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An evolutionary analysis of the innovation policy domain: Is there a paradigm shift?

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Abstract

Researchers focus on understanding the nature of ecosystems and societies as well as explaining how paradigms change. These efforts are presented and disseminated through scholarly work in scientific literature. The pool of knowledge generated through databases allows one to track how our understanding changes and how paradigms shift through time. The present study is concerned with the domain of innovation policy, which is affected directly by societal and technological change and is a good archetype for demonstrating the scientific change perspective. In recent years, scientometrics has been frequently used to measure and analyze progress in science, technology and innovation. This study makes use of a combination of scientometric analysis and evolutionary framework analysis to demonstrate the evolution of innovation policy domain. Kuhn's seminal approach is applied for classifying and interpreting the phases across the evolution of the domain within a 30-year timeframe. The analysis demonstrates that the innovation policy domain is at the "crisis stage" as a result of ongoing with transformations in the society, technology, economy and policy. These transformations affect both supply and demand sides of innovation and call for an evolution in the innovation policy domain. Although this by no means represents that the innovation policy domain is in a "deadlock", the present study asserts that there is a new quest in innovation policy by adapting, re-framing or re-constructing the scope of the domain. The anticipated paradigm shift is expected to lead to a more de-centralized and distributed understanding of the world for innovation policy making.

Keywords Innovation · Policy · Technology · Scientific change · Paradigm · Evolutionary analysis

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Introduction

Innovation policy concepts have mostly been developed as part of economic theories. From linear to systemic perspectives, a number of policy tools have been suggested in the literature to deal with these traditional and evolutionary approaches. However, technology, economics, finance, environment, and particularly society have been changing rapidly, which necessitate the adaptation of policy processes to these transformations.

Martin (2016) identifies 20 new challenges for innovation studies based on the assumption that the innovation studies have failed to keep pace with our rapidly changing world. Most of the concepts, definitions, and approaches in relation to innovation are based on the past studies; they therefore may miss the new issues arising in the innovation landscape and in the broader global context. Some of Martin (2016)'s challenges question past innovation studies, while others propose doing research on responsible innovation, innovation for wellbeing, ideology-free policy processes, governmentrepreneurship[1] and evidence-based policy making process for future studies.

For instance, recent years have witnessed the emergence of the collaborative consumption and a sharing economy, which serves as a shift in societal and behavioral patterns as this was considered irrational for traditional economies. Hamari et al. (2016) define the 'sharing economy' as an emerging economic-technological phenomenon that was triggered by the developments in Information and Communication Technologies (ICTs), growing consumer awareness, the proliferation of collaborative web communities as well as social commerce/sharing. They analyzed the concept as a technological phenomenon and found that on sharing platforms there are different ideological and communal tendencies, such as anti-establishment sentiment, freedom of information, and, especially the environmental friendliness of an activity, which were considered important internalized drivers for behavior.

Developments in technology, changes in production and consumption cultures, and broader socio-economic transformations force economists to think about behavioral sciences. The Nobel Prize awarded to Richard H. Thaler proposed an integrative view of psychology and economic decision-making by exploring the consequences of limited rationality, social preferences and the lack of self-control. In his study, Thaler (2016) argued that evidence-based economics should be embraced by economists and that attention on economic studies should be turned from 'Econs' to 'Humans'.

Furthermore, a new perspective has been introduced with the 'knowledge democracy' concept (Veld 2010) based on the assumption that the combination of a network society and media-politics creates new problems, tensions, and innovative solutions. Veld (2010) states that advanced societies face an increasing intensity and speed of reflexive mechanisms, which lead to overwhelming volatility for bodies of knowledge related to social systems.

Investigating the key drivers of change for society, economy, technology, and policy, this study aims to understand the evolution of the theoretical basis of innovation policy and questions whether any weak signals of a scientific change and paradigm shifts concerning innovation policy discourse can be detected. In order to investigate changes and paradigm shifts, the study makes use of Kuhn (1962)'s theory of scientific change. The aim is to initiate a creative discourse for innovation policy scholars and policymakers to reflect on

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[1] Proposed by the authors to indicate government entrepreneurship.

the wide ranging transformations both in supply and demand sides of innovation, and thus to enable an evidence-based discussion for new research directions in the domain. Thus, the study is outlined as follows. The second section reviews the theoretical discussions and critical studies in the innovation policy domain. In this review, classification and failure perspectives are explained simultaneously. Then, some other views are elaborated upon following recent criticisms of the current literature. In the third section, scientific change and paradigm shift models are examined with their applications and critical assessments. The methodology of the study is described in the fourth section and findings are presented in the fifth section. The final section discusses the findings with a future-oriented scenario-based perspective and draws conclusions.

