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1.0.3 Viewing the innovation process as a system

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Abstract

The concept of the national innovation system regards interaction between firms—the central players in innovation—and actors (e.g., the government and universities) as a system in a country. This concept has played an important role in the introduction of innovation policy into science and technology, facilitating a way of thinking that considers not individual actors and institutions but the entire picture they comprise as the subject of policy discussion.

Keywords

National innovation systems, innovation ecosystems, sectorial systems, regional innovation systems, clusters

1 Introduction

The innovation process is characterized by interaction between various actors and institutions. Accordingly, as long as the analytical approach is limited to elements like specific actors and the accumulation of knowledge obtained through analysis, so analysis will fail to capture the impact of the interaction between elements in the innovation process. Addressing this shortfall, the concept of the national innovation system (NIS) takes a holistic view of the characteristics of the innovation process within a country as a system consisting of the interactions between elements. This paper first summarizes the history of NIS research and defines the NIS concept, before providing an overview of how this concept has influenced science and technology innovation policy debate.[2] It then looks at the development of a systems

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2 The following review is a revised version of part of Nagata Akiya (2002) and Nagata Akiya and Koichiro Onishi (2007).

theory perspective on science and technology innovation research and policy, in line with discussions concerning innovation ecosystems and regional innovation systems.

2 The National Innovation System Concept

NIS research was pioneered by Freeman (1987) and Dosi et al. (1988), among others. Freeman (1987) defined NIS as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." Although various attempts have been made to redefine the NIS concept, such definitions remain similar to that proposed by Freeman, and continue to focus on the interaction between the actors and institutions related to innovation.[3] Indeed, the various understandings of NIS can be distilled into the following definition: "a holistic picture of the interactions formed between firms—the central players in innovation—as well as government, universities, and other actors, viewed as an organic system within a country."

3 The History of NIS Research

The NIS concept emerged from the recognition that in order to understand the innovation process of people with different historical and cultural backgrounds, it is necessary to capture whole that which cannot be reduced to the sum of individual institutional parts. This point is clearly evidenced in Freeman's (1987) application of the NIS concept to understand the Japanese system, which built up its international industrial competitive strength through innovation, as indicated by Freeman's chosen subtitle, Lessons from Japan.

In the field of NIS research, international comparative studies have been conducted from the outset. For instance, Part 5 of Dosi et al.'s (1988) "National Systems of Innovation" comprises papers by Freeman, Nelson, and Lundvall. Freeman outlines the Japanese NIS, while Nelson provides an overview of the US NIS. Meanwhile, Lundvall's paper examined the interactions between actors down to the subsystem level, with Ludvall (1992) later systematizing the results of this approach.

In 1993, the results of a full-scale international comparative study were published in a volume edited by Nelson. Nelson (1993) divided fifteen countries into three groups according to per capita income level and other indicators, and offered a description of the NIS in each country. In this comparative study, Nelson et al. focused on the question of why, in the midst of the globalization of economic activity, each country's NIS did not converge but remained diverse. The study revealed that each country's NIS is dependent on its own institutions and historical background, and thus has a path-dependent character. Each country's institutions have coevolved while interacting with technology, resulting in the generation of a unique NIS in each country. Nelson's (1993) comparative study also contained the first comprehensive description of

3 For example, the OECD (1999) defines NIS as "a set of institutions that jointly or individually contribute to the development and uptake of new technologies." It is defined as "a system of interrelated institutions for the creation, possession and transfer of the products of civilization, which can be defined as knowledge, skills and new technologies." Moreover, the Science and Technology Agency (1999) defines innovation as "the totality of the activities of the institutions involved in the innovation process (firms that play a leading role, public research institutions that provide knowledge, universities, etc.), the flow of resources (knowledge, human resources, etc.) between these institutions, and external factors (e.g., government regulations and incentives, financial policies, employment policies, education and human resource development policies, etc.) that affect each of these activities."

the Japanese NIS by Odagiri and Goto. Odagiri and Goto (1996) extended and developed this research in later publication.

