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Markus Balzat, Andreas Pyka

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Markus Balzat and Andreas Pyka

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Markus Balzat and Andreas Pyka

University of Augsburg (Germany), Department of Economics, Chair of Economics V,
Phone: +49 821 598 4174/4178, Fax: +49 821 598 4229
e-mail: markus.balzat@wiwi.uni-augsburg.de, andreas.pyka@wiwi.uni-augsburg.de

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Abstract

The purpose of this paper is to present new findings about the structure and the organization of innovative activities in selected OECD countries. By using the approach of national systems of innovation as a conceptual framework and by applying multivariate data analysis techniques, this paper aims to add new insights into the specific structures of the eighteen national systems of innovation under study. A central result from this comparative study is a categorisation of national systems of innovation into different clusters, with each cluster representing distinctive cross-national structural similarities. By accounting for sectoral specifics, the commonly taken perspective on national innovation systems is extended. Thereby, a more precise picture of the structural composition of the analyzed national innovation systems accrues. Also, a new linkage between the two approaches of national and sectoral innovation systems is created.

Introduction

Within the last few years, the consideration of institutions and their role in economic organization has led to various approaches classifying different forms of capitalistic market organization. One of the most prominent of these is the *varieties of capitalism approach* introduced by Hall and Soskice (2001). Only recently, Amable and Petit (2001) and Amable (2003) have elaborated this approach by applying econometric techniques to this previously merely descriptive concept. In detail, they generated a systemic taxonomy of capitalism in its various forms of appearance in industrialized economies. Obviously, the organization of innovation within an economy plays an important role in market-based economies and in their institutional set-ups, which is due to the meanwhile uncontested growth-spurring impact of innovation. Similar to the varieties of capitalism concept, and already since the 1990s (e.g. Lundvall, 1992a), the approach of national innovation systems (NIS approach) also concentrates on institutional settings and their location-specific features. In particular, it emphasizes the interdependencies between the historically developed designs of institutional frameworks on the one hand and patterns in innovative activities on the economy level. The NIS approach meanwhile constitutes a widely applied concept in modern innovation research and enjoys growing acceptance by policymakers in industrialized economies.

Motivated by the complementarities between these two lines of research, the present study aims to elaborate empirically the structural similarities and dissimilarities of national innovation systems. By means of multivariate data analysis, a taxonomy of national innovation systems will be presented. To accomplish this central purpose, this paper focuses on the structure of innovative activities on the national level in selected highly industrialized countries. It thereby aims to identify and explain nation-specific − as well as nation-spanning − structural characteristics of innovation-related activities and of their major institutional surrounding conditions. To do so, the concept of national systems of innovation will be employed as a conceptual framework, mainly because this concept together with its theoretical underpinning allow for a realistic and holistic analysis of modern innovative activities. However, this rather young scientific concept still leaves room for extensions along several research avenues, but especially in empirical respects (see Edquist, 2005; Balzat and Hanusch, 2004). Correspondingly, the present study attempts to contribute to the important field of international comparisons of national innovation systems and to add new insights into the organization of highly developed national systems of innovation.

Based on the broad international comparison that is carried out here, this paper seeks to expand the empirical treatment of the NIS approach. Especially, it aims to identify not only cross-national *dissimilarities* but primarily cross-national *similarities* in the structure and in the innovative performance of eighteen national innovation systems in the OECD area.[1] In doing so, this research goes one decisive step further than just adding new evidence to the path dependent – and therefore strongly nation-specific – organization of innovative action in national economies.

Viewed more broadly, the results from this study may be relevant to the design and the efficiency of political measures directed towards innovative action on the country level. The reason for this is that the identified different clusters of national systems of innovation show the degree and the areas of structural similarities across the analyzed systems. In this way, the country clusters that are detected may affect the efficiency of mutual learning processes (see Lundvall and Tomlinson (2002)) when it comes to the planning, the conduct and the targeted international coordination of technology policy action. This latter aspect particularly applies to the member countries of the European Union[2]. However, the derivation of policy consequences lies outside the focus of this paper.

The structure of this paper is as follows: The subsequent section gives a brief introduction to the conceptual background of this study, i.e. the national innovation systems approach. In the following section, the underlying empirical approach of this study is motivated by introducing the data, the NIS models that are applied as well as the employed analytical method. The following section then deals in detail with the outcomes of this international comparison, namely with the country classifications that have been found. In the final part of this paper, conclusions are drawn and a brief outlook on future research is given.