Literature review on innovation policy studies

Technological innovation has been a key driving force for economic growth, industrial development, and increasing welfare. Many studies have been undertaken to understand the nature of innovation for preparing compatible and applicable policy studies. According to Giddens (1979), science and technology policy is an organizational field, which can be understood as of the creation of a recognized area of institutional life with the aim of serving explicit and implicit interests as well as concepts defined by policy-makers and other interest groups in the field. These institutions may include R&D organizations, firms, and government agencies among the others.

Edler and Fagerberg (2017) asserted that innovation policy was not involved in policy-makers' agenda a few decades ago and suggested that the term became popular among users only starting the mid-1990s. They classified the approaches to innovation policy into three different categories as: (1) mission-oriented policies (Ergas 1987); (2) invention-oriented policies; and (3) system-oriented policies. Mission-oriented policies were explained by their mostly defense-related applications, where great economic impact was achieved as the result of such policies. While explaining invention-related policies, Bush (1945)'s report during the post-WWII period was given as an example for this category. From the 1960s onwards, the creation of new public entities and research organizations was led by this invention-related policy understanding, which was considered R&D, research, or science policy at that time. Regarding system-oriented policies, the national innovation system approach and systemic perspectives were considered in the study of Edler and Fagerberg (2017).

These general policy classifications and policy tools were mainly explained with two perspectives as 'market-failure' and 'system-failure'. The market-failure approach was put forward by Arrow (1962). Based on a firm's characteristics, Arrow (1962) assumed that the most important source of innovation was the creation of new knowledge. However, given that the commercialization of basic research needed more time and was highly uncertain, high R&D expenditures could not be afforded by private firms. The firms also could not claim their intellectual property rights. All these factors forced governments to take some responsibility for innovation by funding public research bodies, incentivizing firms, and strengthening the intellectual property rights regime. Martin and Scott (2000) narrated this issue by citing Schumpeter's seminal works 'The Theory of Economic Development' and 'Capitalism, Socialism, and Democracy' with two main views on scale of the innovative firms. Due to the financial constraints, small and medium enterprises (SMEs) were not investing at such a desirable level as large firms.

This situation created a prima facie case in favor of public intervention to promote innovative activity. Competition policy, tax policy, subsidies, and actual R&D carried out by public research units were the policy tools for promoting innovation (Martin and Scott 2000). This could also be interpreted as 'market failure' given that there is justification for market interventions aimed at increasing investments for science in the economy (Fagerberg 2017). However, it may be noted that an important criticism of this perspective was its linear understanding. Edquist (2001) asserted that it was almost impossible to use an optimal equilibrium approach within innovation system theory, hence the market failure theory could not be used in this context.

By the end of the 1980s, Christopher Freeman made his contribution on the systemic perspective of innovation with his innovation system concept. According to Smith (2000), the underlying idea of Freeman could be traced back to List with its institutional aspect and Marx with its combination of a theory of technological change and a theory of development. Freeman examined the network relationship of the actors in the Japanese Innovation System, related to R&D development, knowledge transfers from abroad, and absorption capacity of the education system. Then, he defined the innovation system as "the network of institutions in the public and private sectors whose activities initiate, import, and diffuse new technologies" (Freeman 1987). Afterwards, Lundvall (1992) and Nelson (1993) studied the innovation system concept for setting the theoretical background. The authors focused on the system's efficiency rather than a firm's productivity, which was considered important for the linear approach. Nelson (1993) analyzed case studies to understand the convergence of indicators and suggested the importance of intellectual property rules as a pillar of innovation system. Lundvall (1992) probed the innovation system at two levels. One of them was economic and production structure and the other was the institutional configuration with their directly related R&D activities. However, because of the complex nature of the innovation system, there was not a consensus on the actors and their roles in the system. For instance, Edquist and Johnson (1997) generalize the concept with a broader inclusion of "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist 1999). Beyond all these discussions, it can be concluded that the systemic perspective leverages the innovation system from firm level to institution level for economic analysis (Metcalfe 1994). Therefore, studies and evaluations focused on learning, adaptation, coordination, and the knowledge flow structure of the institutions with an evolutionary theoretical perspective.

