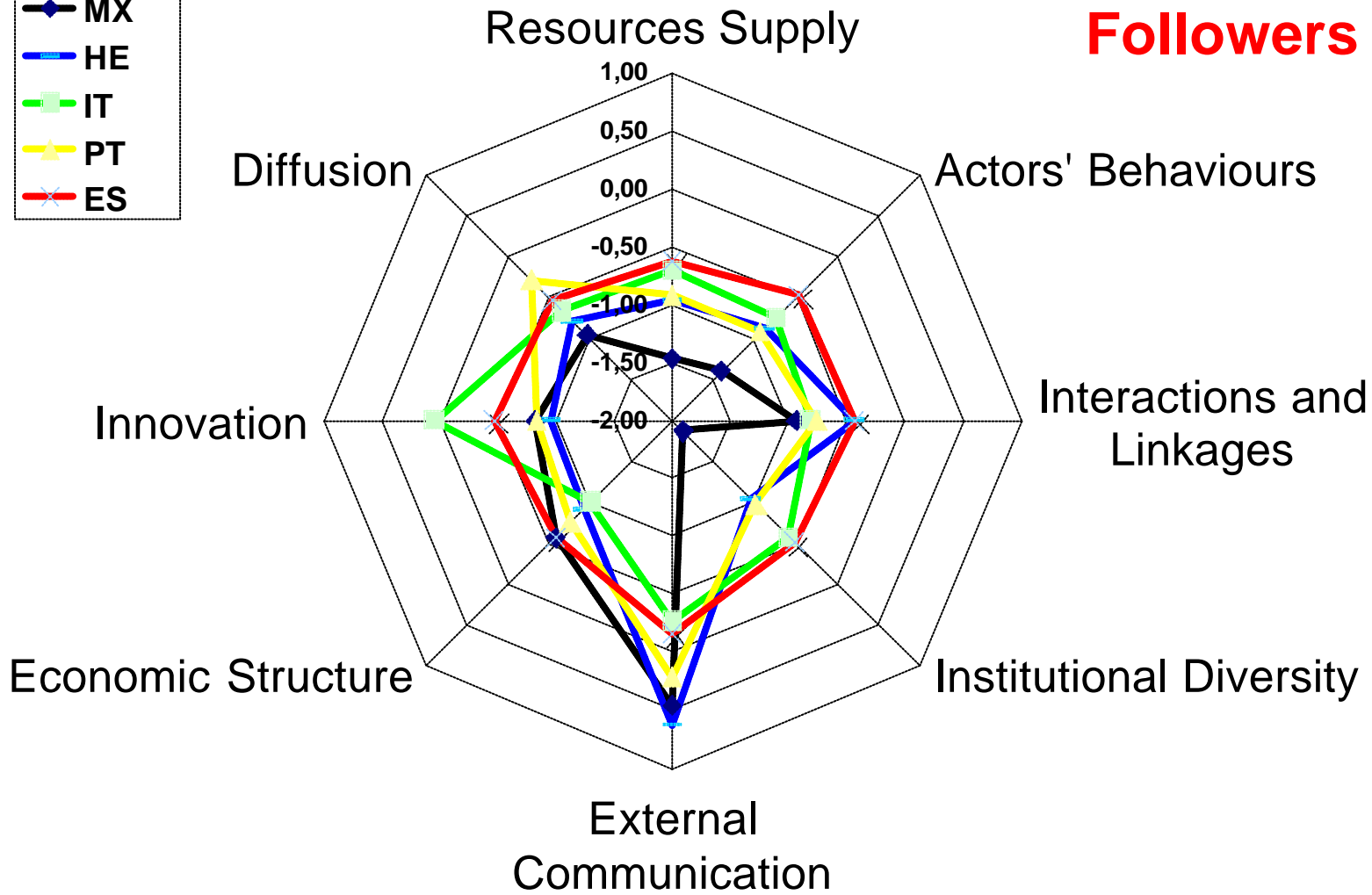


Figure 5.