Conceptual background: A brief overview on the NIS approach

After its introduction in the late 1980s[3], the concept of national innovation systems (NIS concept) has been further elaborated and theoretically underpinned in the early 1990s[4]. It meanwhile can be regarded as an established approach within modern innovation research and it has shown to constitute an adequate conceptual framework for the empirical study of innova-

[1] The empirical work by Amable and Petit (2001) goes in the same direction. That is because on the basis of the conceptual framework of social systems of innovation and production (SSIP concept), their comparative study generates a classification of 21 OECD economies in total.
[2] As regards the design of this empirical study, fourteen out of eighteen analyzed countries are EU members.
[3] Cf., for example, Lundvall (1988), Freeman (1987, 1988) and Nelson (1988).
[4] See, e.g. Lundvall (1992a) and Edquist (1997).

tion processes on the country level. Above all, the approach focuses on the analysis of nationwide structures of innovative activities, their institutional determinants and economic effects.

In numerous single-country studies, being typical of early applications of the NIS concept[5], all these aspects have been found to be highly nation-specific. A theoretical explanation for these findings is provided by the notion of path dependence, which is associated with the assumption of historical uniqueness. Although, or perhaps because there have been revealed profound country-specific elements in the organization as well as in the outcomes of innovative action, numerous partial or holistic international comparisons of national systems of innovation have been conducted recently. In these comparisons, which may now even be considered as a distinctive line of research within the NIS literature,[6] new alternatives to the empirical treatment of national systems of innovation have been provided. Specifically, these comparative empirical studies may contribute to the advance of the NIS concept in the sense that they entail evaluations of the functioning (or 'performance') of entire national innovation systems or of their main structural elements.[7] These evaluations can be carried out on the basis of analytical models or by means of a set of subjectively chosen indicators of innovation and learning activities on the macroeconomic level.

Apart from these mere scientific interests, the rationale behind the carrying out of international comparisons within the conceptual framework of NIS often lies in the initiation of mutual learning processes through the identified nation-peculiar strengths and weaknesses of innovation-related activities. On that basis, an ultimate purpose often lies in the derivation of policy-relevant recommendations.

Empirical setting

a) Data

It is a central aim of this empirical study to gain new findings as regards the structural characteristics and the functioning of national innovation systems in highly developed countries. To meet this target and thus to be able to take a holistic or system-level perspective, our analysis is grounded on a comprehensive set of indicators. In total, more than sixty variables have been collected, reflecting many different activities in and characteristics of national innovation sys-

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[5] For a collection of these studies, see Nelson (1993).

[6] An overview on the latest development lines of the NIS approach is, for instance, provided by Balzat and Hanusch (2004). A concise survey of the emergence and the - both scientific and conceptual - frontiers of the systems of innovation approach is provided by Edquist (2004).

[7] See, e.g. Nasierowski and Arcelus (2003), Furman, Porter and Stern (2002) or Porter and Stern (2002).

tems. Above all, the set of variables reflects structural specifics of national innovation systems. But the data also comprise several indicators of the functioning of NIS, including outputs of the innovation process such as patents or the commercialization of technology- and knowledge-intensive goods and services on international markets.

The utilized indicators originate from various sources, the most important one being the OECD, especially its *Main Science and Technology Statistics*, its *Educational Database* and its *Patents Database*. From these three OECD databases, patent statistics, R&D expenditure data as well as several indicators of national education systems and of qualification structures of national workforces have been extracted. Further main data sources are the World Economic Forum and the UN.[8]

b) Underlying delineation of the NIS concept

The empirical analysis of our country sample as well as the composition of the array of variables employed for it rest on our delineation of the NIS concept in the form of two simple, indicator-based NIS models. A common feature of both NIS models is that they have a hierarchical structure, which implies that the concept of a national innovation system is decomposed into several main elements or building blocks. Each NIS building block consists of several variables, so that each of the selected indicators can be attached to one of these different NIS components of our NIS models.

Although both of our simple NIS elements share their basic hierarchical structure, the main difference between them lies in the number of their building blocks and consequently in the number of considered variables. NIS model 1 consists of five building blocks. These are labelled *innovative efforts*, *institutional framework conditions*, *knowledge base*, *openness* and *financial conditions*. Each of these five central elements of our NIS models will now be briefly explained.

The NIS element *innovative effort captures* the investment in R&D-related activities on the macroeconomic level by taking account of three different types of R&D expenditure data. These are private, public and gross domestic values of R&D spending in percent of GDP.

Without doubt, the innovative strength of a country's innovation system depends on many more aspects than just investments in R&D-related activities. Thus, apart from the consideration of the different monetary measures of innovative activities that are captured in the block

[8] A complete listing of all utilized data sources can be found in the Appendix.

innovative efforts , the NIS element *knowledge base* includes numerous further variables estimating the current and future outcomes of national innovation systems. To approximate the present inventiveness of an NIS, mainly patent data and employment ratios of scientific personnel are utilized, while the future inventiveness of an NIS is evaluated by several indicators of the quality of national education systems and by structural variables of the national workforce.

Since the financial market conditions are a critical factor to the conduct as well as the maintenance of R&D-related activities and projects, a distinctive model element which is called *financing conditions* evaluates the perceived sophistication of national financial markets, the level of capital costs in a country (indicated by the levels of short-term and long-term interest rates) as well as by the disposability of venture capital to firms in technology- and knowledge-intensive industries.