In addition to these focused subjects, the evolutionary theoretical perspective was differentiated by Smith (2000) from the traditional economic perspective not only through the equilibrium approach but also through mainstream industrial economics and organization theory. The system failure approach was revealed in this conceptual framework by Edquist (2001), who questioned whether the system was not functioning because of the inappropriate or missing functions, organizations, institutions, interactions, or links in the innovation system. However, again it was not the end of the discussion. According to Malerba (1997) and Smith (2000) the underlying idea of system failure came from failures in infrastructures, capabilities, institutions, and networks.

Smith (2000) listed other innovation systems approaches based on the history of technology (see also Hughes 1986), science and technology studies (see also Jasanoff et al. 2001), business organization studies and the theory of the firm (see also Chandler 2003), regulation school (see also Boyer 1990), and industrial cluster approaches (see also Porter 1998). All approaches took the systemic perspective from their study domains and tried to interpret innovation policy approach at the operational level.

It can be seen that the interest of economists in innovation studies mostly derives from their attempt to compose the market structure from linear to systemic and from traditional to evolutionary perspectives. These discussions have created significant improvements from the firm level to the government level strategy and policy developments.

There are some other perspectives and classifications in the literature. One of the most frequently used classifications comes from Ergas (1987). Taking the focus of policy is as a basis, two sorts of innovation systems are distinguished as mission- and diffusion-oriented. Based on Ergas' study, the mission-oriented systems are characterized by the centralization and the concentration of policy support on focused fields. On the other hand, the diffusion-oriented systems concentrate their policy efforts on increasing an economy's capacity to innovate by establishing scientific infrastructure, technology transfer, and formal/informal cooperation between actors. Cantner and Pyka (2001) approached this classification from the evolutionary perspective and asserted that diffusion-oriented policy with its clear focus on a target would sustain an appropriate degree of heterogeneity. Mission-oriented policy appeared to be in direct contrast with diffusion-oriented policy by favoring one specific development path as it might have a disadvantage for alternative technological trajectories. However, these assertions could be justified by the mission-oriented policy's potential to exploit cross-fertilization effects by bringing seemingly unrelated technologies together.

From the management perspective, Grant (1996) analyzed the knowledge-based theory from a firm's perspective. He stressed the role of common knowledge with the necessity for knowledge integration. Based on his research, common knowledge should be common to all organizational members so that this knowledge permits individuals to share and integrate aspects of knowledge that are not shared between them. Moreover, he implied that the primary task to accomplish for firms should be the coordination of knowledge integration and dealing with the complexity of tacit knowledge. Based on this perspective, it can be concluded that an effective and efficient knowledge coordination mechanism may be the facilitator of innovation. Another knowledge-based approach came from Foray (2004) who explored the economics of knowledge. Foray (2004) in his book focused on the emergence of knowledge and knowledge-based economy with a historical perspective, proposed a conceptual framework for considering the issues raised above. From this assumption, a networked society enabled by the ICTs may play a critical role for increasing the distribution and exchange channels of all types of information and knowledge.

The review undertaken so far has demonstrated the historical work, different perspectives as well as different classification efforts by major scholars in the field. Following this background, it is also important to have a brief discussion on the present state of innovation systems and policy approaches. In their recent work, Bleda and del Rio (2013) analyzed the market and system failure rationales in technological innovation systems with a micro, meso, and macro evolutionary framework. Within this framework, they discussed the issue from the following perspectives: (1) the dynamics of market formation, (2) coordination failures in evolutionary markets, (3) neoclassical market versus evolutionary markets in innovation, and (4) neoclassical market failure and the systemic failure rationales in innovation policy. They argued that both approaches are still used as theoretical justifications for government intervention. However, it can be seen that based on the applications, governments have been using both theoretical perspectives.

In another recent study, Fagerberg (2017) synthesized the systems of innovation with technological dynamics and policy. He proposed that the innovation system perspective would lead to a holistic perspective on policy and this 'holism' would be challenging for policymakers. This systemic perspective requires an interaction and collaboration of different domains, which complicates policy development. Fagerberg proposed that policy development might require the development of systemic instruments that facilitate the creation, adaptation, and coordination of policy for a successful application of the innovation system approach. In addition, Flanagan and Uyarra (2016) criticized the innovation policy process by stressing the sustainability of policy researchers' essential instrumental and critical roles in the longer term. From these findings, it can be highlighted that for policymakers, observing the system and considering it with a holistic perspective may need an innovative approach that is either theoretical or applied.

