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The Theoretical Basis and the Empirical Treatment of National Innovation Systems

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Abstract

This paper deals with theoretical as well as empirical issues in research on national innovation systems (NIS). The aims of this paper are the following: first, some basic concepts of the NIS approach as they are used here are defined and explained. This seems to be necessary for reasons of clarity, since different authors in this field still make use of different concepts. Second, and based on this theoretical introduction, the empirical treatment of national innovation systems is discussed while recent trends in the NIS literature on performance measurement of innovation systems are summarized. Third, details of a research agenda with the goal to improve performance measurements of national innovation systems are given whilst potential pitfalls of benchmarking exercises in the context of national innovation systems are also discussed.

Keywords: innovation, national innovation systems, performance measurement
(JEL Classification: O10, O30, P51)

Contents

1. Introduction[1]

In the last decade, research on innovation systems has been gaining ever more significance in the field of economics of innovation and technical change. This can be attributed to a number of aspects, of which the most important ones are the following: the theoretical fundament of the innovation systems approach allows for a realistic treatment of innovation processes; the empirical studies that have been carried within these approaches have yielded valuable insights into the determinants and the organization of innovation processes at different levels; innovation systems studies have proved to be highly relevant to technology and innovation policy; finally, there has been an observable shift in policy design in highly industrialized countries away from focusing on the elimination of market failures towards improving the organization of innovation processes while concentrating on the numerous actors involved in innovative activities, on the linkages between them, and on innovation-shaping institutional factors.

In spite of all these encouraging developments of research on innovation systems, there are still some theoretical as well as empirical shortcomings. These stem partly from the fact that in heterodox economic theory (being the theoretical basis of the systems of innovation approach), different authors sometimes make use of different definitions of actually similar terms or phenomena. Also, the variety of empirical methods to analyze economic behavior, e.g. innovative action, is rich and the methods are often not rigorously formalized. Already these two points show that it is rather difficult to establish a common theoretical platform for a certain approach within the body of heterodox economic theorizing.

Hence, the structure of this paper is as follows: After a brief introduction, the emergence of NIS research is reviewed, basic concepts of a systemic analysis of innovation processes are defined and some of the key assumptions underlying the NIS approach are explained. Based on this theoretical part, the empirical treatment of national innovation systems is dealt with. First, recent trends in

[1] I would like to thank Arnold Wentzel for his valuable comments on an earlier version of this paper.

capturing and comparing the innovative performance of national systems are summarized. Second, some potential drawbacks of such comparisons are addressed and details of a research agenda with the aim to improve the performance measurement of innovation systems are presented.

In the following subsection, points of departure for this research work will be exposed while subsection 1.2 deals with the feedback model of innovation processes since this is an indispensable starting point of a systemic approach to innovation.

1.1 Innovations and growth

Based on the work by Schumpeter, innovations are often defined as the introduction of new or improved products, production techniques, and organizational structures, as well the discovery of new markets, and the use of new input factors (Schumpeter (1934)). Each of these five types of innovation has the potential to increase productivity and thus to improve competitiveness.[2] There are manifold ways[3] in which innovations can lead to economic growth: For instance, firms that introduce new or significantly advanced products to the market have bright chances to expand their market shares in domestic as well as in international markets and hence to increase revenues; by introducing new production processes or by re-arranging the organization of production methods, firms raise their efficiency which allows them to lower product prices (and thus to stimulate demand as well) and/or to raise profits.

Many empirical studies on the growth-spurring impact of innovations have supported these kinds of relations, so that it is meanwhile undisputed that innova-

[2] Competitiveness can be either defined in terms of (international) market shares and the development of the same, or in terms of productivity. According to Porter, competitiveness is the outcome of productivity gains. He argues that "[p]roductivity depends both on a nation's products and services, measured by the prices they can command in open markets, and the efficiency with which they can be produced" (Porter (2002), p. 55).

[3] See McKinsey Global Institute (2002), p. 12.

tions are a major source of economic growth.[4] Recent empirical evidence (see Porter and Stern (2002)) also confirms a strong relationship on the country-level between innovative performance and economic prosperity (measured in terms of GDP per capita).

It can be assumed that a considerable fraction of cross-country disparities in economic success (expressed in terms of GDP growth, productivity growth, employment, etc.) can be explained by differences in innovative performance. Hence, the ability of countries to develop, absorb and diffuse new technologies depending on the organization of national innovation processes needs to be thoroughly analyzed. That is because detailed studies of the innovative performance of countries can yield important insights into their competitiveness and thus contribute to a better understanding of their past and future economic success.

As a conceptual framework for an analysis of the main determinants of the innovative performance of countries, I will employ the NIS approach in future research because the innovation system approach is "highly relevant to the study of economic growth - particularly growth based on innovation...[and it is] especially appropriate to an understanding of the interactions and interdependencies...in the processes of innovation"[5]. Niosi makes a similar argument when he claims that the "concept of national system[s] of innovation is the key to explaining the behavior and the performance of the set of institutions [and organizations] on which long-term economic growth and sustainable development are based"[6]. Therefore, important features of the NIS approach will be presented below.

[4] Neoclassical growth models as well as recent contributions by evolutionary economic theory to this subject come to this conclusion, although researchers are still confronted with severe measurement problems. Brief surveys of different theoretical approaches to measure empirically the growth-spurring effects of innovations and technical change can for instance be found in Gregersen and Johnson (1998), and in OECD (2000, pp. 218-224).

[5] Edquist et al. (2001), p. 1.

[6] Niosi (2002), p. 300.

1.2 From a modern perception of innovation processes to the concept of innovation systems

The concept of innovation systems is rooted in heterodox economic theory. Especially with regard to the analysis of innovation and technical change, the main differences between orthodox economic theory and heterodox economic theory have been accentuated in a very instructive way by many economists (see e.g. Nelson and Winter (1982), Metcalfe (1995a, 1995b, 1998), Pyka (1999)). It has been shown that the discrepancies between the two theoretical branches stem primarily from two points: first, from the dissimilar assumptions made concerning economic actors, their behavior and capacities (for example satisfycing behavior versus optimization); second, from the dissimilar principles that underlie economic processes (for example change and dynamics versus state and equilibrium). It is not intended here to restart that discussion in great detail.