Of course, it is a key feature and also a major advantage of the NIS concept that it explicitly accounts for the decisive impact of institutional structures on innovation and learning. Measuring institutions per se or even the interdependencies between institutions and innovative outcomes in empirical studies, however, are difficult tasks. Still, with the composition of the NIS element *institutions* , it is sought to approximate the institutional framework conditions of a country in terms of direct and indirect incentives to innovative action on the basis of a broad range of indicators.[9,10] The variables that enter this model element reflect general macroeconomic framework conditions, specific incentives to conduct innovative efforts, the utilization of modern information and communication technologies by national actors together with the quality of the infrastructure they require and incentives to participate in higher education programs.

Proposing that national innovation systems are open systems[11], the NIS building block *openness* of our model measures the degree of internationalization of the eighteen national innovation systems under study. In particular, this model element comprises data on the market shares of the studied OECD countries on international product markets for technology-

[9] Admittedly, the interrelations between innovation and learning activities on the one hand and institutional incentive structures on the other hand are complex in reality and the definite causalities are far from being fully understood. With the consideration of a wide-ranging set of indicators, though, we abstract from these complex linkages and merely aim to approximate the favourability of nation-specific institutional settings to innovation and learning processes on the country level.

[10] Perhaps, not only advances of the systems of innovation approach but also its acceptance in the future will depend on the ability of scholars in the field to develop methods that allow for a better understanding of the co-evolutionary processes of institutional setting, industrial structures and of location-typical innovation patterns.

[11] The assumption of system openness is fully with the basic properties of our conceptual framework as they have been defined in earlier contributions to the NIS literature. See, for instance, Lundvall (1992b), Galli and Teubal (1997) or Edquist, Hommen and McKelvey (2001).

intensive goods as well as indicators of cross-national collaborations in the generation of scientific outputs.

With these five elements, it is aimed to capture in a structured way many of the core activities in an NIS as well as central determinants of the direction and outcomes of innovative and learning activities on the national level.

All these five central NIS components therefore constitute NIS model 2 as well. Additionally, though, our second indicator-based NIS model comprises a further building block which is denoted *sectoral specifics*. The definition of this NIS component rests on the presumption that the sectoral composition of an economy co-determines the institutional setting of a national innovation system as well as the structure and direction of innovative activities in a country.

This specific element of NIS model 2 is constituted by numerous variables indicating the size, the innovative output and the competitiveness of technology- and knowledge-intensive industries. By including these sectoral characteristics, this NIS model not only goes beyond the set of commonly considered variables that seek to capture the activities in national innovation systems, it also takes account of the interdependences between industrial structures and institutional framework conditions. Furthermore, the consideration of sectoral data in NIS studies also contributes to the creation of a more explicit linkage between two important sub-concepts within the innovation systems approach, especially between the concepts of national and sectoral innovation systems (see, e.g., Malerba, 2002).

In the subsequent Figure 1, the basic set-up of our two NIS models is illustrated.

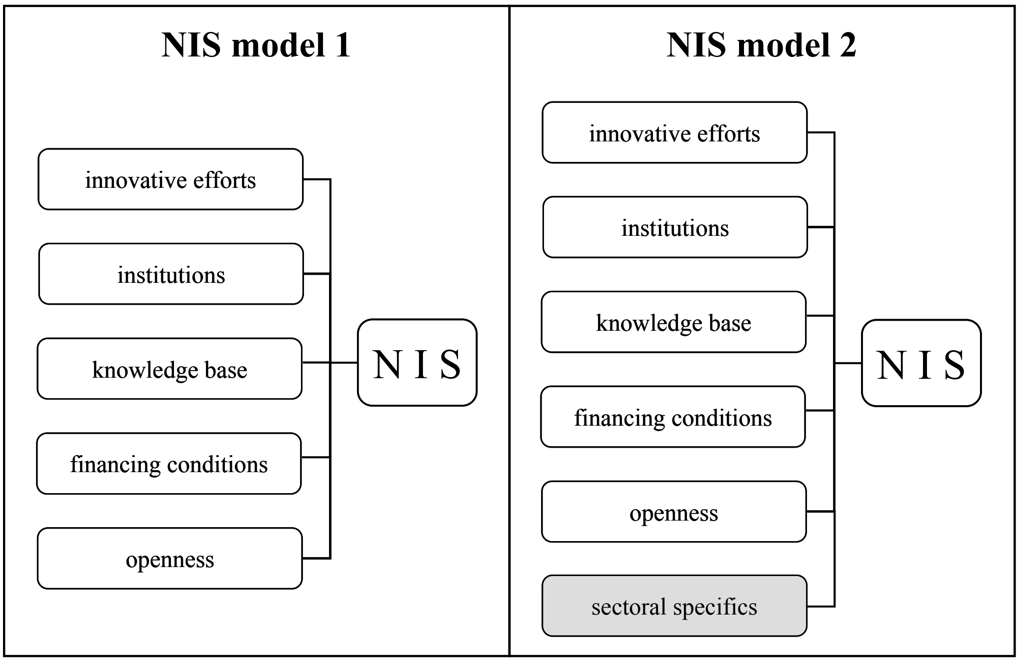

Figure 1: Illustration of the two NIS models that are used in the empirical analysis.