# Leaders 2000

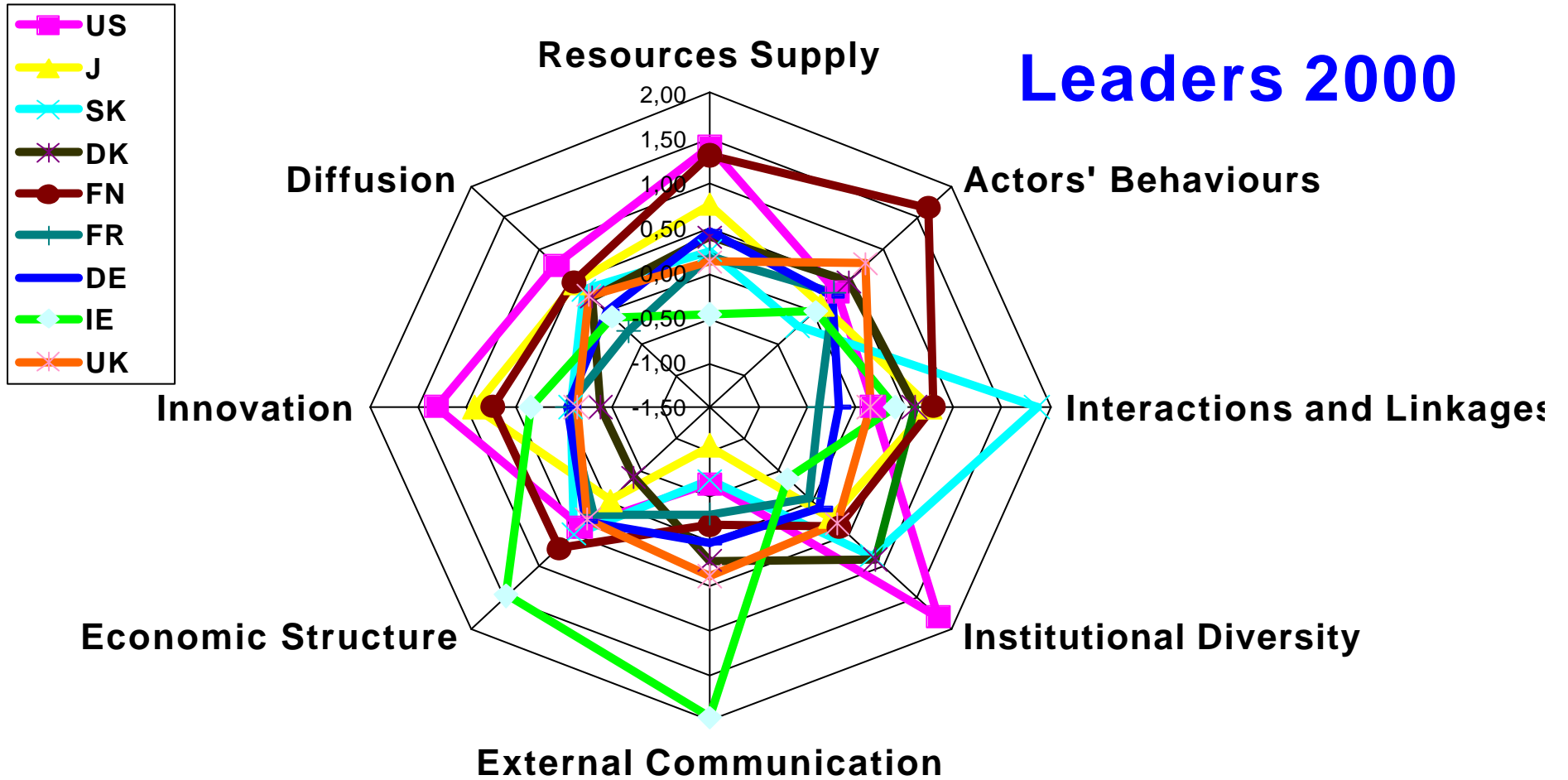