However, it seems helpful to review the fact that innovation processes are viewed differently in orthodox and in heterodox economic theory, since this very aspect is central to an understanding of a systemic approach to innovation: In heterodox economic theory, innovations are not perceived to be the result of a linear process made up of different stages that take place in a strictly sequential order. Instead, it is argued that the different phases of innovation processes are inter-linked in the sense that there are feedbacks[7] between various stages of innovative activity (see figure 1 below). Hence, innovation does not end when the diffusion/imitation phase is completed. Rather, innovative action can be influenced by the interaction of various actors like researchers, marketing experts, and customers at a later phase of the whole innovation process. This implies that minor improvements (which are often called incre-

[7] To make this more apparent, a simple example for the feedbacks between the diffusion phase and the invention phase would be the following: As a result of its innovative efforts, a firm introduces a new product to the market. After some time, it carries out market analyses in order to learn about how its clients assess the new technology that has been embedded in the product (e.g. in terms of quality and usability); based on the results gained, the firm then tries to improve its product and to come up with a new model being technologically superior to the previous model.

mental innovations) are no longer generated by researchers alone but they can also be induced by those involved in the commercialization of an innovation or by the users of a product (see Kline and Rosenberg (1996)) and in response to competitors.

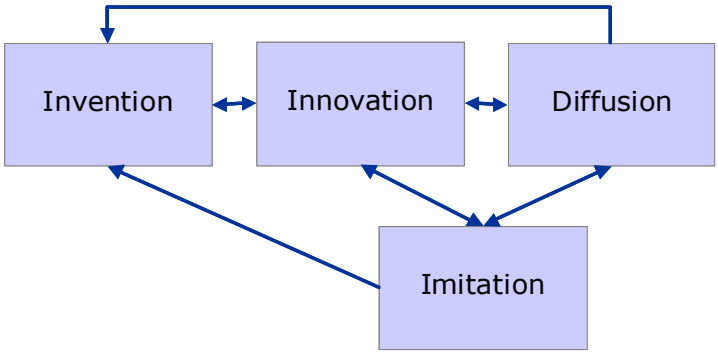

Figure 1: The feedback model of innovation processes.[8]

This perception is in line with the results gained in empirical studies of innovative behavior that have shown that innovations result rarely from isolated research activity alone (e.g. OECD (2000)). Rather, they are mostly the outcome of collaborative innovative efforts made either by the science sector and the business sector or by networks of various business firms.

Thus, science, technologies and the economy are closely connected spheres and it is nowadays mainly due to these linkages that innovations enter the economy. In addition, innovative activity is to a large extent shaped by the institutional framework of an economic system, although the precise cause-and-effect mechanisms between institutions and economic (or innovative) action are not yet fully understood. It is therefore not easy to quantify and compare the institutional set-up of nations or regions.

[8] Source: Cantner (2000), p. 97. The differences between the notion of linear, strongly sequential innovation processes on the one hand and the chain-linked model of innovation processes are summarized in Cantner (2000), pp. 81-98.

Ultimately, it is this perspective of innovation processes which can be used as a starting point for a systemic approach to innovation: it is required first to identify and explicitly analyze the main actors and organizations involved in the collective learning and search activities as indicated by the feedback model of innovation. Second, it is necessary to take account of an institutional endowment with which economic actors (single actors as well as organizations) are confronted and which shapes economic and hence innovative activity.

Now that some of the central ideas underlying a systems of innovation approach have been shown, it is necessary to go one step further in the next section and to clearly define the key concepts used in this approach.

2. Explanations of fundamental concepts

2.1 Clarifying the term 'national innovation system'[9]

The concept of national innovation systems allows to focus on much more than just the number of product or process innovations that have been brought about in a certain country within a certain period of time. National innovation systems need to be understood in a broader sense: The concept does not deal with the innovation phase exclusively. Rather, it puts emphasis on the main determinants and the organization of innovative action. Hence, the entire innovation process on the national level including the pre-commercialization phase as well as the diffusion phase can be taken into account. Regarding the former phase, particular interest is given to those factor conditions (e.g. the availability

[9] Although the focus is on the NIS approach in this work, it must be noted that the innovation systems approach consists of various branches. Depending on the chosen perspective for the analysis, it is also possible to use the concept of regional innovation systems (e.g. Braczyk et al. (1998), Ohmae (1993, 1995)) or sectoral innovation systems (Breschi and Malerba (1997), Malerba (2002), Cooke et al. (1997)). In addition, some related concepts like the concept of industrial clusters (e.g. Porter (1998)) or of technological systems (Carlsson (1995, 1997), Carlsson and Stankiewicz (1995)) have emerged.

of highly skilled personnel) that are essential to generate innovations as well as to the institutional framework of an economy. Concerning the latter, the diffusion phase, the knowledge base of national actors[10] and again the institutional environment are equally important to allow for the adoption of new technology developed abroad or, in contrast, to facilitate the dissemination of innovations created by domestic actors throughout the economy.

Moreover, the systemic approach to innovation is based on the perception that innovations are mainly brought about by various actors and the relations between them. Accordingly, co-operation between the science sector and the business sector and/or co-operation between various firms (networks) are of central interest. That is because the innovation systems approach aims at identifying the main actors of novelty-creating and -absorbing processes and the relative significance of each of these actors.

Additionally, all the systemic concepts of innovation rest on the assumption that economic action in general and innovative action in particular are shaped by the institutional set-up of the system analyzed. Consequently, the innovation systems concepts go one step further than just taking into consideration that various actors and organizations collaborate with the purpose to generate innovations. They put emphasis on the role of system-specific institutional factors spurring and hampering innovation and technological change. As recent NIS studies have shown, there are indeed great differences between nations regarding the development, commercialization, improvement and diffusion of new products and processes (see Nelson (1993)).

To put all these points into a nutshell, a definition of the term 'national innovation system' should include and accentuate at least three crucial things: first, the consideration of the entire innovative process; second, the analysis of various main actors involved in these processes (plus the linkages between them);

[10] With regard to the significance of human capital for the exchange of knowledge and thus for the innovative performance of an innovation system, it is argued that "[t]he most important elements in current innovation systems have to do with the learning capability of individuals, organisations and regions" (Lundvall and Tomlinson (2002), p. 218).

and third, the institutional set-up serving as a framework for economic action.[11] Accordingly, a national innovation system consists of organizations and institutions that influence each other in developing, absorbing and diffusing innovations in a country.[12] This definition is fully in line with the one given by Charles Edquist (1997). For him, an innovation system is made up of "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations"[13]. Beije argues that "system of innovation can be defined as a group of private firms, public research institutes, and several of the facilitators of innovation, who in interaction promote the creation of one or a number of technological innovations [within a framework of] institutions which promote or facilitate [or hamper] the diffusion or application of these technological innovations"[14].

Consequently, the NIS approach is a means to learn about the impact of organizations and institutions on national innovative activity understood as the result of interactive processes determined by various actors and framework conditions.

Since the terms 'organization' and 'institution' are still inconsistently employed and defined in the literature, it seems reasonable to clarify these terms as they are used here. This will be done in the next subsection.

