



Characteristics of Innovation System 4.0 in the Edge of the Fourth Industrial Revolution Four Relevant Cases in Germany

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Abstract

This paper deals with the characteristics of the Innovation System 4.0 at the edge of the fourth industrial revolution. It concerns the taxonomy of the Innovation System and, last but not the least, the description of features of the Innovation System. As a theoretical approach to the taxonomy of the Innovation System, a combination has been created herein between Innovation Process and Innovation System. It assumes that process in the broad sense is the totality of interrelated occurrences within a system. Because of the changes in the German Innovation System triggered by environmental problems and the Industry 4.0, four relevant cases have to verify according to the new core features. Although the theoretical foundation of the Innovation System 4.0, which is commenced in this paper, is still in its infancy, from a structural point of view, three aspects of this changed innovation system were highlighted: openness, participation and work-life balance. This could be a starting point for further discussions on the Innovation System 4.0.

Keywords: *Innovation System 4.0, Innovation Model, Innovation Process, Socio-technical Transition, Industry 4.0*

1. Introduction

The purpose of this paper is to compare the different approaches and models of the innovation system. It concerns the taxonomy of the Innovation System and the description of features of the Innovation System that has occurred not only in times of environmental problems, but also on the margins of the fourth industrial revolution in literature and practice. Current technological developments, such as Artificial Intelligence, 3D printers or self-driving cars has provoked debates about the fourth industrial revolution, will fundamentally change our way of living and working. We know that the appropriate responses to these changes shall be familiarized within the system, because these changes are not only positive but also negative, such as unemployment. In this context, this article deals with the reaction of the Innovation System. The need for response within the innovation system exists not only in the current technical developments, but also in environmental issues such as climate change, which appeals into question the basis of the survival of humanity.

While some countries respond promptly, such as Germany, which is preparing for the Industry 4.0 and others, an adequate response seems to be an overwhelming burden for most countries. For example, a simple adoption of the German model is impossible because each country has different levels of development and different conditions. Therefore, this article seeks to provide conceptual frameworks that can be of use in different countries to analyze the adequacy of the countermeasure under the Innovation System. Against this background, the classification of the Innovation System comes first: from 1.0 to 4.0. Then it is about features of the Innovation System 4.0.

This article attempts to analyze the evolution of the Innovation System and the characteristics of the Innovation System 4.0 using a descriptive theory. Conceptual frameworks and analysis heuristics that do not specify causal relationships between concepts are not deliberating as explanatory theory, but rather as descriptive theory. Descriptive theory aims to improve categorization schemes to better identify the relevant attributes of a phenomenon. The theory of explanation formulates assumptions with theoretical terms (often based on categorization schemes) about relationships and conditions to which they apply [1]. Explanations can be certain at various levels of abstraction with theoretical or observable concepts. Methodically, this paper presents itself as a descriptive theory.

Furthermore, this paper is understood as process theorizing. Process theorizing uses a theory-building perspective that focuses on changes over time. It asks questions such as: "How does one develop, grow or end over time?" [1]. The results are explained by sequences of events. Consequently, a process analysis examines the consequences of changes and their emergence. A commonly used process analysis method is the narrative approach, which uses a conceptual framework to describe how things evolve and change.

2. Conceptual Framework

As a theoretical approach to the taxonomy of the Innovation System, a combination is making here between Innovation Process and Innovation System. It assumes that process in the broad sense is the totality of inter-related occurrences within a system. Historically, companies forcing to bring new products and services to market within a short term, due to shorter technology and product

life cycles. This dynamism of business activity has led to increasing attention in innovation management in science and business practice. Here, process models are an integral part of innovation management.

There are many definitions and concepts of "Innovation Process" that exists in literatures and also, in practice. Historically, different generations of process models can be recognized primarily in America. A leading author who contributed to the historical analysis of the development of Innovation Process Models is Roy Rothwell [2]. Rothwell identifies the differences between five generations of the Innovation Process Model. Based on his historical analysis of the development of Innovation Process Models, four classifications will be tested out from Innovation System 1.0 to 4.0, as a conceptual framework for describing the Innovation System.

2.1. Innovation System 1.0

The Innovation System 1.0 can be theoretically associated to the 1st, 2nd, 3rd generation of the Innovation Process Model. Structural features of the Innovation System 1.0 can be explained by these models. 1st generation of the Innovation Process is the technology push model. The linear technology push model became widespread until the late 1960s, post-war years. The economic environment of large companies at that time was generally characterized by a high growth rate. The market was simply a place that secured the fruits of research and development, in simple terms, people bought what was offered. The technology push model was developed by NASA in the 1960s, and was used later by the U.S. Military and some companies such as Hewlett Packard. This linear model means a chronological orientation of each phase, from basic research to the preparatory phase of production, production, marketing and final sales [3].