c) Analytical method

By using the conceptual framework of national innovation systems, the specific targets of our study are to detect and then to analyze cross-national (dis-)similarities in the structure and performance of innovative activities on the country level. To meet these objectives, cluster analysis techniques are applied to the data (see, e.g. Jobson, 1992). The general rationale behind this analytical tool is to test a sample for the degree of structural commonalities between the units of analysis. Its outcome is a categorisation of the analyzed units so that the coherence of each group (or cluster) as well as the heterogeneity across different clusters is to be maximized. To determine the coherence of a certain cluster and to calculate the existing diversity of different clusters, distance values between the units of analysis need to be determined on the basis of the characteristics of each entity. From the various methods to calculate distances between the entities, the squared Euclidean distance measure is applied. That is because this is a frequently applied distance measure of metric data. Furthermore, it more strongly accounts for differences between entities than the linear Euclidean distance does.

Hence, the distance between two countries *i* and *j* can be calculated as follows:

$$d(i,j) = \sum_{k=1}^{m} (a_{ik} - a_{jk})^2$$

Here, a_{ik} represents the parameter value of characteristic *k=1,…,m* for country *i=1,…,n*. Thus, the entire quantitative data matrix is $\mathrm{A} = (a_{ik})_{m \times n}$.

The determination of distances between entities is a crucial but at the same time preliminary step in the entire cluster analysis. It needs to be completed by the application of a classification algorithm. Depending on the quality of the underlying data and on the research target, various classification procedures exist.

The data are characterized by a relatively small number of units of analysis (i.e. eighteen countries in total) and at the same time by a relatively large number of variables (more than sixty variables in total) and by a cardinal data level.

Given these specifics of the underlying data and the country sample, a hierarchical, two-step cluster method (which rests upon the average-linkage principle of cluster membership) is applied to the sample.

The determination of the inter-cluster diversity between two classes *K* and *L*, $v(K,L)$, can thus be described formally as follows:

$v(K,L) = \frac{1}{|K|\cdot|L|}\sum_{\substack{i\in K\\ j\in L}} d(i,j)$, with both distinctive classes *K* and *L* (i.e. *K≠L*) belonging to the entire classification **K**.

Since it is not intended to impose a given, pre-determined classification of countries ex ante, an agglomerative classification method is utilized. This method starts with single-country clusters and entails a step-wise concentration of countries according to their degree of structural similarities. Given that is it intended to attach all countries in the sample to a certain cluster and that cases in which a certain country belongs to several clusters shall be ruled out, the selected clustering method yields an exhaustive as well as a disjunctive classification. A classification is exhaustive if $\bigcup_{K\in\mathrm{K}} K = N$, with N being the total amount of analyzed objects. A disjunctive partition meets the condition that $K, L \in \mathrm{K}, K \neq L$, so that $K \cap L = \phi$.

This clustering method is applied to both of our NIS models, while for each of the models one *global analysis* as well as several *partial analyses* are carried out. With the expression *global analysis*, the specific case is denoted that the entire set of indicators which underlies the corresponding model is subject to a hierarchical cluster analysis. *Partial analyses* denote those cases in which the above described clustering procedure is applied to single building blocks of our NIS models.[12]

[12] Given the structure of these two NIS models, the outcomes of the so-called partial analyses of the two models are identical for the building blocks *innovative efforts*, *institutional framework condition*s, *knowledge base*, *financing conditions* and *openness*.

Empirical results

To introduce the results from the cluster analysis, it is first shown how the optimal number of different classes for the different building blocks and models has been derived from the employed data. For this purpose, the so-called elbow criterion is applied. This is a commonly employed measure in cluster analysis that will be briefly described below. In a second step, the found composition of the various country clusters is introduced and interpreted.

a) Cluster determination

The following two figures (Figures 2 and 3) display for the various cluster analyses that have conducted a measure of quality of the different stages of the clustering process.[13] For all different steps in the hierarchical clustering analysis, this measure indicates the degree of similarity between those two clusters that are consolidated at different stages of the clustering process on the basis of distance values between the entities. Low coefficient values indicate strong coherence of two clusters that are to be consolidated, a high coefficient value points to little similarity across the objects belonging to the two clusters that are merged in a certain clustering step. The results of this inter-group distance coefficient can be directly used in order to determine the optimal number of clusters. It arises when a further merging step would result in sharp rise of the coefficient, i.e. a strong loss in the coherence of the different clusters and thus in a strong quality reduction of the entire classification.[14]

In our case, the global analysis of NIS model 1 yields four clusters, just as for the partial analyses of the model components *institutions* and *openness*. An optimal number of only three clusters accrues both for the building block *financial conditions* and for the NIS element *innovative efforts*, while the *knowledge bases* of the studied countries can best be classified into five groups.