2.2 Defining the components of a national innovation system

Generally speaking, systems are made up of various components, linkages between these, and an environment (see Carlsson et al. (2002)). This general

[11] Many definitions of the term 'national innovation system' have meanwhile been established. A list with some of the most often used definitions can be found in Niosi (2002), p. 292.
[12] See Lundvall (1992), Lundvall and Tomlinson (2002), and Nooteboom (2000).
[13] Edquist (1997), p. 14.
[14] Beije (1998), p. 256.

composition is also applicable to national innovation systems: They consist of organizations, linkages between these, and an institutional environment.[15]

The distinction between 'institutions' and 'organizations' as it is made here draws heavily on the work by North (1990) and on the work presented in Lundvall (1992) and in Edquist (1997). For reasons of clarity, it is made here as well. Some authors in the literature on innovation systems, however, use the term 'institution' for both 'institutions' and 'organizations' (as defined below) and fail to make this distinction. This procedure has been criticized: "It seems as if most innovation theorists think of institutions in accordance with the everyday meaning of the term. [...] This way of using the concept of institution is not based in institutional theory - or any other theory"[16].

Yet, conceptual ambiguity of this type should be avoided. This can be achieved by referring to institutional economics. At least those elements of institutional economic theory that are fitting with a systemic view of (national) innovation patterns need to be built in the theoretical fundament of the innovation systems approach. Then, institutions in general can be described as formal and informal norms providing a framework for the interaction of the members in a society. They can be defined as "the rules of the game in a society"[17]. Economic institutions in particular are those norms that assess planned economic action ex ante, serve as yardsticks to evaluate economic action ex post, and generate trust in economic interaction (e.g. through property rights); furthermore, they ensure, define and steer the functioning of markets. Innovative activity, the outcome of which is a driving force of economic growth (see subsection 1.1), is hence shaped by the institutional framework of an economy. Since institutions serve as guidelines for intended economic action ex ante, they have a behavioral dimension; because they serve as yardsticks of revealed economic action ex post, institutions also have a normative function.[18] Examples of institutions are laws, regulations, contracts, market exchange rules, common values, and

[15] Due to the interdependencies between an NIS and further subsystems of an economy, one could also add these to the environment of an NIS and thus define the surrounding of an NIS more broadly.
[16] Edquist and Johnson (1997), p. 43.
[17] North (1990), p. 3.
[18] See Reimann et al. (1991), p. 169.

rules of conduct. Two of the basic properties of institutions include first institutional change, and second path-dependence. These properties imply that institutions evolve instead of being static, and that there is no optimal institutional set-up. Moreover, institutions are to a large extent country-specific since their current form depends on historical, political, cultural, social and economic contexts. As a consequence, institutions are hard to transfer from one country to another.[19]

Organizations, which are another decisive component of any innovation system, can be defined as structured and institutionalized systems that have been built in order to carry out a certain array of tasks. To meet this purpose, the members of organizations act individually as well as in collaboration. Concerning the differences between institutions and organizations, Edquist and Johnson (1997) claim that organizations are "are consciously created. They are players or actors. In contrast, institutions may develop spontaneously and are often not characterized by a specific purpose"[20]. To clarify the same aspect, Nooteboom uses North's terminology when he says that organizations "are not institutions but players confronted with institutions"[21] while Reimann et al. (1991) point out that a person can only be member of an organization (but not of an institution)[22]. Examples of organizations are business firms, research centers - regardless if they are privately funded or publicly funded-, and universities.

Now that a national innovation system together with its main components have been defined, it appears vital to illustrate which role a nation's innovation system plays in its entire economy. In a simplified way, this can be illustrated by the following figure 2.

[19] In addition to this, there is no optimal institutional environment of an innovation system. Both points have are closely related to technology policy issues and have important consequences for the design and selection of national as well as international technology policy measures.
[20] Edquist and Johnson (1997), p. 47.
[21] Nooteboom (2000), p. 92.
[22] See Reimann et al. (1991), p. 169.

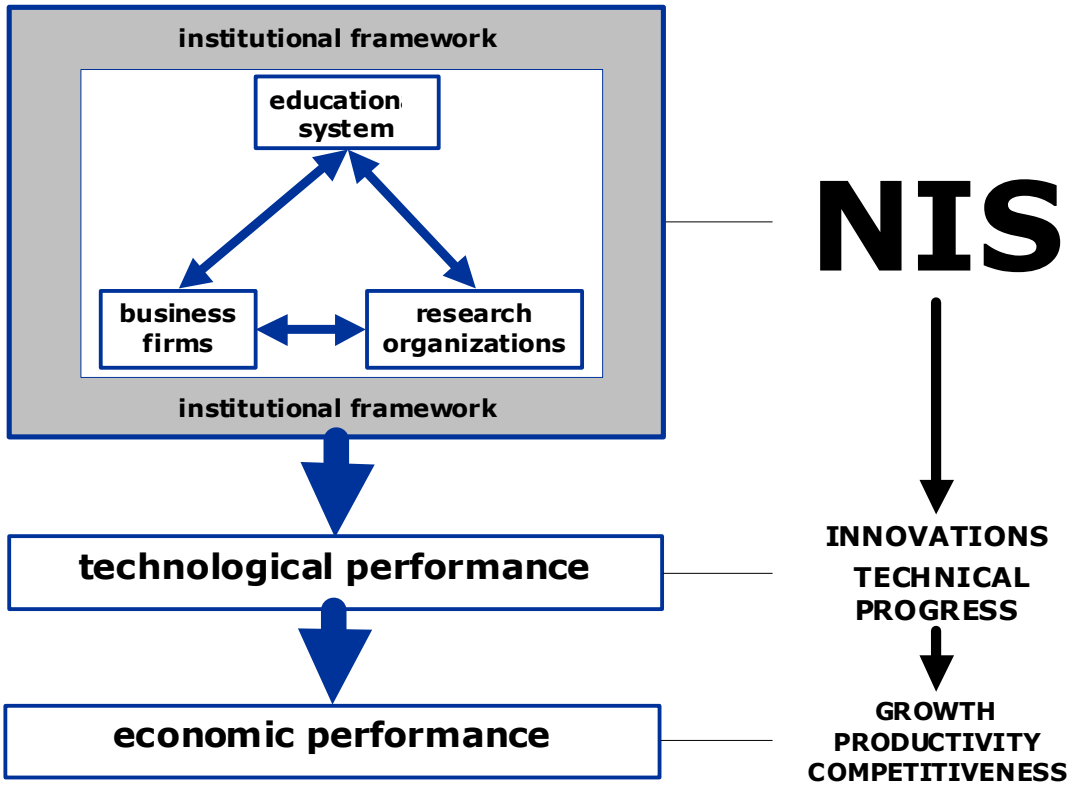

Figure 2: The significance of a national innovation system for economic success.[23]