The 2nd generation of the Innovation Process theory is the market pull model. As a result of increased market competition and diver-

sification in the 1960s to the mid-1970s, integrating the customer's needs into the Innovation Process and thus also into marketing was important. Nevertheless, the market pull model was exemplified by a linear organization of each phase, as in the previous generation [4].

The 3rd generation model was a coupled model that recognizes the influence of technological capabilities and market needs within the framework of the innovating firm. This involved the coupling of R&D and marketing. Because of the post-World War II economic crisis in the 1970s, the further detailing of the phases and the implementation of feedback steps in the sense of rationalization, consolidation, and control and cost reduction were necessary to overcome inflation, saturation of the market and high supply capacity. In the mid-1970s, a new, generally accepted model was introduced that combined the "Technology Push" and "Market Pull" models. It was enhanced with feedback loops and was called the interactive model of technological possibilities and market needs [3]. Despite the emphasis on market needs and feedback, the institution that conducts basic research is highlighted. This represents an important element of the Innovation System 1.0.

2.2. Innovation System 2.0

National Innovation System (NIS) is considered as a good example of the Innovation System 2.0. Friedrich List is considered the "father" of the National Innovation System: economists and politicians (1789-1846). His concept is "national production systems" [5]: optimization of production, national infrastructure and institutions. Christopher Freeman formulated the term "National System of Innovation" (1982) and further developed List's idea. In this sense, Freeman considers it necessary for the state to promote the technological infrastructure and to make it clear that short-term strategies (such as wage and currency changes) have only limited effectiveness in strengthening the international competitiveness of an economy [6].

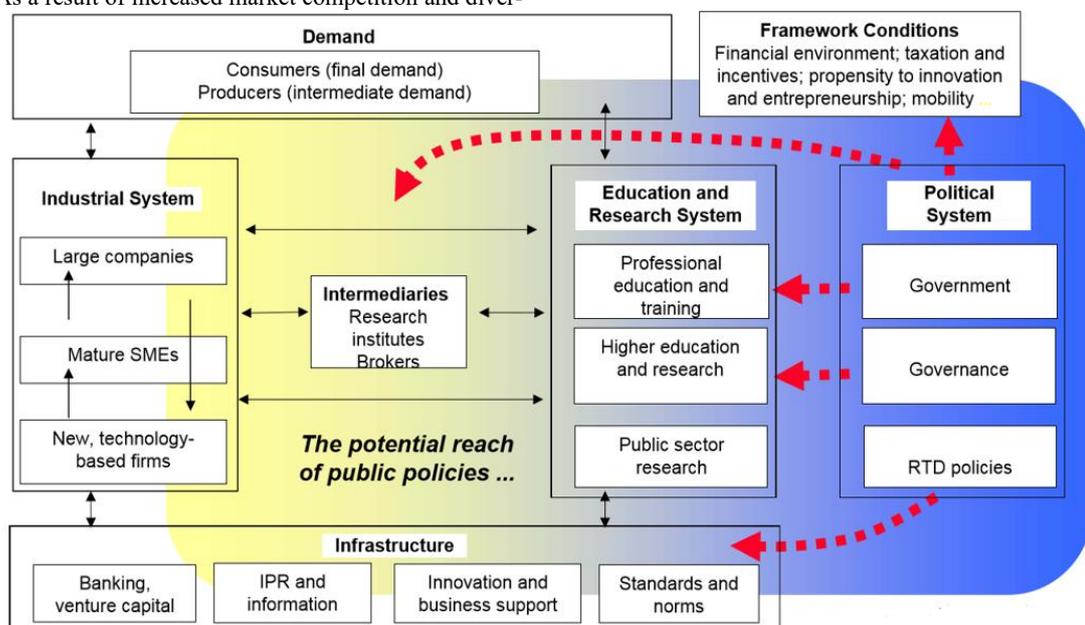


Fig. 1: Model of the research and Innovation System

Source: Technopolis 2000, modified and extended by S. Kuhlmann, Fraunhofer ISI, https://www.isi-lehre.de/lehre-wAssets/docs/hannover/vergleich_innosystem/folien/Innovationssystem.pdf

Bengt-Ake Lundvall is regarded as the founder of the NIS concept [7]. According to his point of view, innovation is more inherent part of the normal economic activities. Interactive learning is at

the core of his approach.