4 Implications of NIS research for science, technology, and innovation policy

Reflecting on the NIS research trends identified above, discussions focused on creating policy introducing the NIS concept have gathered pace within administrative bodies and international organizations involved in science, technology, and innovation policy in various countries around the world. The OECD has played a central role in such discussions. The OECD's Technology and Economics Programme (TEP) introduced the NIS concept in a statement published in 1991, stating that in order to improve the environment for research and development, a wide range of policies—including economic, social capital development, education, and employment policies—should be made consistent, and that consideration should also be given to international harmonization. In 1993, the OECD established a new Working Group on Innovation and Technology Policy (TIP). Overseen by the Committee on Science and Technology Policy (CSTP), the TIP project was intended to study measures to improve the efficiency of the system based on the analysis of NIS. According to the results of this project (OECD, 1999), there is an emerging consensus that the role of government in relation to innovation is not only to take measures to increase the total volume of R&D to compensate for market failure, but correct systemic deficiencies that hinder the efficiency of R&D.

In Japan, there is no government ministry officially responsible for the promotion of "innovation." According to Ishiwata Yuko (2019), the term "innovation" was first used in Japan in 2008, in the Act on Improving the Capacity, and the Efficient Promotion of Research and Development through Promotion of Research and Development System Reform (Act No. 63, which was renamed the Act on Promoting the Creation of Science, Technology and Innovation in 2018). As is well known, as a result of the partial revision of the Act for Establishment of the Cabinet Office in 2014, the name of the Council for Science and Technology Policy was changed to the Council for Science, Technology, and Innovation, and "innovation" was stipulated as an administrative duty under the jurisdiction of the Cabinet Office.

However, in Japan, the White Paper on Science and Technology was the first publication to use the NIS concept to report on science and technology activities in the country—the paper published in the same year as the OECD (1999) report. Approved by the Cabinet in March 2006, the Third Science and Technology Basic Plan set "reform of the science and technology system" as its goal, and stated that industry, academia, and government should work together to promote "strengthening the system for generating innovation." As such, the NIS concept had become widespread among the ministries and agencies interested in innovation by this point.

5 The “ecosystem” metaphor

As noted, the NIS concept was proposed by innovation researchers in the late 1980s, and has influenced science, technology, and innovation policy since the 1990s. It was in the 1990s that the term “innovation ecosystem” came into widespread use among innovation-oriented management practitioners and policymakers. The term is a metaphor for the interaction between the players involved in creating innovation, such as companies, universities, and governments, and the overall image of the surrounding environment. This metaphor is based on a practical awareness that innovation cannot be achieved through the efforts of a single company alone, but rather through the interdependence of diverse players. It was initially used in the term “business ecosystem” by Intel and other IT companies. The notion of the innovation ecosystem was conceptualized by Iansiti and Levien (2004) and others from 2000, and used by the US Council on Competitiveness (COC) in its 2004 policy proposal, “Innovate America,” that is, the Palmisano Report.

When the innovation ecosystem concept is compared with that of the NIS, it is hard to recognize any significant theoretical novelty. However, the choice of the word “ecosystem” is significant insofar as it includes an orientation toward the description of interaction relationships among actors that are broader than the boundaries of a national system. The way in which the researchers who proposed the NIS concept understood the issue was not based on the premise that the innovation process was a system confined to nation states; rather, they were actively motivated to understand the relationship between the globalization of economic activities and the national system. This motivation led them to focus on the characteristics of the national system. In contrast, the concept of innovation ecosystems has shifted the focus of description toward the direction of the global economy itself being understood as an ecosystem.

6 Expansion to middle range categories: Sectorial systems

The concept of the NIS was also reconsidered on the basis that the industries and regions that make up a country’s system cannot be homogeneous. These attempts at reexamination have raised a middle range of categories that mediate between national systems and individual actors. Among these, the category concept that focuses on the characteristics of innovation systems in each industry is the Sectoral Systems of Innovation (SSI) proposed by Malerba (2004).

By “sector,” Malerba means a series of activities that are combined for a product group that meets an existing or emergent demand. SSI are also defined as being composed of a set of agents that share a knowledge base or technology and interact within and outside the market to create, produce, and sell products in the sector. In this respect, agents are individuals and organizations at various group levels with special learning processes, capabilities, organizational structures, beliefs, objectives, and behaviors. Agents interact through processes of communication, exchange, collaboration, competition, and instruction, and their interactions are shaped by institutions.