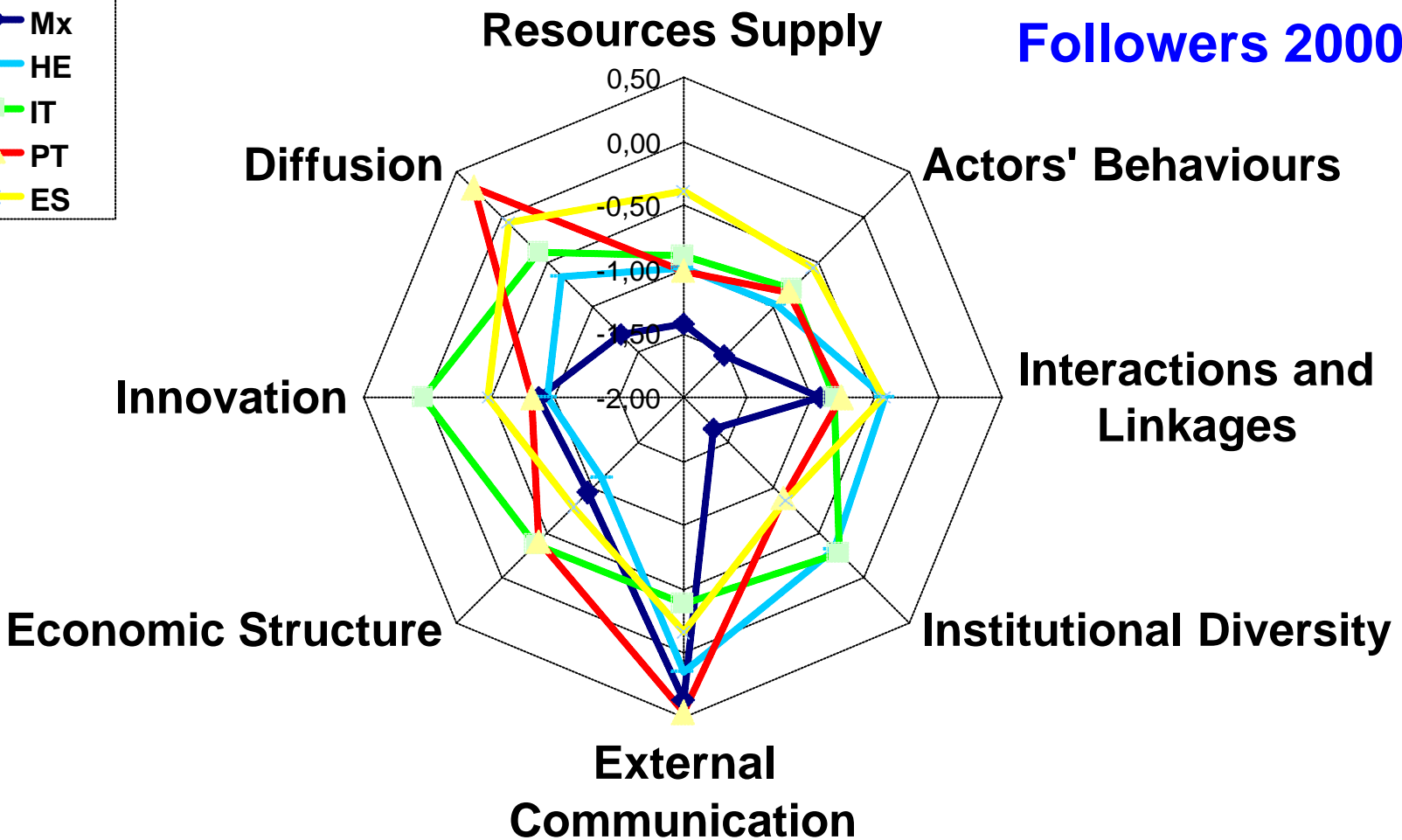