Figure 2 accentuates the strong linkage between innovative performance (which is generated by an NIS) and competitiveness which in turn affects economic performance. Yet, even if the focus is on innovation in this figure it is obvious that innovations are definitely not the only driver of economic growth. Furthermore, it needs to be emphasized an NIS is not an isolated system. Many of the processes going on within an innovation system are decisively influenced by further subsystems of an economy like the legal system, the tax system, the financial system, or the labor market. Even if these subsystems are typically not perceived as the building blocks of an innovation system, important aspects of them with regard to innovative behavior need to be dealt with and included in the mentioned 'institutional framework' of an NIS. Doing this, it is possible to

[23] Own illustration inspired by OECD (1999), p. 23.

focus on the main determinants of innovation[24] attempting to reveal differences between countries or even to derive policy conclusions.[25]

So far, it has been explained why it is important to deal with innovations. Also, basic concepts of the NIS approach have been summarized. In a next step, some remarks on the development of the NIS approach will be made while its theoretical roots will be sketched (subsection 3.1) and its emergence in the theory of innovation and technical change will be reviewed (subsection 3.2).

3. The development of the NIS approach

3.1 Notes on the theoretical roots of the NIS approach[26]

Essentially, the NIS approach as it has been described here is rooted in two branches of economic theory that are closely related with each other. These are evolutionary economic theory and neo-institutional economic theory[27].

The apparent linkages between evolutionary theories of economic change (see e.g. Andersen (1996), Witt (1993)) and systemic approaches to innovation stem mainly from the following theoretical assumptions and research interests: First, in both NIS research and evolutionary economics, innovative activities lie at the heart of the analysis. Second, technological change is in both cases treated as an endogenous process which means that innovations are coming from within

[24] As it has been made clear by Edquist (2001), it is the main purpose of the systemic approach to innovation to identify and explain the main determinants of innovative action (see Edquist (2001), p. 2).

[25] That innovation systems can never be analyzed exclusively because there are many other subsystems in the economy that shape innovative behavior as well has also been emphasized by Nelson (see Nelson (1993), p. 518).

[26] The systemic perception of innovative activity as outlined here is normally not labeled as a theory in its own right but as a concept, as a "conceptual framework", or as an "approach" (Edquist (1997), p. 2 and p. 28, respectively). The main reasons for this are given by Edquist (1997), pp. 28-29.

[27] Neo-institutional economics is a combination of mainly old (or traditional) institutionalism and modern sociology (see Nooteboom (2000)). For a helpful summary of the differences between the various branches of institutional economics, see Nooteboom (2000), pp. 91-112.

the system rather than being introduced exogenously. It furthermore implies that the sources of innovations and the patterns of innovative activity are key issues in the analysis. Third, learning processes are a fundamental success factor of innovative effort. As a consequence, the quality of a country's workforce, its education system, but also further aspects like the interaction between the science and the business sector need to be analyzed. All these aspects are crucial success factors of the innovative efforts that are made. Fourth, as already pointed out above, historical time matters in the sense that the historically grown structures of a system cannot be abstracted from, since they determine current economic performance. Also, they cannot be modified immediately or without costs. Related herewith, and fifth, institutions as a selection framework for economic action are subject to change themselves. Institutional change thus enters the analysis. The innovative performance of an innovation system is largely affected by the fit between the technological and the institutional sphere.[28] Finally, instead of equilibria and steady-states, economic processes and dynamics are central to the analysis in evolutionary economic theory as well as in innovation systems studies. In light of these similarities between heterodox innovation theory and innovation systems research, the NIS concept can be seen as a conceptual spin-off from evolutionary economic theory, though the latter has various branches.

While it is undisputed and often explicitly stated that evolutionary economic theory provides a basis for the NIS approach, the theoretical connection between neo-institutional economic theory and the NIS approach is mostly not mentioned. Equally, it is safe to say that this connection would not be confirmed by every author doing research on innovation systems. Yet if institutions and organizations together with their basic properties are defined as it has been done above, it follows naturally that neo-institutional economics is also part of the theoretical foundation of the systemic approaches to innovation.

[28] See Johnson (1997) who uses the term "mismatch" between institutions and technologies in this context.

3.2 The emergence of research on national innovation systems

Research on national innovation systems emerged at the end of the 1980s.[29] Essentially, the pioneering work in that field was done by Chris Freeman, Bengt-Åke Lundvall and Richard Nelson who approached the issue of a systemic treatment of national innovation processes from different (though not controversial) perspectives. With their work on national innovation systems that appeared in the book *Technical Change and Economic Theory* (edited by Giovanni Dosi et al. (1988))[30], the just mentioned scholars presented their basic ideas on the subject. It is not exaggerated to say that this publication had a large impact on the advancement of systemic approaches to innovation or to the establishment of what is nowadays labeled the 'national innovation systems approach'.[31] Many studies with the aim to reveal the structure of national innovation processes and the main actors being involved in them followed. The countries analyzed included not only highly industrialized countries in Western Europe, the USA, Canada or Japan; the conceptual framework of national systems of innovation has been applied to newly industrialized and countries as well. A collection of these studies is published in Nelson's 1993 volume *National Innovation Systems: A Comparative Analysis*.

The main conclusions that have been drawn from this extensive research work are the following[32]: Although the maintenance of geographical-political national borders proved to be useful for analytical purposes, innovation processes cannot be strictly separated between nations in reality of course. This is because research and development activities are increasingly carried out on an international level, knowledge flows not only within but also across national borders by

[29] For a precise description of the origins of national innovation systems research, see Lundvall (1998), p. 418.

[30] 'National Systems of Innovation' is the title of Part V of this famous book (Dosi et al. (1988)). Lundvall, Freeman, Nelson and also Pelikan each wrote a chapter of this part of the volume.

[31] The use of expressions like 'the approach to national innovation systems' or 'the NIS approach' could tempt the reader to believe that there exists only one concept in this strand of literature. But this would be a wrong implication. In fact, there are at least two sub-approaches within the conceptual framework of national innovation systems. For a detailed analysis of the differences between the facets of NIS concepts, see McKelvey (1991), Lundvall ((1992), pp. 16-18) and Lundvall ((1998), p. 414).