After describing the basic concept of SSI, Malerba identified its special characteristics. SSI undergo change and restructuring through the coevolution of diverse components. Moreover, SSI comprise three "building blocks": 1) knowledge and technology, 2) actors and networks, and 3) institutions.

7 Regional innovation systems

The idea that the internal structure of the NIS should not be geographically and spatially homogeneous led to the proposal of the concept of the Regional System of Innovation (RIS). However, as Cooke (1998) shows, its logical structure is generally the same as that of the NIS, and it can be regarded as an argument for NIS on a reduced spatial scale. Even within a given region, the industrial sector—a major player in innovation—will co-evolve while interacting with universities and other academic and governmental institutions.[4]

Saxenian (1994) also attempted to model regional superiority in innovation. Saxenian conducted a comparative study of Silicon Valley and the area around Route 128, both known as high-tech industrial clusters, and analyzed why entrepreneurial activity remained high in the former but declined in the latter. The results revealed the regional system of Silicon Valley, which has a concentration of specialized entrepreneurs, as a "regional network-based industrial system," and the regional system around Route 128, which consists of a concentration of highly integrated large firms, as an "independent firm-based system." Saxenian also noted the superiority of the former in responding to market demand and technological changes.

8 Clusters as systems

Concepts that can be understood as modelling RIS have been independently raised by researchers not directly influenced by NIS research. The concept of "clusters" proposed by Porter (1990)—that is, clusters of competitive industries—is an example of this.

Porter (1990) analyzed the factors that enable firms in one country to innovate more quickly than those in another country in a particular industrial sector. Comprising the four conditions raised within this analysis and their interaction, the framework is widely known as the "cluster" conceptual model. The four conditions are: 1) "factor conditions," which refer to resources such as skilled labor and infrastructure that form inputs for production activities; 2) "demand conditions," which refer to the level of demand in the market; 3) "related and supporting industries," which include suppliers to the industry in question; and 4) "corporate and competitive strategies," which are prompted by the existence of competitors. Porter emphasizes the interrelationship of these four conditions and refers to them as "diamonds," presenting a framework that connects four points (Figure 1).

4 Etzkowitz's (2008) discussion of this kind of relationship as a "triple helix" structure can be understood as an attempt to model the middle range category.

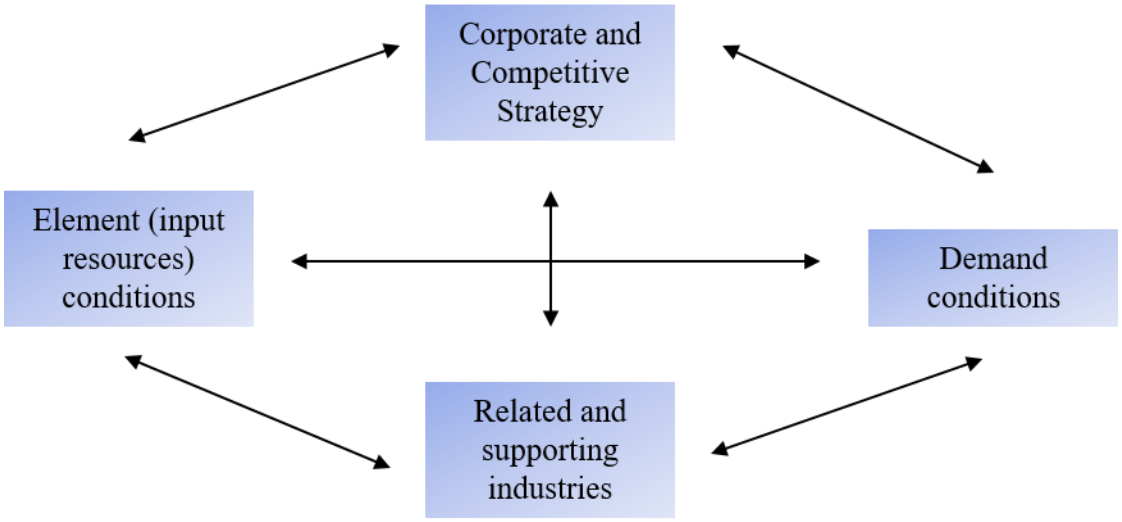

Figure 1. Factors of industrial competitiveness.
Source: Porter (1990)