[13] All cluster analyses have been carried out with SSPS 12.0 software.

[14] According to its graphical representation, this decision criterion is called *elbow criterion*. The top left chart in Figure 2 shows the inter-cluster coefficient values for the building block *innovative efforts*, and it exemplifies very clearly that on according to the elbow criterion the optimal number of clusters for this model element is three.

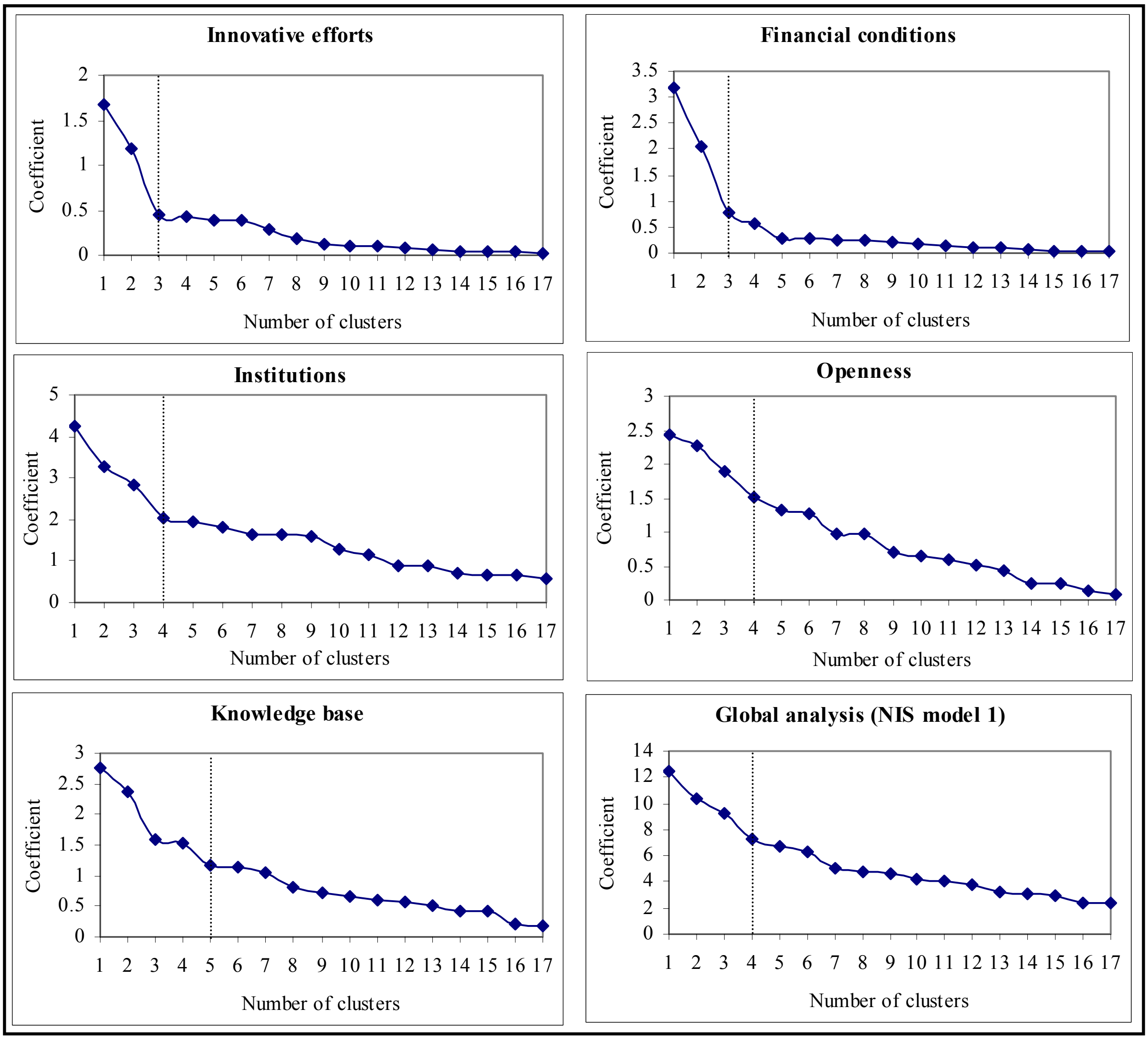

Figure 2: Elbow criteria of the cluster analyses of NIS model 1 (**without** sectoral specifics).