Along with economists, there are studies performed by scholars engaged in public administration. The science-policy gap, ideological bias, citizen participation in the scientific policy process, and the democratization of knowledge may be accepted as hot topics for this group. For instance, (Bhushan 2015) stressed the significance of the participation of scientists and engineers in the legislation process to influence and shape the R&D policy. He also proposed that scientists and engineers should learn about policy decision-making and funding issues by participating in the studies undertaken by federal agencies. Lejano and Dodge (2017)'s study was a good example of demonstrating the effects of political ideologies on technology policy decisions. They analyzed the narratives on climate policy in the US and found that ideologies were reflected partly in the narratives and might block the potential formation of coalitions and consensus opportunities.

A brief overview of scientific change and paradigm shift

Science and technology develop in an evolutionary fashion with theories, tools, and applications. Science philosophers study this evolutionary change using different philosophical perspectives. One of the most well-known theories of scientific change is Thomas Kuhn's scientific revolutions (Kuhn 1962). Kuhn considered scientific progress through a series of revolutions. In these revolutions, paradigms are replaced by new ones for a continuous adaptation. Kuhn uses paradigm as a broad concept covering all rules, methods, and consensus knowledge a group of scientists agrees upon, which is enough to use regularly within a discipline. According to Kuhn's structure of scientific revolutions, scientific advances in an iterative process, which consists of several stages: (1) pre-paradigmatic phase, (2) normal science, (3) crises, and (4) revolutions. The current paradigm dominating research in the field is considered to be at the normal science stage. According to Paker (2017), Kuhn distinguished normal science from revolutions and thought that scientists work to develop and deepen the paradigm by putting forward definitions and answering the outstanding questions. The use of tools and solving problems by using the current paradigm helps scientists feel comfortable during this period. However, anomalies are recognized and become inevitable and they challenge the foundation of the current paradigm at the crisis stage. At this stage, disagreements are revealed and questions arise concerning the current paradigm. At the revolutionary stage, compelling evidence is accumulated and competing paradigms become mature enough to take over the existing paradigm that has been evidently incapable of handling the pressing crises. As a result, a new paradigm replaces the existing one and provides an overarching framework for the research community. This process repeats itself as the new paradigm becomes the norm. From now on scientists take this new norm as normal science. Kuhn (1962) had criticized several aspects of relativism and incommensurability in the reviewed literature. He gave answers in his book for defending his hypothesis. Although some criticisms remain unaddressed, his ideas should not be expected to measure revolutions, disruptions, or emergences with a positivist approach because of the recognized nature of ambiguity and complexity.

Furthermore, in their study, Ankeny and Leonelli (2016) proposed a post-Kuhnian perspective on scientific change called “Repertoires”. They focused on the intensity of collaboration with the assertion that their approach permitted one to investigate the relationship between various components of scientific practice. With this perspective, they assumed that the concept would provide a framework that could facilitate a more comprehensive view of the drivers of scientific change (Ankeny and Leonelli 2016). The science mapping perspective is compatible with the collaboration focus of the authors for understanding the scientific change properly.

A scientometric application of Kuhnian paradigms was demonstrated by De Langhe (2017)’s study. De Langhe proposed a conceptualization of paradigms and their dynamics to test the existence of scientific revolutions by using agent-based modeling and scientometric data based on Kuhn’s paradigm. He assumed that the distribution of the community would change as α increases, where α represents an increase in specialization allowed by an increase in adoption. The number of paradigms would decrease as the incentive for exploitation (α) increases.

Fuchs (1993) challenges the Kuhnian paradigm shift model as an oversimplified view of a complex reality. Therefore, Fuchs (1993) proposed that the uncertainty of the task and mutual dependence are the two variables from which four types of scientific change can be derived. Task uncertainty refers to the level of uncertainty involved in the course of scientific inquiry. Task uncertainty is high in scientific frontiers where research is essentially exploratory in nature and there is a high amount of tacit knowledge involved. In contrast, the task uncertainty is low in areas where tasks are routinized. Mutual dependence refers to the social and organizational dependencies between scientists and their competing peers. A combination of high task uncertainty and high mutual dependence will lead to original scientific discoveries, whereas a combination of low task uncertainty and high mutual dependence will result in specialization in order to maintain the tension between scientists with high mutual dependence while they work on routinized research.