The National Innovation System has key structural features of the Innovation System 2.0. There is no generalized definition of a National Innovation System. What is important is the network of interaction or system. The concept of National Innovation System is based on the premise that understanding links between innovators is crucial to improving technology performance. Innovation

and technological advancement are the result of a complex set of relationships between actors that produce, distribute and apply different types of knowledge [4].

The following points can be presented as elements of a National Innovation System, as shown in Fig. 1 [8].

- (1) Institutional structures of a country: They are formed by companies, universities, research and training institutions, standards, routines, networks, financial institutions, and government measures to promote and regulate technological change.
- (2) Incentive system of a country: This includes among others incentive systems for innovation, for technology transfer, for learning and qualification, for start-ups and occupational mobility in and between organizations.
- (3) Skills and creativity of the innovation and economic actors of a country: Both between countries and between companies in a country, there are huge differences in the diversity and quality of products and services, as well as the opportunities to develop new development paths.
- (4) Cultural peculiarities of a country: The cultural features are also reflected, for example, in different acceptance and understanding of usage of technology.

From a structural point of view, the Innovation System 2.0, like the National Innovation System, can be theoretically linked to the 4th, 5th generation of the Innovation Process Model. To improve

the lack of functional integration in the linear models, the fourth generation Innovation Process Model (the interactive approach) was developed. This is also known as the integrated business process model. The ever-shortening product life cycle, has led to the improved cooperation between research, development and production and also improved horizontal cooperation, regardless of company boundaries. Therefore, it is also considered to pursue a time-based strategy [3]. This approach views the Innovation Process as parallel activities across organizational functions. Therefore, Combinations of push and pull models, integration within a firm, emphasis the importance of external linkages.

2.3. Innovation System 3.0

While the National Innovation System can be considered as an example of the Innovation System 2.0, Regional Innovation System identifies the key structural features of the Innovation System 3.0 and is about the regional institutions that are relevant to entrepreneurial innovation. Regional Innovation Systems are referred to as "geographical distinctive, interlinked organizations supporting innovation and those conducting it, mainly firms" (Cooke et al., 1996). The Regional Innovation System can theoretically be linked to the network model of the Innovation Process, such as the National Innovation System. The network of internal and external stakeholders and the connections between all role players are important in this model [10]. How can these connections be analysed?