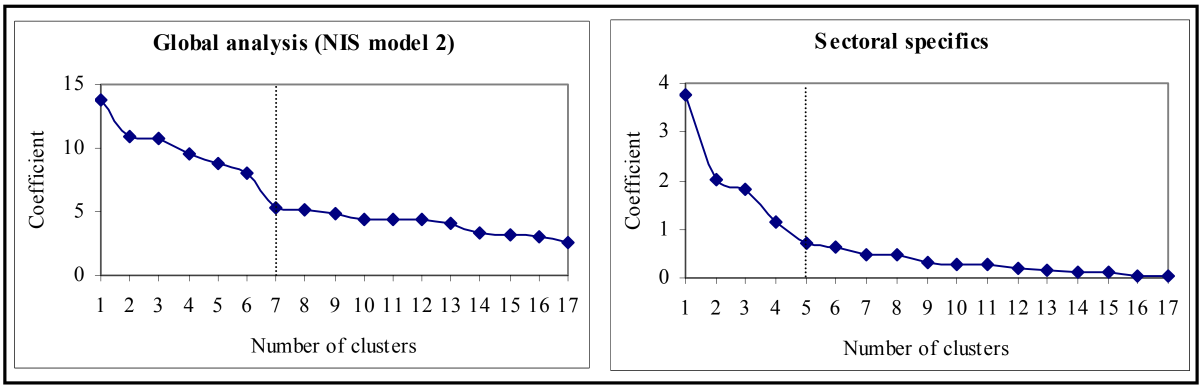

Figure 3: Elbow criteria of the cluster analyses of NIS model 2 (**with** sectoral specifics).

If NIS model 2 is utilized, identical results are naturally obtained for the five building blocks *innovative efforts* , *institutions* , *openness* , *financing conditions* and *knowledge base* because these are components of both of our indicator-based NIS models and the indicators that enter these model elements are identical in both models. The *global analysis* of NIS model 2 as well as the partial analysis of the model element *sectoral specifics* , though, yields new classification results. With respect to the sectoral characteristics of the analyzed national innovation systems, a classification of five country clusters emerges according to the elbow criterion. Obviously, this result, which is associated with the consideration of sectoral data, exerts a strong impact on the categorisation of the NIS under study on the system-level. That is because deviating from the five-cluster solution that results from the application of NIS model 1, an optimal number of seven country clusters arises from the *global analysis* of NIS model 2.

b) Cluster composition

The varying composition of clusters for the two models and the underlying building blocks is illustrated in the following tables (Tables 1 and 2).

		Country																	
		DK	**NO**	**AT**	**FR**	**DE**	**NL**	**GB**	**BE**	**FI**	**SE**	**CH**	**IT**	**ES**	**GR**	**PT**	**IE**	**JP**	**US**
Level of analysis	Global analysis[15]	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	4
	Financial conditions	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3
	Institutions	1	1	1	1	1	1	1	1	1	1	1	3	3	3	2	2	1	4
	Openness	1	1	1	1	1	1	1	3	1	1	1	1	1	2	1	2	4	4
	Innovative efforts	2	2	1	2	2	2	2	1	2	3	3	1	1	1	1	1	2	2
	Knowledge base	1	1	1	1	1	1	1	1	3	3	3	2	2	2	2	2	4	5

Table 1: Summary of the cluster analysis **without** sectoral characteristics: Composition of the country clusters by level of analysis.[16]

The pattern to be observed in the *global analysis* for our NIS model 1 basically differentiates between four types of national systems of innovation in our sample. A large cluster is composed of eleven northern and middle European nations, indicating no further structural differences between the NIS of this broad set of economies. A second cluster of NIS which comprises the Mediterranean countries and Ireland can be considered as a rather stable configuration. It is only subdivided in the analysis of the NIS building blocks *institutions* and *openness*. Japan and the United States each form their own cluster. This is also pointing to the specific role played by these two non-European countries in our sample.

For the building block *institutions*, a four-cluster-solution is found as well. Surprisingly, Japan is allocated to the middle European cluster. This finding might reflect the strong role played by the Ministry of International Trade and Industry (MITI) in coordinating industry. Compared to the United States (building a distinctive cluster), being an example *par excel-*

[15] It shall be noted again that with *global analysis* the case is described where the entire set of indicators – without being grouped into different building blocks of an NIS – enters the cluster analysis.
[16] All country abbreviations used in this paper are based upon the two-letter-codes as defined by the *International Organization for Standardization* (homepage: www.iso.org).

lence for a liberal market economy, the twelve countries in cluster 1 show some similarities in the degree of political coordination of their markets. Outside these extreme cases of a single-country-cluster and a wide NIS-grouping, Italy, Spain and Greece as well as Ireland and Portugal form two separate clusters in terms of their institutional settings, which points to different intensities of the incentive mechanisms to innovation and learning but also to distinctive degrees of political influence on market coordination in these countries.

The building block *innovative efforts* in a way leads to a taxonomy of NIS clusters which deviates from the remaining building blocks. Here, complementary effects between country size and potential innovative strength seem to determine the classification of NIS. Austria and Belgium, both of which belonging to the group of smaller countries in our sample, supplement the Mediterranean cluster, although country size effects have been controlled for in the data. Two other smaller countries, however, namely Sweden and Switzerland, now build their distinctive clusters. These latter findings clearly result from the strong commitment to innovation in Sweden and Switzerland.