Figure 6.



To conclude this section we will turn to another aspect: how can we consider the evolution of NSIs within the analytical and graphical framework that was put forward? As the composite indicators estimated for each year derive from a standardization procedure, the absolute values of the variables they are based on lose their specific meaning. In these circumstances we can not measure the growth (or eventual decline) from year 1 to year 2.<sup>4</sup>

Even so, a comparison is possible. For that, we can determine how the individual NSIs evolved in relation to each year's average. In practical terms this translates into a comparison of each NSI relative size in both years, as indicated in table 5. In figures 7 to 9 we provide visual information respectively about a "expanding", a "stable" and a "contracting" NSI, being all these qualifications relative to the average trends.

Table 5. NSIs relative evolution

1996 - 2000	
Portugal	0,12
Denmark	0,09
Italy	0,08
Germany	0,07
Finland	0,05
South Korea	0,02
US	0,01
Greece	0,01
Spain	0,00
Japan	-0,02
Mexico	-0,05
France	-0,10
UK	-0,15
Ireland	-0,18

Note: This "evolution" indicator stems from the consideration of the distance between each NSI and the 14 countries' average in both 1996 and 2000. Specifically, in each year we divided the country's NSI size by the mean area value (11,3137085), and then we calculated the difference between both years' quotients. The countries with positive values are those that evolved at a higher speed than the average, while those with negative values are the ones that evolved at a lower speed.

---

<sup>4</sup> That would be possible if the standardization is carried out not for each specific year but for both years together. But that would introduce other requirements, namely the need for price indexes to deflate monetary values.

Figure 7.

### Expanding NIS

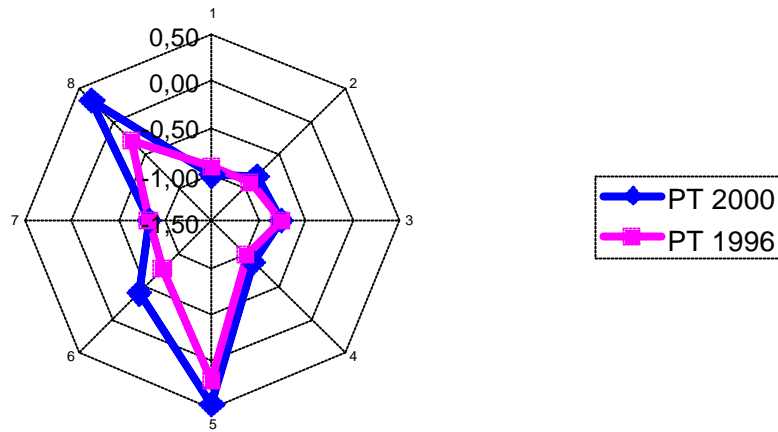


Figure 8.

### Stable NIS

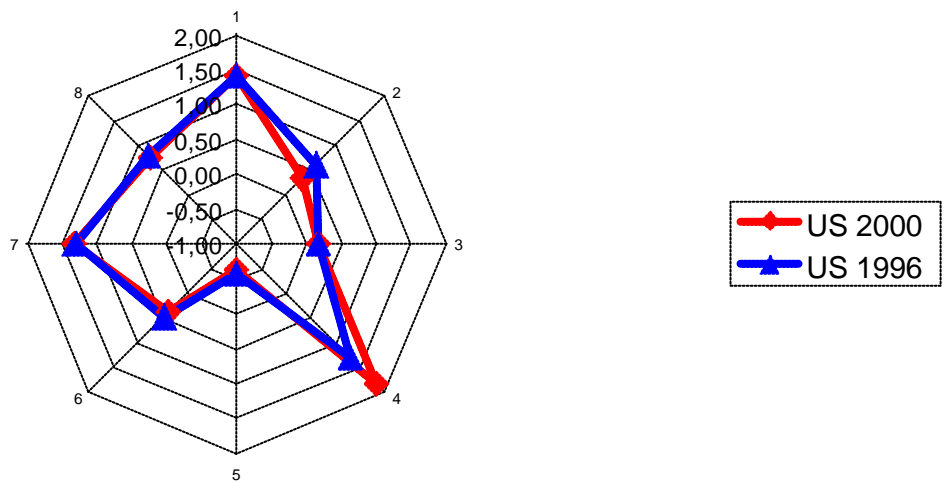
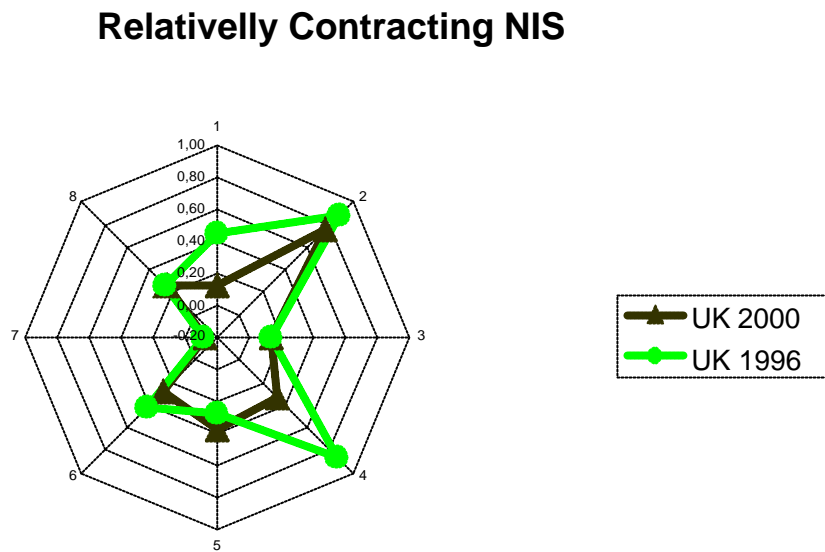