Roe (2017) advocates for a focus upon scientific collaboration with complex social interactions among individual scientists and the scientific community. Then she states that individuals would be motivated to adopt a more radical or innovative attitude when confronted by the striking similarities between model systems and a more robust understanding of specialized vocabulary. She states that communicating a radical idea to the scientific community was often a struggle that could greatly hinder scientific change. This situation initially could discourage radical thinkers from communicating to the scientific community. By using graph theory, it is assumed that one can find these radical clusters in the selected science domain. Another theory of the evolution of a scientific discipline is proposed by Shneider (2009). He posits that the evolution of a scientific discipline is divided into four stages: (1) the conceptualization stage; (2) the tool and instrument development; (3) the investigation of the research questions supported by the newly developed enabling techniques; and (4) transforming tacit knowledge into codified and routinized knowledge.

Various other approaches were proposed in the literature, but according to findings of Chen and Song (2017), the aforementioned three theories by Kuhn, Fuchs, and Roe are mostly representative and cover the major characteristics of the development of a scientific field. Moreover, Chen and Song (2017) elaborated upon these theories and demonstrated that all approaches had similarities. In the present study, Kuhn (1962)’s perspective is taken into consideration and the findings are explained by using his analogy. Even Kuhn’s concept was proposed for scientific change, in the present study, we use it for understanding social science paradigm shifts. We understand social science as a scientific field and innovation as one of its branches. Fagerberg and Verspagen (2009) discussed whether innovation is a scientific field or not. They concluded that innovation is a cross-disciplinary and thematically oriented scientific field.

In this respect, Kuhn (1962) argues that development of science occurred in a cumulative manner. He introduced the ‘paradigm’ to explain the development of science. Here, the term paradigm is described as the formulation of a concept, the gathering of various facts, methods, assumptions, and theories to solve a research problem. Moreover paradigm is defined by Vanner and Martha (2013) as a term that has come to be applied loosely with a range of different meanings; it is synonymous and used interchangeably with belief, concept, theory, and even tradition, practice, or attitude. Therefore, we assume that innovation studies have been demonstrating these aspects of paradigm too.

From the social science perspective, Gutting (1980) states that Kuhn’s seminal work influenced four areas including (1) philosophy, (2) social science, (3) the humanities, and (4) the history of science. In the social sciences section of Gutting’s book, there are two essays that explore the relevance of Kuhn’s views for sociology, as well as views that apply to economics and political theory. King’s essay argues that the earlier works of Kuhn are more helpful for analyzing the sociology than his later works, though the former do not provide a complete sociological theory of scientific change.

Furthermore, According to Rees (2012), a paradigm shift is fundamentally not a scientific but a philosophical change, because the incommensurability of paradigms means that there is no external stance from which one can be shown to be superior to another. Particularly for social sciences, he asserted that “Despite these criticisms, many social scientists embraced—or perhaps appropriated—Kuhn’s thesis. It enabled them to elevate the status of their work. The social sciences could never hope to meet the high standards of empirical experimentation and verifiability that the influential school of thought called positivism demanded of the sciences. However, Kuhn proposed a different standard, by which science is actually defined by a shared commitment among scientists to a paradigm wherein they refine and apply their theories. Although Kuhn himself denied the social sciences the status of paradigmatic science because of their lack of consensus on a dominant paradigm, social scientists argued that his thesis could still apply to each of those competing paradigms individually. This allowed social scientists to claim that their work was scientific in much the way Kuhn described physics to be.”

Polsby (1998)’s study may be a comprehensive example for explaining social science and scientific change by considering Kuhn’s contribution. Polsby believed that social science seemed quite helpful and more viable than hard sciences when considering Kuhn’s account of conflict-ridden scientific revolutions. For instance, Burns et al. (2018) traced paradigm shift in Game theory by exploring the sociological roots of it. Also, Hall (1993)’s study on policy paradigms encourage us to think policy procedure from a paradigmatic perspective as well.

Starting with a question “is there a paradigm change in innovation policy?”, the present study aims to start a creative discourse to indicate that transformations in the society, technology, economy and policy affect both supply and demand sides of innovation, which can be considered as a call for an evolution in the innovation policy domain. This discourse is represented with Kuhn’s “crisis stage”. In our work the crisis stage by no means represents a “deadlock” in the innovation policy domain. Instead, the term ‘crisis’ is used to point out new attempts to address the emerging issues due to wide-ranging transformations. It is believed that there are no clear cut shifts between different phases of the evolution, such as the continuation of normal science during the crisis stage. However, it is asserted that in the crisis stage there is a new quest in innovation policy by adapting, re-framing or re-constructing the scope of the domain.