Further confirmation for this can also be found in the *partial analysis* of the NIS element *knowledge base*, where these two European countries build a distinctive cluster together with Finland. As can be seen on the level of indicators that enter this building block, the knowledge bases of the countries in this cluster are relatively strong. Deviating from this, the cluster that comprises Ireland and the Mediterranean countries can be characterized by comparatively weak knowledge bases, indicating obstacles to future innovativeness. In terms of the relative performance of national knowledge bases as approximated by the utilized indicators, the largest cluster of this building block, entailing most of the middle European countries, lies between these two extreme cases. Finally, Japan and the United States again constitute their own clusters. Here, the structure of the knowledge bases in these nations apparently is rather different compared to these of the European countries in our sample.

A particular pattern of the cluster taxonomy emerges for the building block *financial conditions*. There, all European economies are summarized in one coherent cluster, while Japan and the United States again form their individual clusters. This finding clearly reflects the effects of the financial integration and harmonization within Europe. This applies not only to the Euro-zone members but to all European economies.

The analysis of the building block *openness* shows four clusters slightly differing from the general pattern observed in the *global analysis*. Japan and the United States are forming one cluster. This result is due to the existing complementarities of these nations in country size, in the particular organization of innovation and in a broad domestic technological basis. A further result from this building block shows the impact of the integrated European market. Spain, Portugal and Italy here join the large European country cluster whereas Ireland and Greece are composing a separate cluster, showing the important influence of foreign direct investments and the import orientation with respect to knowledge of these two countries. The importance of foreign direct investment associated with external technology adoption is the major reason why Belgium constitutes its own cluster in this model element.

		Country																	
		DK	NO	AT	FR	DE	NL	GB	BE	FI	SE	CH	IT	ES	GR	PT	IE	JP	US
Level of analysis	Global analysis	1	1	1	1	1	1	1	1	3	2	2	5	5	5	5	6	4	7
	Financial cond.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3
	Institutions	1	1	1	1	1	1	1	1	1	1	1	3	3	3	2	2	1	4
	Openness	1	1	1	1	1	1	1	3	1	1	1	1	1	2	1	2	4	4
	Innovative efforts	2	2	1	2	2	2	2	1	2	3	3	1	1	1	1	1	2	2
	Knowledge base	1	1	1	1	1	1	1	1	3	3	3	2	2	2	2	2	4	5
	Sectoral specifics	3	1	1	1	1	1	1	1	5	3	3	1	1	1	1	4	1	2

Table 2: Summary of the cluster analysis **with** sectoral characteristics: Composition of the country clusters by level of analysis.

Table 2 shows the cluster taxonomy resulting from our NIS model 2. For reasons of completeness the table displays the cluster composition for all building blocks of the NIS. However, with respect to NIS model 1 only the lines for the *global analysis* as well as for the building block *sectoral specifics* provide additional empirical findings.

Focussing on the differences on the industrial level, the building block *sectoral specifics* leads to a cluster classification that differs strongly from the one that has been found in the remaining building blocks. Now, the underlying country sample is split up into five clusters. One large cluster encompasses twelve countries and attaches the Mediterranean countries as well as Japan to the *middle-European cluster,* which indicates that our data do not allow a further discrimination in terms of the sectoral composition. Nevertheless, the available information reveals some peculiarities concerning the countries outside this broad cluster. First of all, three single country clusters emerge, entailing Finland, Ireland and again the United States. The Finland cluster highlights the important and profound transformation of this country towards a knowledge-based economy within the previous two decades, but in particular Finland's leading role in information and communication technologies. Ireland's exposed role can be attributed to the immense efforts made in attracting foreign direct investments, especially in knowledge-intensive industries. This strategy has led to the label of the so-called 'Celtic Tiger' in the 1990s. The results from the building block *sectoral specifics* also add further evidence to our previous finding concerning the meaning of innovative efforts. The observed *sectoral specifics* lead to a distinctive cluster that besides Switzerland and Sweden also includes another economy, namely Denmark. Again, the interrelatedness of the innovation orientation of the NIS combined with a knowledge-based industrial structure leads to an accentuated classification of these three countries to a separate cluster.

The consideration of the *sectoral specifics* building block has a considerable impact on the *global analysis* of NIS model 2. In this case, our sample is divided into seven clusters, while four of these are single-country clusters. Already by applying NIS model 1, which does not explicitly account for sectoral characteristics, both the national innovation systems of Japanese and the US have been found to constitute separate clusters. By including sectoral data, however, the Irish and the Finnish NIS also form distinctive clusters. Correspondingly, the impact of the NIS element *sectoral specifics* together with the component *innovative efforts* translates into the global classification, as the cluster including Sweden and Switzerland clearly shows.