Figure 9.



## 5. Concluding Remarks

This paper argues the case for extending the NSI research by means of quantitative analysis. In the previous sections we have attempted to answer several questions that were put forward in the beginning. Those questions include: Is it possible to measure NSIs? What specific technique may be used for that? Can we apply that technique both to the advanced and the catching up economies?

The exercise we carried out above in mapping NSIs shows that satisfactory replies can be given to those questions. The technique which was put forward, although simple in the steps it requires to produce the graphical representations and the quantitative indicators of NSIs, shows a significant potential for both analytical and policy-making purposes. This paper by no means is a claim of a finished solution to the problem of the quantitative assessment of NSIs. Instead it is intended as a plea to open an explicit line of quantitative investigation in the innovation systems agenda. There is much to be gain from this effort, including making the NSI concepts more operational, creating taxonomies of NSIs and rendering the complementary qualitative case study research more useful for informed policy-making purposes.

In what regards the analytical value of the identification of eight major dimensions, we are aware that arguments can be put forward to criticize both those dimensions and the indicators that were used to illustrate them. It might be argued namely that our choices do not represent fairly the diversity of theorisations that have been produced on the subject. However, what is relevant in the process that was implemented, is not so much the choices that were undertaken in terms of the identified dimensions or selected indicators. What is relevant is the process itself, in the sense that by getting involved in it one is forced to be specific about what exactly is meant by “NSI” and also about the identification of its components, or aspects, that deserve to be analysed with greater attention. This process might therefore help the conceptual work on NSIs to evolve

further in the future, from elaborations which have essentially been qualitative in their nature to more precise and operational definitions of “NSI” and its components.

In what concerns the practical policy-making dimension, the cartography of NSIs that is produced through this method, together with the associated indicators, indisputably show high potential. In this respect, it is clear that our work is fully in line with the indications stemming from core research on innovation systems: “Concrete empirical and comparative analyses are absolutely necessary for the design of specific policies in the fields of R&D and innovation. The S[systems of] I[nnovation] approach is an analytical framework suited for such analyses. It is appropriate for this purpose because it places innovation at the very centre of focus and because it is able to capture differences between systems. In this way specific problems that should be objects of innovation policy can be identified.” (Edquist 2002, p. 22). In the same vein, we must also recall the conclusions of a recent OECD project on *Dynamising National Innovation Systems*: “the need to engage in effective learning processes suggests that governments may benefit from intensified international benchmarking of policy practices in this [NSI] respect” (OECD 2002, p. 81).