[32] See Nelson (1993), pp. 505-523.

means of personnel mobility or due to information and communication technology, or through the international exchange of goods and services. Besides, the studies confirmed that innovation patterns differ remarkably between nations. However, these differences are to a lesser extent obvious between nations that have reached a similar stage of their economic development and between those nations having a similar political regime. On this point, Nelson claims that "to a considerable extent the differences in the innovation systems reflect differences in economic and political circumstances and priorities [while] size and the degree of affluence matter a lot"[33]. It follows from this that it is not always reasonable to make country comparisons on the basis of the national approach to innovation systems. Third, private firms contribute largely but by no means exclusively to the innovative performance of a country, because the innovative output of private organizations is heavily determined by (publicly defined) institutional framework conditions as well as by the education level of the national population. Without a doubt, the public sector plays a crucial role in influencing the stock of human capital of an economy. Fourth, low R&D statistics do not necessarily imply low innovative performance. This observation confirms the statement made earlier that innovation is not merely the outcome of formal R&D spending. Also, this aspect points to the discussion on the strengths and weaknesses of innovation indicators and supports the use of multiple innovation indicators when analyzing the innovative performance of firms, industries, or entire nations. Finally, and based on the historically grown structure of economies and the innovation systems they embed, the studies confirmed the view that the strengths of one innovation system cannot be easily transferred to another system. This is even more true for nations having only few similarities in their size, industrial structure, and institutional environments. Of course, this latter aspect is especially relevant to policymakers seeking to enhance their nation's innovative performance.

That empirical issues lie at the heart of Nelson's comprehensive collection of country studies is reflected by its key findings summarized above. But in the

[33] Nelson (1993), p. 507.

early 1990s attempts were also made to elaborate the theoretical side of the concept of national systems of innovation. The first major contribution in this respect is the volume *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* edited by Lundvall (1992). Especially in the first part of the book, the central aim is to give the concept of national innovation systems a more robust theoretical underpinning. Put differently, "one main purpose of the book is to contribute to a theoretical understanding of interactive learning and innovation"[34] while arguing that the NIS approach is suitable to meet this purpose.

For instance, Lundvall (1997) explains fundamental assumptions on which the systemic approaches to innovation are based and presents the main features of innovation systems. Johnson (1992) deals with institutional economics and discusses aspects like institutional change and institutional heterogeneity in order to exemplify the decisive impact of institutions on learning as well as on innovative activities in an economic system. The usefulness of the concept of industrial networks for the NIS approach is shown by Gelsing (1992) while Gregersen (1992) puts emphasis on the role of the public sector in national innovation systems and on the linkages between the private and the public sector of an economy. With the financing of innovation processes, another important part of innovation systems is in the center of Christensen's work (Christensen (1992)). He develops some stylized facts of financial systems and reveals several basic national institutional differences in financial systems by testing his hypotheses for five countries.

Thus, even if much of the work in the Lundvall 1992 volume on national innovation systems is theoretical, a further central aim of it concerns the empirical treatment of the NIS approach. In particular, suggestions for the analysis of the building blocks of national innovation systems are given, but also the international dimension of NIS is dealt with. This is confirmed by the discussion and specification of meso- and macroeconomic variables to capture aspects like the structure, the evolution or the technological specialization of innovation sys-

[34] Lundvall (1992), p. 4.

tems. Examples for such variables are the production structure of an economy, the flow of foreign direct investment or the export structure and performance of nations. It is argued that these variables - which have traditionally been used in standard trade theory but have seemingly been neglected by many economic scholars working in the field of economics of innovation - can have high explanatory value in the context of innovation studies. For example, Andersen (1992) claims that by analyzing the product mix and the production structure of an economy, important conclusions on the innovative behavior of business firms can be gained, because innovations are often new combinations of already existing processes or products.[35] It follows from this perspective that consumers exert a strong influence on the search and development activities of private enterprises (see for instance Lundvall's work on user-producer relations or the chapter by Fagerberg (1992) on the same topic).

An appraisal of the emergence of systemic approaches to innovation needs to include the seminal volume *Systems of Innovation: Technologies, Institutions and Organizations* edited by Charles Edquist (1997),[36] because this work clarifies what can be called the theoretical basis of innovation systems, regardless of whether or not they are analyzed from a national perspective. For instance, it is explained which facets of institutional economic theory can be part of this basis (see especially Edquist and Johnson (1997)). Equally important appears the discussion of why and how the innovation systems approach is based on or springs from evolutionary economic theory (see the chapters by Saviotti and McKelvey in Edquist (1997)). Again, in contrast to Nelson's 1993 book on innovation systems, Edquist's volume (Edquist (1997)) does not contain applied case studies on the regional or the national level.

The above mentioned three book contributions (Lundvall (1992), Nelson (1993), Edquist (1997)) had a large impact on the spread of the innovation systems approach, not only among the academic community but also among policymak-

[35] This is also emphasized by Lundvall (1992), p. 8.

[36] The list of contributors to this volume includes numerous of the leading economic scholars in the economics of innovation literature (e.g. Edquist, Andersen, Saviotti, McKelvey Lundvall, Carlsson and others). These contribute to a precise conceptualization of what has become known as the 'Aalborg-version' of innovation systems within the systemic approaches to innovation.

ers around the globe. The reasons for the rising number of applications of the systemic approaches to innovation are mainly due to the fact that these approaches are grounded on plausible and realistic assumptions on innovation processes.

As a consequence, corresponding studies are a useful starting point to derive innovation policy implications, because differences between the entities analyzed are put in the center of attention than being abstracted from. In light of the large number of publications that have been appearing in the last decade, it is meaningful to have quick reference to the origins of the innovation systems concepts. Presumably motivated by this aim, Edquist and McKelvey (2000a, 2000b) have recently edited a helpful two-volume collection of some of the most often referred articles or book chapters in the literature on innovation systems and technological systems.

While primarily conceptual issues were given attention to thus far, the empirical treatment of national innovation systems will be reviewed and discussed in the following section 4. Additionally, future research challenges concerning the measurement and comparability of innovative performance across nations will be described (subsection 4.2).

4. The empirical treatment of national innovation systems

From the previous section it can be concluded that the theoretical foundation of the NIS approach leads to realistic assumptions of innovation and learning processes. As a consequence, the carrying out of empirical studies within the conceptual framework of national innovation systems is highly encouraged. And in fact, as the large number of studies of national innovation systems shows, the NIS approach is strongly empirically oriented.

Yet, there are certain shortcomings in the empirical treatment of national systems of innovation: First, studies of national innovation patterns are typically descriptive and mostly do not include a larger sample of countries. This could reflect the research interests of many authors in the field: Apparently, most innovation system studies done so far were meant to uncover and describe the main components of the innovation system under consideration as well as to explain the relations between its building blocks. Second, it seems that in many NIS studies the number of used indicators of innovative activity is rather small.[37] Third, empirical country studies using a systemic approach to innovation are normally static or comparatively static.[38] Because of this shortcoming, it is difficult to retrace the relative technological position of nations over a longer time period. But processes of catching-up with technological lead countries or processes of falling behind technological leaders are certainly important. They not merely affect but also reflect international competitiveness and real economic development of nations. Fourth, formalized cross-country comparisons concentrating on performance measurement of national innovation systems still very rare in the literature.[39] This is surprising because it has been made clear that "the innovation system approach can be used to compare how efficiently

[37] An exception here is for instance Patel and Pavitt (1994) who use various innovation indicators and include Western European nations and the USA in the empirical part of their study.