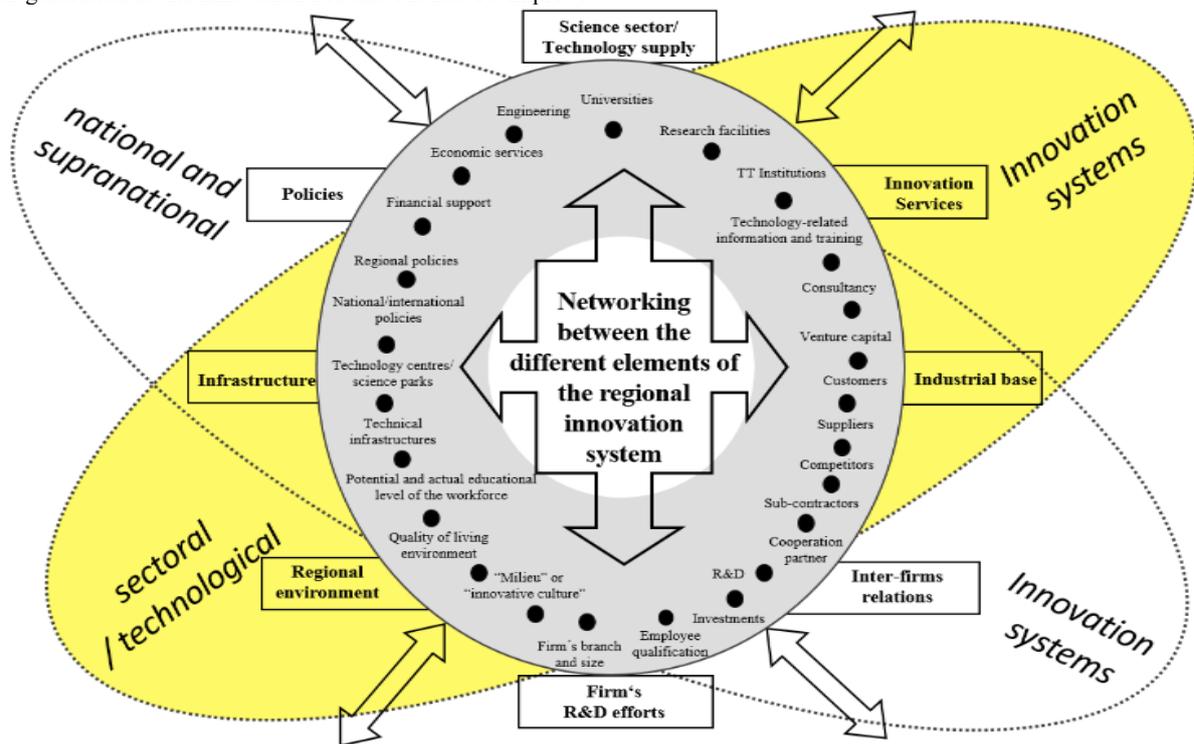


Fig. 2: Regional Innovation System

Source: Design by K. Koschatzky, Fraunhofer ISI, https://www.isi-lehre.de/lehre-wAssets/docs/hannover/vergleich_innosystem/folien/Innovationssystem.pdf

In the available definitions of Innovation Systems, the concept of the institution plays a dominant role. Stakeholders or role-players can be called institutions here. In other words, Innovation Systems are usually defined institutionally. In all the definitions used, various economic, social and political institutions that influence innovation are central elements and aren't taken away. Examples of such institutions are universities, R&D laboratories, schools, patent systems, labour market organizations, banking systems, various government agencies, etc [4].

Earlier studies focused on regional support systems (with a strong reference to regional innovation policy) [11], today it is a knowledge application subsystem (regional companies and their customers, suppliers, competitors and cooperation partners) and the knowledge production and diffusion subsystem (universities and other research institutions, transfer organizations, training institutes) [12]. Precisely this differentiation that has shifted the focus of analysis within the institutional framework to the relationship between scientific institutions and companies and the mediating role of the state. By doing so, the institution is emphasized in terms of norms, habits, practices and routines.

In this context, other types of institutions are emphasized. This is considered to be very important influences on innovation and

Innovation Systems.

Both of National Innovation System (NIS) and Regional Innovation System (RIS) can be linked to the Network Model of the Innovation Process, however, norms, habits, practices and routines are not given any value in the literatures on National Innovation System, while they are emphasized in the context of embedding regional innovation activities in the literatures on the Regional Innovation System. The core of the Regional Innovation System discussion is that interactive learning based on tacit knowledge, geographical proximity, and common value shared geographically are key to the process of innovation. The space here does not mean physical space, rather, it is close to a cultural space in terms of the sharing of the value system. In this regard, the regional Innovation System, unlike the NIS, can be classified as an Innovation System 3.0 [13].

The fifth generation or network models originated in the 1990's and attempt to explain the complexity of the Innovation Process. Major characteristics of the network model are the influence of external environment and the effective communication with the external environment. Innovation happens within a network of internal and external stakeholders. It is important therefore is to establish links between all the role-players (See Fig. 2). Collaboration with external research organizations and marketing is much stronger than in the fourth generation [9].

2.4. Innovation System 4.0

The Innovation System 4.0 is a system that includes RIS as a primitive system. However, openness, participation and work-life balance can be seen as new structural features in the Innovation System 4.0.

First, the Innovation System 4.0 can theoretically be based on a new sixth generation of the innovation model. The sixth generation is an open innovation model, while the fifth generation models are mainly closed innovation networks. Traditionally, new business development processes and the marketing of new products took place within the firm boundaries. In closed Innovation Systems, employees within the organization develop the ideas internally and in secrecy [13].

The sixth generation of innovation models (open innovation models) is also network models of the Innovation Process, but instead of concentrating on internal idea generation and development, internal and external ideas as well as internal and external paths to market are combine to advance the development of new technologies, hence their openness [14].

The concept of open innovation was first named by Chesbrough. One of the most obvious benefits of open innovation is the much larger base of ideas and technologies that can drive internal growth. In addition, leading companies recognize open innovation as a strategic tool to explore new growth opportunities with lower risk. The innovation environment has changed through networking and collaboration. Open innovation requires a new logic that focuses on openness and collaboration. Connected or web communities are the open and agile tools to implement the open innovation concept [15].