Porter (1990) also noted that the systemic nature of these various conditions promotes the clustering of competitive industries, providing a variety of specific examples. In other words, Porter's (1990) cluster concept referred to a state in which several competitive industries are clustered in one country (i.e., a cluster of industries) through the "related and supporting industries" condition, which occupies one corner of the "diamond system." However, Porter (1998) later revised the concept, defining it as "a geographically proximate group of firms and institutions that belong to a particular sector and that are interrelated." Moreover, its geographical spread "may range from as small as a single city to an entire country or a network of several adjacent countries." Porter (1998) then argued that "it may be possible to define [a cluster] as a system, the value of the whole of which is greater than the sum of its parts."

Porter (1990) believed that the role of policy should stop at being a catalyst for creating a competitive environment, government thus not explicitly described as an actor in the cluster model. However, Porter's (1998) revised argument holds that macroeconomic policies alone are insufficient to create a competitive environment, and that microeconomic policies such as taxation, labor market policies, intellectual property systems, and antitrust policies play an important role in determining the intensity of competition. He expanded his focus to examine the role that governments should play in strengthening "corporate strategy and the competitive environment," that is, one corner of the diamond. In doing so, Porter cited administrative infrastructure, information infrastructure, and science and technology infrastructure as examples of "elemental conditions," alongside natural and human resources. He further cited "university research institutes that companies can depend when competing" as an example of science and technology infrastructure.

The term "cluster" entered widespread use in Japan at the beginning of the 2000s. This is due to a series of regional policies including the word "cluster" in their titles, such as the Industrial Cluster Plan (Ministry

of Economy, Trade, and Industry) and the Knowledge Cluster Creation Project (Ministry of Education, Culture, Sports, Science, and Technology). The definitions of "cluster" set out in the policies are as follows:

- Industrial cluster: A system in which, in addition to technological innovation between public research institutions such as universities and surrounding companies, collaboration is promoted between universities and companies and between companies over a wider area, resulting in a chain reaction of innovation and the creation of new businesses and industries.
- Intellectual cluster: A technological innovation system consisting of a core of public research institutes and other organizations with unique regional R&D themes and potential, with participation from companies and other organizations from both within and beyond the region.

While these definitions differ from the original definitions in that they focus on the role of universities and public research institutions as policy instruments, it is important to note that both definitions specify clusters as innovation systems.

Japan's measures to support regional innovation in science and technology based on the Science and Technology Basic Plan were promoted on the basis of cluster policy between the second (FY2001–2005) and the third plans (FY2006–2010). Some cluster policies were abolished, combined, restructured or pared back in FY2010 as a result of the project reorganization carried out in 2009. However, it can be said that the introduction of the clusters-as-a-system concept played an important role in preparing policy goals, including "building a regional innovation system" in the fourth plan (FY2011–FY2015) and "building an innovation ecosystem" in the fifth plan (FY2016–FY2020).

9 Implications for policymaking

This paper has reviewed theories and conceptual frameworks that view the innovation process as a system together with changes in the focus of study from NIS to RIS. In doing so, I have noted the influence of the results of such research on actual science, technology, and innovation policies. General implications for future policymaking can be summarized as follows.

The innovation process is a complex process comprising the interaction of diverse actors and institutions. Therefore, when planning policy interventions for this process, it is necessary to not only consider the effects of the measures in question on the actors and institutions directly targeted by such measures, but the indirect effects on the actors and institutions that are in an interactive relationship with the targets of these measures. It should also be taken into account that individual measures do not act in isolation, but may have complementary or substitutional relationships with other measures. The extent of interrelationships between policy measures may extend beyond the boundaries of science, technology, and innovation policy.

This paper also shows that there is diversity in the sectoral system and the RIS as subsystems forming an NIS. This multi-layered system structure needs to be considered when developing complementary relationships between macro policies implemented at the national level and industry- and region-specific measures. If policies are not formulated with this perspective in mind, individual measures may not be sufficiently effective. Moreover, because scientific and technological innovation can have significant

socioeconomic impact, for better or for worse, those responsible for formulating the policies regulating this process require both foresight and broad-mindedness so as to anticipate and avoid potential negative consequences. Viewing the innovation process as a system provides such a mindset.

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