The tool that was developed in this paper fits well into the type of benchmarking and comparative analyses that have been sought in the literature on innovation systems. At the same time it avoids the oversimplification dangers that have been associated with much recent scoreboard exercises. In addition to that the fact that it helps in identifying clearly the weaker and stronger aspects of each NSI, and that it might also provide indications about NSI evolution and development over time, has policy-making value for both the advanced economies and the intermediate catching up countries. In this respect the mapping approach invites the policy-makers’ attention to the vast array of policy instruments must be combined in order to promote self-sustaining social and economic development (Adelman and Yeldan, 2000).

To finalise we must say that besides eventual conceptual shortcomings, regarding the definition of the NSI dimensions etc., an aspect to be dealt with more thoroughly in the future concerns data quality and comprehensiveness.<sup>5</sup> As regards the results of the present exercise they shall be seen as strictly experimental. The summary measures we presented and the graphical depictions of NSIs that were produced shall therefore be taken as merely indicative of what is actually happening in the 14 countries that were selected for analysis.

---

<sup>5</sup> The publication of CIS-3 results for European countries might help in this respect, even though similar data will still not exist for many other countries.

## 6. References

- Abramovitz, M. (1994), "The Origins of the Post-war Catch-Up and Convergence Boom", in Fagerberg, J., Verspagen, B., and von Tunzelman, N. (eds.), *The Dynamics of Technology, Trade and Growth*, Edward Elgar, Aldersho.
- Adelman, I. And E. Yeldan (2000), "In this the end of economic development?", *Structural Change and Economic Dynamics*, vol. 11, pg. 95-109
- Arundel A. (2003), *Innovation Scoreboards: Promises, Pitfalls and Policy Applications*.
- Asheim, B. and Gertler, M. (2004), "Regional systems of innovation", forthcoming in J. Fagerberg, D.C. Mowery and R.R. Nelson (eds), *Understanding Innovation: The Oxford Handbook of Innovation*, Oxford: Oxford University Press.
- Autio E. and T. Laamanen (1995), *Measurement and Evaluation of Technology Transfer: Review of Technology Transfer Mechanisms and Indicators*, in Int. J. Technology Management, Vol. 10, Nos 7/8, pp. 643--664.
- Braczyk H. J. et al. (1998), *Regional Innovation Systems*. UCL Press, London.
- Breschi S. and F. Malerba (1997), Sectoral systems of innovation: technological regimes, Schumpeterian dynamics, and spatial boundaries, in C. Edquist (ed.), *Systems of Innovation: Technologies, Institutions and Organization*. London: Pinter.
- Carlsson B. and R. Stankiewicz (1995), On the nature, function and composition of technological systems, in B. Carlsson (ed.), *Technological Systems and Economic Performance: The Case of Factory Automation*. Boston: Kluwer Academic Publishers.
- Carlsson B. and S. Jacobsson (1997), In search of a useful technology policy – general lessons and key issues for policy makers, in Carlsson B. (ed.), *Technological Systems and Industrial Dynamics*. Boston: Kluwer Academic Publishers.
- Cooke P. (1998), Introduction. Origins of the concept. In Braczyk, H.-J. et. al. (Eds.), *Regional Innovation Systems*. UCL Press, London.
- David P. and D. Foray (1995), *Accessing and expanding the science and technology knowledge base*, in *STI Review*, 16, 13-68.
- Edquist C. (2003), *Innovation policy – A systemic approach*, paper presented to the IES Seminar, ISEG/UTLisbon.
- European Commision (2003), *Third European Report on Science and Technology Indicators*. Brussels. CEC.
- Eurostat (2002), *Towards a European Research Area; Science, Technology and Innovation; Key Figures 2002*. Luxembourg: Eurostat.

Evangelista R., T. Sandven, G. Sirilli, and K. Smith (1998), *Measuring innovation in European industry*, in *International Journal of Economics and Business* 3 (5), pp. 311-333.

Fagerberg, J. (2003a), "The Potential of Benchmarking as a Tool for Policy Learning", *The IPTS Report*, N° 71, Feb., pp. 13-9.

Fagerberg J. (2003b), *Schumpeter and the revival of evolutionary economics: An appraisal of the literature*, in *Journal of Evolutionary Economics*, Vol. 13, N° 2, pp. 125-159.