In summary, open innovation requires a new logic centered on openness and collaboration. Networked or webbed communities are the open and agile vehicles to implement open innovation concepts pragmatically. In the new network paradigm, it is possible to use the linear and the coupling processes in combination as required. However, this requires new forms of cooperation between companies that compete at the same time.

Second, besides openness, the participation shows the difference between Innovation System 3.0 and 4.0. The development of the

discussion on Regional Innovation Systems (RIS) is taking place in two different ways. On the one hand, within the paradigm, specific questions are examined empirically and theoretically. On the other hand, changes are taking place in real Innovation Systems and innovation policy strategies. New impulses that are relevant to theoretical discourse have been set in recent years, above all by the European Commission and the OECD [16]. In this context, so-called "socio-technical transitions" play a respectful role in theory and practice. The resulting new feature of the Innovation System 4.0 is participation. NIS and RIS basically show no need for citizen participation in their theories.

Unlike the Innovation System 3.0, the Innovation System 4.0 seeks to serve as an answer to current environmental issues. Addressing environmental issues requires a factor of 10 or more improvements in the environmental performance index that can only be achieved through profound structural changes in transport, energy, food, and other systems [17]. These systemic changes are often referred to as "socio-technical transitions" as they involve changes in the overall configuration of transport, energy and food systems, including technology, policies, markets, consumer practices, infrastructure, cultural significance and scientific knowledge. These elements are reproduced, maintained and transformed by actors such firms and industries, policy makers and politicians, consumers, civil society, engineers and researchers. Transitions are therefore complex and long-term processes involving multiple actors [18].

In this context, one can observe a new tendency of participation in some European countries like Germany, and Holland. New developments and technologies are discussed openly and are receptive. Your opportunities and risks are balanced and unbiased. In this way, a society is promoting who are interested in social and technological innovations, brings in its own ideas and actively participates in the Innovation Process [19].

Third, the Innovation System 4.0 should also serve as a response to the economic challenges associated with the fourth industrial revolution. Among other things, digitization raises a number of challenges to the Innovation System. Nevertheless, as Germany does Industry 4.0, most of the tasks can be solved within the Innovation System 3.0. But a resulting new feature of the Innovation System 4.0, unlike 3.0, is the deepening of the work-life balance. It is noted that the trend towards increasing digitization of the working world potentially has a strong impact on employees and their situation in companies in general and specifically on forms of work organization [20].

When designing the work processes, it will be important to create meaningful and learning-promoting workplaces that allow working under appropriate physical and psychological stress. To do so, it will be necessary to design the tasks in such a way that "mentally more (e.g., more problem solving requirements) and less (e.g., less routine requirements) demanding" sophisticated "operations are required in proportion. Here one can take an increasing aspect of art in production as a good example. Moreover, the work-life balance in a broader sense cannot only be reduced in the area of the work process, but includes the unconditional basic income debate in the sense of human rights [21].

3. Four Relevant Cases in Germany

Because of the changes in the German Innovation System triggered by environmental problems and Industry 4.0, four relevant cases can be systematically verified according to the new core features [22].

Innovation Systems are always part of an economic or social system that includes several subsystems (for example, the production system and the financial system), each of which has specific func-

tions. The main function of the Innovation System is the generation of new knowledge and thus the stimulation of permanent change and Innovation Processes in all sectors of society, especially in the economy [23]. Due to the strong influence of the economic and social system surrounding the Innovation System, there is a connection between the Innovation System and the type of market economy.

Since the collapse of the social and economic system of the Soviet Union (late 1980s), the central administration economy and planned economy no longer play a role as "counter-models" to the market economy. Rather, different types of market economy have evolved, and today they are competing against the backdrop of globalization; mainly, the Anglo-Saxon free market economy, the continental European social market economy, and especially those that originated in Germany [24].

The free market economy and the social market economy differ in the extent they offer in different social areas in which they intervene through government policies. In the free market economy, the functioning of the laws of supply and demand is very far-reaching, while the state in the social market economy tries to avoid the deficits and shadows of the market by a political strategy [25].

German Innovation Systems are emerging within the framework of the social market economy, and the pursuit of consensus between social forces is an important pillar of conflict regulation, with the central levels of the associations involved playing an important role. Therefore, one can observe relatively significant changes in the German Innovation System, which is triggered by social and environmental problems [26].

Another characteristic is that RIS is traditionally strongly emphasized in Germany in addition to the NIS. In recent years, openness in the German Innovation System in conjunction with open innovation has been strongly emphasized.