Methodology

Exploring scientific changes and paradigm shifts in a scientific discipline is a challenging task for researchers. One of the most commonly used methodologies for understanding the evolution of theoretical domains is science mapping. Small (1999) defined science mapping as a spatial representation of how disciplines, fields, specialties, and individual documents or authors are related to one another. The focus of these studies is monitoring a academic domain and delimiting the research areas in order to determine its cognitive structure and its evolution in a determined timeframe (Cobo et al. 2011). According to Klavans and Boyack (2017), efforts on understanding the progress and evolution of science and technology and using this understanding for preparing research policy could be traced back to Price (1965)'s landmark article "Networks of Scientific Papers". Since then, the past 50 years have seen a number of studies aimed at delineating the topography of the literature and understanding that science requires effective science mapping, which is a generic process of analysis and visualization. According to Noyons and Van Raan (1998), mapping is a way to monitor the production of researchers in a particular scientific domain and a science map is two or three-dimensional representation of this domain (Noyons 2001).

Generally, science mapping is performed with following steps: (1) data retrieval, (2) preprocessing, (3) normalization, (4) network extraction, (5) mapping, (6) analysis and visualization, and (7) the interpretation of the findings, which is an expert dependent process.

Data retrieval requires a lexical search query strategy for acquiring a focused data corpus. There are different approaches for lexical search queries such as selecting journals, scientific/research categories, or using keywords. Common sources of scientific literature are Web of Science (WoS), Scopus, Google Scholar, and PubMed. Mongeon and Paul-Hus (2016) compared WoS and Scopus based upon journal coverage and found that for comparative research evaluation, WoS and Scopus should be carefully used due to their biases. Moreover, they did not conclude that one database was superior to the other in terms of journal coverage. However, retrieved data should be handled carefully before starting a comparative analysis. Hence, in the second step, data preprocessing is applied, where duplicates and irrelevant files are removed.

The third step is about normalization. For the purpose of normalization, there are similarity measures in the literature and these measures can be classified into two fundamental approaches, direct and indirect. A detailed comparative review can be found on similarity measures in van Eck and Waltman (2009). Direct approaches were defined as determining the similarity between two objects by taking the number of co-occurrences of the objects and adjusting this number for the total number of co-occurrences of each of the objects. There are different similarity measures in the literature but the most popular ones are the cosine (Salton 1963; Salton and McGill 1983) and Jaccard index (Small 1973; Small and Greenlee 1980). The mathematical expressions of the common direct similarity measures are:

$$S_A\left(c_{ij}, s_i, s_j\right) = \frac{c_{ij}}{s_i s_j} \tag{1}$$

$$S_A\left(c_{ij}, s_i, s_j\right) = \frac{c_{ij}}{\sqrt{s_i s_j}} \tag{2}$$

$$S_A\left(c_{ij}, s_i, s_j\right) = \frac{c_{ij}}{\min\left(s_i, s_j\right)} \tag{3}$$

$$S_A\left(c_{ij}, s_i, s_j\right) = \frac{c_{ij}}{s_i + s_j - c_{ij}} \tag{4}$$

where $S_A\left(c_{ij}, s_i, s_j\right)$ is a function of the direct similarity measure, $c_{ij} = \sum_{k=1}^{m} o_{ki} o_{kj}$ (let o_{ki} denote the element in the kth row and ith column of occurrence matrix of $\mathbf{O}$ (mxn) and o_{ki} equals one if object i occurs in the document that corresponds with the kth row of $\mathbf{O}$, and it equals zero if otherwise) denotes the element of the co-occurrence matrix and let s_i denote either the total number of occurrences of object i or the total number of co-occurrences of object i. These measures are referred to as association strength (Van Eck and Waltman 2007) with Eq. (1), the cosine with Eq. (2), the inclusion index (Jones and Furnas 1987; Rorvig 1999) with Eq. (3), and the Jaccard Index with Eq. (4). Based on van Eck and Waltman (2009)'s findings, the issue of choosing an appropriate similarity measure is not only of theoretical interest but also has a highly practical relevance and they asserted that for the terms with limited number of occurrences, probabilistic similarity measures such as association strength performed better.