[38] This has been revealed by Carlsson et al. (2002) as well. They argue that "nothing in principle is preventing a more dynamic analysis" (Carlsson et al. (2002), p. 236).

[39] As it will be explained in section 4.2 below, I intend contributing to closing this gap in the NIS literature.

different institutional frameworks and combinations of agents point innovative activities in directions that are favorable for economic growth"[40]. Recent trends in the NIS literature to overcome this latter empirical shortcoming are summarized in the following section. However, there are always two sides of the coin with international comparisons focusing on the performance of nation innovation systems. Therefore, some of the potential drawbacks of comparisons between NIS together with future research challenges are discussed in section 4.2 below.

4.1 Recent trends in comparing national innovation systems

Particularly since the late 1990s, several attempts have been made to evaluate, to compare, and finally to rank national innovation systems. These attempts may have been motivated largely by two aspects: First, the creation of innovation-enhancing framework conditions seems to constitute a central target of policymakers around the globe.[41] As a means to derive technology policy implications, the NIS approach enjoys growing popularity among technology policymakers. Second, if policy-relevant implications are sought to be derived, it is important to acquire knowledge about the structure and efficiency of various innovation systems in a first step. So, the quality of innovation policy conclusions depends largely on processes of learning from (own) experience and learning by comparing.

It is a precondition for anyone interested in comparisons between innovation systems to have access to relevant data. However, especially data on innovative activities and innovative outcomes have long been (and partially still are) not

[40] Edquist et al. (2001), p. 4. A similar point is made by Kuhlmann who claims that national innovation systems "were discovered...as explanations for the differing degrees of competitiveness of economies, especially of their technological competitiveness and their ability to innovate" (Kuhlmann (2001), p. 958).

[41] Kleinknecht confirms this when he points out: "Public policy is increasingly concerned about promoting innovation in order to stimulate economic growth, employment and ecological sustainability" (Kleinknecht (2000), p. 169).

suitable to make cross-country comparisons because there were differences in measurement practices across nations for what were supposed to be 'similar' indicators.[42]

In the light of these practical obstacles, the OECD began an extensive and ambitious NIS project in 1994 with the aim to contribute to a better comparability and thus to a better understanding of national innovation systems.[43] This project has been running for several years now and it has lead to the construction of large databases on innovative activities.[44] The empirical insights presented so far are a highly valuable information source for those interested in innovation systems. Most of the empirical results of the different set-ups of national innovation systems and of the coordination mechanisms between the building blocks of the same are put into a technology policy context.[45]

An example for an outstandingly broad empirical cross-country analysis that in many parts draws heavily on OECD data is the analysis carried out by Eichhorst et al. (2001).[46] They compare, or in the authors' terminology "benchmark", Germany with seventeen other OECD member countries. Although this benchmarking study actually concentrates on the German labor market, "all" the factors affecting its performance are attempted to be investigated as well.[47] Therefore, the authors have decided to present data revealing not only the relative size and strength of the German educational system, but also measures of the innovative performance of Germany's business sector, and of the founding climate in the business sector together with various proxy variables of the degree of product market regulation in Germany.[48] Given the structure of this study that explicitly and separately deals with what is commonly labeled as the "building blocks" or "main components" of a national innovation system, it is amazing that the authors fail to refer to the corresponding NIS literature, though. Instead, endogenous growth theory (Aghion and Howitt (1998)) is referred to in

[42] See e.g. Kleinknecht (2000).
[43] See OECD (1999), p. 13.
[44] It is divided into three phases each focusing on different conceptual and empirical issues. For details, see OECD (2002), pp. 83-85.
[45] A summary of innovation policy suggestions resulting from the analysis of NIS and of innovation processes in the OECD countries can be found in OECD (2002), pp. 81-82.

the theoretical introduction of the chapter that deals with the relative innovative strength of the German economy.

Both the OECD (1999, 2001a, 2001b, 2001c, 2002) as well as Eichhorst et al. (2001) present a large variety of indicators of various determinants of innovative activity as well as of innovative outcomes. However, both of these rather broad benchmarking studies are based on a descriptive analysis of the data.

In contrast to this descriptive way of doing empirical analysis, a non-descriptive and more formalized way of doing cross-country comparisons of innovative performance has been introduced by Furman et al. (2002) with the concept of "national innovative capacity". This concept is based on a combination of three different, though closely related, theoretical concepts: endogenous growth theory (see e.g. Romer (1990)), Porter's theory of international competitiveness (Porter (1990)), and the national systems of innovation approach as already outlined above. National innovative capacity is defined as "the ability of a country to produce and commercialize a flow of innovative technology over the long term...[depending] on the strength of a nation's common innovation infrastructure..., the environment for innovation in a nation's industrial clusters, and the strength of linkages between these two"[49]. Each of these three components is measured by a number of variables. Then, these three components enter the main regression model in the form of complementary independent variable blocks. Patent data, put more precisely "the number of patents granted to investors from a particular country other than the United States by the USPTO in a given year"[50], are used as the dependent variable called "national innovative capacity". For the main model, an ideas- (or knowledge-)driven endogenous growth model serves as a basis. Hence, a linkage between innovation input factors and innovation output is established. The sample includes seventeen highly

[46] The authors have primarily made use of OECD and Eurostat data. Thus, as it is argued, comparisons of a large sample of countries became possible and the employed data can be expected to have generated reliable results.

[47] See Eichhorst et al. (2001), p. 1.

[48] For a summary of the main findings of the study, see Eichhorst et al. (2001), pp. 11-52.

[49] Furman et al. (2002, p. 899). For a detailed description of these three determinants of "national innovative capacity", see Furman et al. (2002), pp. 910-911.

[50] Furman et al. (2002), p. 909.

industrialized countries in total. Concerning the presented empirical results[51] of the model, three aspects need to be emphasized: First, the impact of technology policy design on nations' innovative performance is confirmed. Second, all the countries analyzed managed to improve their innovative capacity over in the observed time period from 1973 to 1995. Third, countries still differ largely in the level of their revealed technological performance as measured in this model. However, the USA as the worldwide technological leader has lost ground compared with the other countries included in the sample, an observation which points to technological convergence within the analyzed group of highly developed nations.

Based on their previous research, Porter and Stern (2002) have recently applied the national innovative capacity model to a larger number of countries (75 in total) than Furman et al. (2002) did.[52] Apart from the different sample size and differences in the employed data set, a further difference to Furman et al. (2002) is that Porter and Stern (2002) make use of the empirical results in order to generate a ranking of the nations analyzed. A nation's ranking is calculated as follows: For each of the four used sub-indexes labeled "proportion of scientists and engineers", "innovation policy", "cluster innovation environment", and "linkages", a numerical value is derived from the regression analysis[53]. The unweighted sum of these four sub-index values then yields the overall national innovative capacity index.