3.1. Open Source Design

The French-German research project "OPEN! Methods and tools for community-based product development" is a relevant case of open source product development. This aims mainly at modelling the open source product development process as an alternative to well-anchored industrial product development processes and providing concrete process support in the form of methods and IT-tools. It is particularly focusing on the concept of an open design platform. The project started in March 2016 and is co-financed by the German and the French national research foundations [27].

3.2. Citizen Dialogues and Living Lab

In its high-tech strategy, the German government is committed to increasing the participation of all actors (from science and industry to citizens) in shaping Innovation Processes. For this, it strengthens important elements such as technology openness, citizen participation and social innovations. In 2015, the new Citizens' Dialogue Series "Future Forums" was launched at the federal level, focusing on the future orientation of research and science. Citizen dialogues are important exchanges in order to get ideas for political decisions, to increase the accuracy and effectiveness of political projects, to create confidence in new topics and to generate curiosity [28].

Growth in the city is accompanied by an increased burden on urban infrastructures. Digitization can provide solutions to this issue. The city of Ludwigsburg has therefore made its way to the Smart City on a local level. With the founding of the Living Lab Ludwigsburg in 2015, she has taken a significant step in this direction and has thus taken on a pioneering role in Germany. The innovation network connects economy, science and city administration. The interdisciplinary approach makes it possible to test research

ideas, scientific findings and innovative technical solutions in urban space. The urban space serves as a real application laboratory. The city deals with the questions of urbanization and digitization with the 'Innovation Network Living LaB'. There, ideas for solutions, services and business models emerge, which are developed, tested and brought to market as a pilot project. These solutions support the achievement of the goals of the sustainable urban development concept, which was set up together with citizens years ago and regularly developed with civic participation [29]. It is important to note that a response to Innovation 4.0 is Work 4.0.

3.3. Work 4.0

In the Germany's industrial economy, economic activity has become digital. New forms of interaction create opportunities in the organization of work and change the demands on employees. Diverse opportunities for further education and learning-promoting ways of working are crucial for the success of Industry 4.0. In order to continuously develop and adapt, both vocational and academic education and training require a continuous dialogue between business, politics and society [30].

The term Work 4.0 follows the discussion about the fourth industrial revolution (Industry 4.0), but attaches importance to forms of work and employment relationships - not only in the industrial sector, but also in the entire working world. In summary, the term can be described by the fact that the working methods (some of which are already practiced today, and above all the working methods of the next few years) adapt to the challenges and opportunities of the digital world. In this context, Work 4.0 encompasses the process of changing the world of work in the digital age [31].

4. Conclusion

The theoretical contribution of this paper is to consider the content of the term "Innovation System 4.0" and its emergence within a new conceptual Innovation Process Model and social innovation. In practice, the Innovation System 4.0 seeks to answer two fundamental problems. One is contemporary environmental problems, such as climate change, loss of biodiversity, and resource depletion (clean water, oil, forests, fish stocks, etc.) which poses enormous social challenges to the world. The other question is mainly concerned with the fourth industrial revolution, which has received public attention in some countries, such as Germany, South Korea, Japan and others.

In theory, Rothwell identifies the differences between the five generations of the Innovation Process Model. However, the five generations do not imply that progress from one model to another does not mean that the previous model has been completely abandoned and replaced. That is, in practice, models can be mutually exclusive or interrelated. These features of the process model also apply to the relationship between Innovation System 1.0, 2.0, 3.0, and 4.0. In particular, the Innovation System 4.0 does not exclude the Innovation System 3.0, but includes it.

Regions in Europe and around the world face complex socio-economic challenges that need to be tackled in the short and long term. These include the response to climate change, the digitization of the world of work. These challenges have one thing in common: they have a social dimension and their effective management is not possible with technological innovation alone. It also requires new ways of thinking, alliances and processes, new ways of working, organizational and management forms and new forms of dialogue. Essentially, it is about finding new ways to promote innovation that promotes sustainability and quality of life in addition to technological progress and economic growth. This results in the necessity of the Innovation System 4.0.

In contrast to the Innovation System 1.0, 2.0, 3.0, the Innovation

System 4.0 is characterized by being not only commercially but socially motivated. This is the important difference between Innovation System 3.0 and 4.0. Although the theoretical foundation of the Innovation System 4.0, which is commenced in this paper, is still in its infancy, from a structural point of view, three aspects of this evolved Innovation System were highlighted: openness, participation and work-life balance. This could be a starting point for further discussions on the Innovation System 4.0.

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