After normalization, clusters should be prepared based on these similarity measures and for naming these clusters, term selection approaches should be applied. For term selection, there are different approaches in the literature. One of these approaches is Salton and McGill (1983)'s proposal of tf–idf index (term frequency–inverse document frequency). They suggested that the most frequently and least frequently occurring words can be less significant than words with a moderate frequency. Based on this definition, it can be asserted that a weight which increases with the frequency of the term i, but decreases as the term occurs in more documents (k) in the set (of n documents). The tf–idf can be expressed as Eq. (5).

$$\text{tf–idf}_{ik} = \text{FREQ}_{ik} x \left[\log_2\left(\frac{n}{\text{DOCFREQ}_k}\right)\right] \tag{5}$$

During the analysis stage, an evolutionary analysis is performed frequently with a retrospective perspective by using varieties of co-citation analysis and co-word analyses. Cited reference is one of the most frequently used inputs in science mapping. There are three elements in citation to define a relationship, including (1) cited publication, (2) cited journal, and (3) cited author. Furthermore, a relationship between publications may be defined either by their direct citation relationship or by the co-citation relationship. If citers cite the same publication, this is called a bibliographic coupling. Co-citation techniques were developed in the seventies by several scholars in the literature (Garfield et al. 1978; Small 1973; Small and Griffith 1974; Griffith 1974 #1207). According to Noyons (2001) co-citation analysis was used as a policy support tool in the eighties. Noyons (2001) asserted that co-word techniques were also developed for policy purposes. Hicks (1987) criticized and Smith (1981) questioned the use of co-citation with this perspective when applying the findings to science policy development.

Despite these criticisms, mapping studies have been applied more often due to the increasing accessibility of data and improved computation capacity. Gmur (2003) tested co-citation analysis for determining the appropriate clustering techniques for references and found that the choice of the methods had a strong effect upon the results.

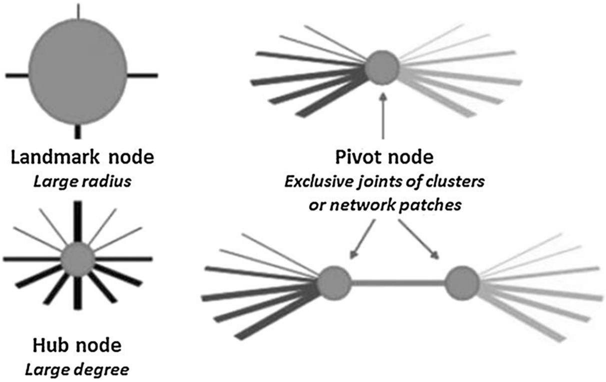

Fig. 1 Three types of nodes in visuals (Chen 2004)

Then Boyack and Klavans (2010) tested different citation models and proposed a full co-citation analysis instead of co-citation clustering by using internal and external linkages. Based upon their findings, among the purely citation-based approaches, a field of research was most accurately represented on a large scale by bibliographic coupling and adding textual information to the citation information as part of bibliographic coupling. The aforementioned co-word analysis is defined by He (1999) as a content analysis technique that uses the co-occurrence patterns of pairs of items (i.e., words or phrases) in a corpus of texts to identify the relationships between ideas within the subject areas presented in these texts. Indexes based upon the co-occurrence frequency of items, such as an inclusion index and a proximity index, are used to measure the strength of relationships between items. Using these indexes, items are clustered into groups and displayed in network maps. The co-word analysis technique has been most commonly used in mapping or tracing patterns and trends in term associatedness. The source words can come from keyword lists, titles, abstracts, or other publication data fields.

In the next stage, these analyses are visualized using graphs, networks, hierarchies, trees, temporal structures, geospatial visualizations, or an integrated view of multiple types of visualizations. At the visualization stage, it is important to interpret the visuals and especially the nodes correctly. According to Chen (2004), three types of nodes should be identified in a co-citation network: (1) landmark, (2) hub, and (3) pivot nodes, as demonstrated in Fig. 1.

As can be seen in Fig. 1, a landmark node has a large radius, which means that this article has been cited often by other articles. Hence, the landmark is considered an important milestone in a research field. A hub node has a relatively large degree, which means it is widely co-cited by a large number of other articles and has made great contributions to an academic field. Pivot nodes are exclusive joints between two different clusters or the gateway of two clusters, representing a turning point for two groups of articles, which may have different topics. A pivot node can be interpreted as a particular article, which has made an important contribution to the subjects addressed in two clusters.