The just sketched method of national innovative capacity (which builds on three different theoretical approaches) also springs from the NIS approach. Within the latter (and without making use of other economic theories like e.g. growth theory), one stream of the present literature concentrates on the performance measurement of entire systems (or at least of some of its building blocks).[54]

[51] See Furman et al. (2002), pp. 930-931.

[52] While it is explicitly explained in Furman et al. (2002) that the national systems of innovation approach is a major component of the national innovative capacity model, Porter and Stern (2002) fail to do so. Implicitly, though, they give a helpful definition of national innovation systems in this article (Porter and Stern (2002), p. 102).

[53] Porter and Stern (2002), p. 104.

[54] As a synonym for 'performance measurement', the term 'benchmarking' appears more and more often in the literature. Yet, the use of this term in the context of national innovation systems is not un-

While some authors have so far contributed to this subject in a more general way (in order to establish a basis for subsequent empirical investigations), others have already shown how their ideas on the performance measurement of systems can be applied empirically.

For instance, Niosi (2002) brings in the expressions "x-inefficiency" and "x-effectiveness" when dealing with the innovative strength (or efficiency) of national innovation systems. While "x-inefficiency" of an NIS is defined as "the gap between observed performance and existing best performance [but not as] the gap between observed performance and any optimal, theoretically determined performance", the term "x-effectiveness" describes "the degree at which institutions attain their organizational missions"[55]. On the basis of these definitions of innovative efficiency, Niosi (2002) argues that benchmarking exercises for innovation systems are a promising way in order to reveal their relative performance.[56] Although Niosi does not fail to present some innovation indicators (like the share of scientific publications per country in percent of its population, or the number of a country's patents granted in the USA), the sketched benchmarking analysis leaves much more room for empirical analysis in time to come. Moreover, much more needs to be done in order to further formalize and specify a benchmarking method for entire innovation systems. One crucial step in this direction is the specification of meaningful and reliable innovation indicators or proxy variables of innovative action. Correspondingly, Niosi presents a list of possible performance measures for innovation systems.[57]

Carlsson et al. (2002) also discuss the issue of performance measurement of innovation systems. They admit that it is extremely difficult to evaluate the performance of entire systems because of their size and complexity. As a possible solution to the problem, the authors recommend to restrict the analysis while

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problematic, because benchmarking presupposes comparisons between equal entities of analysis. See Smith (2001) for a helpful discussion of this topic.

[55] Niosi (2002), p. 293. Beyond these definitions, Niosi gives various reasons of why national innovation systems may not function efficiently (see Niosi (2002), pp. 293-296).

[56] In Niosi ((2002), p. 296), "benchmarking" is defined as "the systemic observation of organizational routines and the comparison of performance with superior units at the levels of resource use and efficiency and effectiveness (inputs and outputs)".

[57] See Niosi (2002), p. 299, table 4.

they make a case for less ambitious and easier to handle research goals: "Measuring the performance of a system seems to be a great deal easier if the level of analysis is a product, industry or group of industries".[58] Accordingly, Carlsson et al. (2002) utilize the concept of technological systems in order to carry out performance comparisons on the system level. If one aspires to measure the innovative strength of national innovation systems nevertheless, they recommend to proceed pragmatically in the sense that one should analyze each of the main system elements individually in a first step. The gained results on the sub-system level need to be combined in a next step so that an evaluation of the entire system becomes possible.[59] Still, the question then is which relative weight each of the building blocks of a system attains.

The suggestions made by Liu and White (2001) differ from the ones made by Carlsson et al. (2002). Instead of analyzing the components of an NIS individually, Liu and White (2001) argue that it is preferable to focus on "system-level characteristics...such as the organization and distribution of activities in the innovation process, control and coordination mechanisms, and information flows, that affect...[the performance of an innovation system]"[60]. In other words, Liu and White (2001) criticize the "actor-centric questions" that most researchers posed in previous research on NIS claim that their focal point of "system-level characteristics" is superior to the former in order to analyze aspects like the structural development or the efficiency of national innovation systems.[61] Correspondingly, the authors introduce a conceptual framework for describing the structure, the dynamics and the performance of innovation systems. This framework is built on five different activities of innovation processes: These activities are research, production (called "implementation (manufacturing)"), "end-use (customers of the product or process outputs)", "linkage (bringing together complementary knowledge)" and "education".[62] In the same article, Liu

[58] Carlsson et al. (2002), p. 242.
[59] A similar argument has been made by Holbrook who claims that "it may be easier to aggregate upwards from a series of regional systems of innovation to the national level than to try to develop an understanding of a complex national system from the top down" (Holbrook (1997), p. 6).
[60] Liu and White (2001), p. 1111.
[61] Liu and White (2001), pp. 1095-1096.
[62] Liu and White (2001), p. 1094.

and White (2002) apply their proposed framework to the NIS of China. They make an inter-temporal comparison between different development stages (or regimes) of China's NIS. To be precise, they compare the differences in the set-up, the organization, the dynamics as well as the performance of China's former (socially planned) NIS with China's current (democratically organized) NIS.

4.2 Future challenges in measuring the performance of national innovation systems[63]

The NIS approach has until now demonstrated its relevance to technology policy matters because it is a conceptual basis that makes it possible to describe the organization of innovation processes within national boundaries. NIS studies can thus be understood as a means to learn more about the structure of an NIS as well as about possible scope for enhancement of the same.

However, it has been criticized that the approach still has "too little operational value"[64] in the sense that precise comparisons between systems are both hard to carry out and difficult to interpret. Although considerable progress has been made in this respect in the previous five years or so, there is still much room for further improvement and for extensions of the NIS approach.[65] This applies in particular to comparative studies aiming at the evaluation of strengths and weaknesses of and of the efficiency of national innovation systems.

Although more and more economic scholars in this research field make use of the term "benchmarking", they typically do not move beyond a descriptive way of analyzing systems. Apart from the framework introduced by Furman et al. (2002) which draws only in part on the concept of national innovation systems,

[63] I would like to thank Keith Smith for his helpful comments on many of the issues discussed here. Moreover, I gratefully acknowledge the fruitful and motivating discussions with my PhD supervisor Horst Hanusch, and with my colleagues Andreas Pyka and Thomas Grebel.

[64] OECD (2002), p. 11.