Freeman C. (1979), *The determinants of innovation*, in *Futures*, June, 206-215.

Freeman C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Freeman, C. (1994),

Freeman, Christopher (1995), 'The National Innovation Systems in Historical Perspective', *Cambridge Journal of Economics*, Vol. 19, No. 1.

Freeman C. and C. Perez (1988), *Structural crisis of adjustment: business cycles and investment behaviour*, in G. Dosi et al. (eds.), *Technical Change and Economic Theory*. Londres: Pinter.

Freeman, C. and L. Soete (1997), *The Economics of Industrial Innovation*. Londres: Pinter.

Gregersen B. and B. Johnson (2001), *Learning Economy, Innovation Systems and Development*, Paper prepared for the Converge Project ("Strategies and policies for systemic interactions and convergence in Europe – Converge").

Kline S.J. and N. Rosenberg (1986), *An overview of innovation*, in R. Landau and N. Rosenberg (eds.), *National Systems of Innovation*. Oxford University Press.

Landabaso M. (1995), *The promotion of innovation in Regional Community Policy: Lessons and proposal for a Regional Innovation Strategy*, Paper presented at the RESTPOR '95 Meeting.

Lundval B.-A. (1985), *Product Innovation and User-Producer Interaction*. Aalborg: Aalborg University Press.

Lundvall B.-A. (ed.) (1992), *National Systems of Innovation - Towards a Theory of Innovation and Interactive Learning*. London: Pinter.

Lundvall B.-Å. and S. Borràs (1999), *The Globalising Learning Economy: Implications for Innovation Policy*, Brussels, DG XII.

Malerba F. and L. Orsenigo (1993), *Technological regime and firm behaviour*, in *Industrial and Corporate Change*, 2, pp. 45-71.

Malerba F. and L. Orsenigo (1997), *Technological regimes and sectoral patterns of innovative activities*, in *Industrial and Corporate Change*, 6/1, pp. 83-117.

Meyer-Krahmer F. et al. (1998). *Internationalisation of Research and Technology: Trends, Issues and Applications for Science and Technology in Europe*. Brussels: European Commission, ETAN Working Paper.

Mowery, David C. and Joanne E. Oxley (1995), 'Inward Technology Transfer and Competitiveness: the Role of National Innovation Systems', *Cambridge Journal of Economics*, Vol. 19, No. 1.

Nelson R. R. (ed.) (1993), *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

OECD (1992), *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: Oslo Manual*. Paris: OECD.

OECD (2000), *Knowledge management in the learning society*. Paris: OECD.

OECD (2002), *Dynamising National Innovation Systems*. Paris: OECD.

Patel P. (1995), *Localised production of technology for global markets*, in *Cambridge Journal of Economics*, n° 19.

Pavitt K. (1984), *Patterns of Technical Change: Towards a Taxonomy and a Theory*, in *Research Policy*, 13, 343–74.

Pereira, T.S. (2002), "The Social Contract for Science and the Models for Academic Research: Implications for the governance of science in the periphery", paper presented at the NPRNet Conference 'Rethinking Science Policy: Analytical Frameworks for Evidence-Based Policy', 21-23 March, SPRU, University of Sussex.

Rush H., M. Hobday and J. Bessant (1996), *Technology Institutes: Strategies for Best Practice*. Routledge.

Saxenian A. (1994), *Regional advantage. Culture and competition in Silicon Valley and route 128*. Cambridge, MA: Harvard University Press.

Smith K. (1992), *Technological innovation indicators: experience and prospects*, in *Science and Public Policy*, 19(6), 383-392.

Smith K. (2004), *Measuring Innovation*, in Fagerberg, Mowery and Nelson (eds.), *Innovation Handbook*. Oxford: Oxford University Press (forthcoming).

Teubal M., D. Foray, M. Justman and E. Zuscovitch (eds) (1996), *Technological Infrastructure Policy: an International Perspective*. Kluwer Academic Publishers

Zanfei, A. (2000), "Transnational firms and the changing organisation of innovative activities", *Cambridge Journal of Economics*, 24, pp. 515-542.