Conclusions

The aim of the paper has been to add new findings into the structure and functioning of national innovation systems. For this purpose, eighteen different countries have been studied on the basis of a broad set of indicators of fundamental activities and institutional settings that are relevant to the description of national innovation systems. This set of indicators has been utilized to compose two hierarchical NIS models. One of these is made up of five building blocks. In particular, these reflect the financial conditions, the innovative efforts, the institutional framework conditions, the national knowledge base as well as the degree of international openness. The second NIS model additionally includes a building block that takes account of sectoral specifics. Yet, the integration of a sectoral view in empirical studies of national systems of innovation is most often missing in the literature. However, the industrial structure of a national economy contributes strongly to its patterns in innovative activities as well as to its innovative performance. It can therefore be held that variables describing the sectoral composition of an economy need to be considered in studies carried out within the NIS framework as well. Therefore, in the present comparative study within the concept of national innovation systems, such indicators of the innovative activities on the industry level are included here. In doing so, the commonly employed set of variables describing the main components of national systems of innovation has been extended.

The findings of the conducted cluster analysis of national innovation systems show that without consideration of sectoral characteristics, a rather coarsely meshed scheme of countries is obtained. This scheme encompasses only four different groups of NIS in the sample. The largest cluster contains the middle and western European as well as the Scandinavian economies, while a smaller cluster of four countries is made up of the analyzed Mediterranean countries and Ireland. The remaining two clusters are constituted by single countries only, namely the United States and Japan. More or less, this classification scheme is also found on the level of several of the NIS building blocks that have been defined. Only the building block that encompasses variables describing the national innovative efforts somewhat disorganizes this relatively stable and consistent country taxonomy. Already this finding hints to the importance of variables that capture innovation and learning activities in greater detail, particularly on the sectoral level. As the innovative activities are unevenly spread across different industrial sectors, this finding hence clearly points to the important impact that sectoral specifics may exert on the structure of entire NIS.

In a second NIS model, a further building block which describes important industrial features is therefore included, while a particular focus is put on knowledge- and technology-intensive industries. By adding these variables to the analysis of NIS, the emerging pattern of country clusters can be described as being finely woven compared to the previous results. Now, seven clusters in total accrue. That is because two of the formerly found country groups are split up by the data. Finland and Ireland now build distinctive clusters, and Switzerland forms another cluster with Sweden. This also implies that the Mediterranean countries are combined in a separate and therefore stable group. Furthermore, the remaining middle European countries constitute a coherent cluster.

To summarize, the present analysis shows that sectoral structures can indeed add important insights into the understanding of national innovation systems. Without doubt, institutional factors decisively shape the innovative performance - however measured- of such systems. However, technological and especially industrial structures and dynamics have been found to exert a significant influence on the interplay as well as on the complementarities of the various major components of these complex systems. Therefore, the consideration of industrial and thus meso-level structures is helpful in explaining some of the cross-national and thus macro-level differences to be observed in reality.

More generally, from the perspective of the conceptual framework that has been applied, it may well be upheld that this type of empirical studies may consolidate the important (though still barely elaborated) linkages and interdependencies between the various sub-approaches within the systems of innovation approach, especially the linkages between the concepts of national and sectoral systems of innovation (see, e.g., Malerba, 2002, 2004; Cooke, Uranga and Etxebarria, 1997).

The kind of analysis carried out here may also have an impact on future research work within the NIS framework because, amongst many research avenues that are worth perusing in this rather young but rapidly disseminating economic discipline, this study may initiate additional and even more detailed comparative studies of national innovation systems that have been found to share broad similarities in their (institutional) settings.

Furthermore, the type of comparative study that has been conducted in this paper also has relevance for the design of national and supranational innovation policies. Given that the identified country groupings point to international disparities and similarities in innovative performance and in institutional structures, the cluster compositions may be used as a starting point for more targeted and more effective technology policy measures in the studied nations. Thereby, the outcomes of this empirical study may give fresh impetus to international coordination in the planning and conduct of policies that are directed towards innovative action. Hence, from the perspective of technology policymaking, international comparisons and especially classifications of national innovation systems are important extensions to the NIS concept. For after all, these types of studies demonstrate where there is scope for mutual learning from experience. This in turn may raise the effectiveness of planned technology policy measures in the countries under analysis.

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Appendix: Data sources

Utilized OECD databases:

- Educational Database, 2003
- Patents Database, 2003
- Main Science and Technology Indicators, Volumes 2003/1 and 2003/2
- Science, Technology and Industry Scoreboard, 2001 and 2003 edition

Further utilized data sources:

Kaufmann, D., Kraay, A., Mastruzzi, M. (2003), *Governance Matters III: Governance Indicators for 1996-2002*, New York: World Bank.

German Institute for Economic Research (2002), *Germany in Figures (2002 edition)*, Cologne, Germany: Deutscher Instituts-Verlag.

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