[65] Concerning this subject matter, Edquist claims that "theoretically based empirical work is...the best way to straighten up the SI [Systems of Innovation] approach conceptually and theoretically" (Edquist (2001), p. 3).

no other standardized measurement procedure has been developed thus far.[66] But it has been argued elsewhere that it is "not only natural but also vital to compare different existing systems. Without such comparisons it is impossible to argue...that a system performs well - or badly"[67]. Furthermore, it is emphasized that national innovation systems "must be systematically compared with each other in a very detailed manner. Only in this way can specific innovation policies be designed"[68]. For this reason, it seems vital to develop and apply a rigorous method allowing for performance comparisons between national innovation systems. This challenging task of will be part of my future research work.

On the other hand, comparisons between innovation systems must not be based on a number of indicators alone. They need to be put in a broader context and consider qualitative and structural aspects being typical of the countries analyzed as well. So, the very essence of the concept of national innovation systems is at stake if the mentioned trends in benchmarking various NIS lead to naive interpretations and the apparent heterogeneity of the systems analyzed is carelessly abstracted from. In other words: If policy implications are derived from "NIS studies" that are merely based on simple empirical analysis without taking into account institutional or structural differences between various systems, this will be detrimental to the reputation of the approach of national innovation systems in the long-run.

It follows from all these points that there is an evident trade-off between explanatory power of the NIS approach and accuracy in the analysis. While the former concerns the requirements to make innovation systems better comparable and to make the concept more dynamic, the latter concerns the maintenance of the concept's fundamental principles.

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[66] Obviously, this reflects the obstacles that a systemic perspective of innovation actually creates to cross-country comparisons: Examples are the large number of elements creating the system, the high number of linkages between these elements, the different intensity of such linkages in different systems, the system-specific and thus dissimilar importance of a specified range of determinants of innovative success, and the diversity of institutional profiles across countries.

[67] Edquist (2001), p. 16. This is because the NIS approach is based on evolutionary economic theory. Consequently, there is no optimal innovation system that could serve as a yardstick for the structure of an NIS or for the interaction between its components.

[68] Edquist (2001), p. 19.

In my future research activities, possible ways to resolve this conflict of interests will be proposed. Doing this, my central aims are twofold: First, I want to demonstrate strengths and limitations of benchmarking methods if they are applied to compare the performance between heterogeneous national innovation systems. Second, and with regard to such benchmarking studies, it is my objective to show that the neglect of fundamental principles of the NIS approach will lead to misleading and ambiguous results. Taken together, it needs to be shown that benchmarking studies of entire national innovation systems have only limited explanatory value if they are not combined with the insights gained in earlier studies of the corresponding systems.

Concerning the just mentioned benchmarking exercise, it is planned to make use of a method of efficiency evaluation known as data envelopment analysis (DEA).[69] The DEA method has a long tradition in the literature on productivity and efficiency evaluations of private business firms but also of public sector organizations.[70]

There are various reasons of why the DEA method appears also applicable to studies focusing on technical change and innovation in general and on national innovation systems in particular[71]: Above all, this method can be applied in a non-parametric way which allows for an inductive procedure starting with the empirical observations. Put simply, this implies that there is no pre-supposed functional relation between (innovative) inputs and outputs; instead, their relation are generated by the empirical data. Such a non-parametric method is especially suitable when different entities of the study make use of different 'production technologies'. Put in the context of innovation systems, this means that different systems are structured in dissimilar ways in order to attain their main and common goal, which is the development or absorption of innovations. Moreover, versions of the DEA method are usually utilized in economics when

[69] See for instance Charnes et al. (1994). A helpful overview on the DEA method is given in German language by Cantner and Hanusch (1998).

[70] It follows from this point that data-based benchmarking can be classified in at least two categories: There can be (a) descriptive benchmarking which consists of simple comparisons that are based on one or various indicators, or (b) efficiency evaluations with the aim to reveal the entities' productivity (or: the input-output relations) of a certain process.

[71] See Cantner and Hanusch (1998), p. 237.

no market prices of inputs and/or outputs exist. This aspect further supports the use of a DEA-based benchmarking method for national innovation systems because many of their innovative determinants and innovative outcomes cannot be measured by market prices.[72]

Regarding the combination of a benchmarking method like the DEA method with the NIS approach, it is first intended to compare systems in terms of a set of core variables and core activities that can be assumed to play a decisive role in each innovation system.[73] Besides that, the innovative efficiency of the selected innovation systems will be calculated. Subsequently, the gained results will be thoroughly interpreted. This step makes it necessary to take into account various of the national specifics of the considered innovation systems. These nation-specific factors are expected to help explain differences in innovative performance across national systems. Finally, the idea of measuring the innovative productivity of innovation systems will be critically discussed as well.

[72] For example, it is impossible to determine the market value of scientific publications.
[73] I owe this point Horst Hanusch.

5. Concluding remarks

There are manifold ways in which innovations exert an influence on economic growth. Above all, the introduction of product innovations, the implementation of process innovations in the business sector, and also organizational innovations in the public sector improve a nation's international competitiveness. Thus, the development path of nations is largely affected by its innovative performance. The latter includes the generation of innovations as well as the adoption of new technologies that have been developed abroad.

In light of the growth-spurring impact of innovations it is important to learn more about the main drivers of innovative activities and of innovative success. For this purpose, the NIS approach has proved to be a highly suitable alternative because of its realistic assumptions about the organization of national innovation processes. The NIS approach springs from and thus shares a lot with evolutionary theories of economic change. As there is still dissimilar use of some core concepts that characterize the NIS approach, it is required to specify and define the utilized theoretical concepts and technical terms in order to avoid misunderstandings.

With regard to the empirical application of the NIS approach, cross-country comparisons are expected to yield further insights into the strengths and weaknesses of national innovation systems. It can be argued that learning processes can be tipped off in the nations analyzed and that policy measures with the goal to enhance the structure and efficiency of the innovation system are brought about (see Lundvall and Tomlinson (2002)). Recent trends in the literature reflect the growing interest in (more detailed) performance comparisons between various national systems of innovation. Meanwhile, many authors use the term 'benchmarking' to describe international comparisons on the level of innovation systems. Typically, these comparisons are based on a descriptive presentation of various innovation indicators; moreover, they do not have much in common with previous benchmarking studies done on the organizational

level, because the latter concentrated on efficiency and productivity evaluations.

Yet, it is still disputed if and to what extent clear-cut performance evaluations make sense in the context of national innovation systems. For instance, it is not straightforward to compare heterogeneous systems. That is because it is problematical to carry out rigorous cross-country comparisons given the fundamental properties of innovation systems. Above all, these include complexity, dynamics and openness. In addition, processes like the production and diffusion of (technology-relevant) knowledge are only indirectly assessable, because knowledge is often local or tacit.

To conclude, it needs to be elucidated in future research work if and how meaningful performance comparisons can be carried out within the conceptual framework of national innovation systems. In other words: It needs to be shown if and under which conditions a higher degree of formalization of the NIS approach is compatible with its fundamental hypotheses.

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