The present study made use of Chen et al. (2008)'s methodology across nine steps:

1. The identification of the knowledge domain: The domain was identified by employing the most frequently used keywords proposed by Edler and Fagerberg (2017): "technol-

ogy policy", "innovation policy" and "science policy". "Research policy" and "R&D Management" were not used because these phrases are also the names of specific journals and generate more irrelevant data. Keywords were searched in Topic (TS) field in the WoS database

2. Data Collection: Data is collected from WoS only because of the aforementioned issues regarding databases
3. Term extraction: Terms were extracted from titles, abstracts, and keywords
4. Time-Slicing: One-year range is specified as the length of a single time slice to easily identify the transitions in a selected time interval
5. Threshold Selection: Most cited 5% of the papers were selected as the threshold for each slice. It is thought that this selection helps to reduce noise
6. Pruning and Merging: Pathfinder network scaling was applied and the slices were merged
7. Layout: cluster graph and time-zone views were performed to demonstrate the conceptual evolution in a timely manner.
8. Visual Inspection: Visualizations were enhanced by using the options such as adjusting cluster names, nodes, etc.
9. Verify Pivotal Points: The pivotal points were described by publications with high centrality. For each cluster, these pivotal points were reviewed and discussed with field experts. In the present study, Kuhn's stages were distinguished by using an expert-based qualitative approach. It is known that Langhe (2017) prepared an agent-based model in latest publication by considering pattern emergence and distinguish trends based on trend observation. The present study differs from Langhe (2017)'s study with reverse approach, but complements his approach and verifies it from a different angle. The study first extracts emerging concepts by using scientometrics approach and then interprets them qualitatively by considering the burst scores of papers. High burst scores are assumed as emerging papers in the examined period.

Analysis and findings

A number of free and commercial software tools are available to carry out the mapping study. Each has its strengths and weaknesses based on different characteristics to carry out science mapping analysis. Cobo et al. (2011)'s study can be reviewed for further comparative information about these tools. Among those, the present study used Citespace II (Chen 2006) software, which takes a set of bibliographic records as its input and models the intellectual structure of the underlying domain in terms of a synthesized network based upon a time series of networks derived from each year's publications. As CiteSpace is easy to use and has some favorable features like author co-citation analysis, it was chosen for the purpose of the present study.

As mentioned in the methodology section, in the first step the domain is determined by using the keywords "innovation policy", "science policy", and "technology policy". The combined use of these terms is based on the research and findings of Edler and Fagerberg (2017), who built upon the work done by Martin (2012). When retrieving policy-related papers, Martin (2012) used the terms 'science policy', 'research policy' (terms that are still in use, although they are generally now seen as covering only part of SPIS field); 'technology policy' (where similar comments apply); and more recently 'innovation policy', which have been used interchangeably in chronological order.

These phrases were searched in the TS field of the WoS database. Data retrieved as a result of the search process contained 7082 records published during the years 1940–2017. These records collectively include 176,116 references. With the help of the document co-citation analysis function in CiteSpace, networks of cited references and authors were generated respectively. CiteSpace uses a time slicing technique to build a time series of network models over time and synthesizes these individual networks to form an overview of the network, which provides a systematic review of the relevant literature. The synthesized network is divided into co-citation clusters of references. Citers to these references are considered the research fronts associated with these clusters. Each cluster represents the intellectual base of the underlying specialty.

As proposed by Chen and Song (2017), clusters were considered the embodiment of an underlying specialty. Therefore, all clusters represented various aspects of the analyzed domain. Cluster members were scrutinized in each cluster by identifying structural and temporal metrics of research impact and evolutionary significance. Betweenness centrality is used for identifying boundary spanning potential based upon the score. It was assumed that the nodes with the highest betweenness centrality scores may lead to transformative discoveries. Moreover, burst detection is also used to identify abrupt changes in events and other types of information. In CiteSpace, the sigma score of a node is a combinant metric of the betweenness centrality and the citation burstness of the node, i.e., the cited references. CiteSpace represents the strength of these metrics through the design of visual encoding, so that the articles that are salient in terms of these metrics will be easy to detect in the visualizations. The nature of cluster is identified by the following aspects: (1) a hierarchy of key terms in the articles that cite the cluster, (2) the prominent members of the cluster as the intellectual milestones in its evolution and as the intellectual base of specialty, and (3) recurring themes in the citing articles to the cluster to reflect the relationship between the intellectual base and the research fronts. The aim is to understand the indicators of the evolutionary stages of a specialty as a concept, research tool, or application.

For clustering, co-citation analysis was applied by using cosine similarity measures. The cluster-view graph was generated based on publications between 1940 and 2017 (Fig. 2). The top 5% of the most cited publications in each year are used to construct a network of references cited in that year. The final network contains 17 co-citation clusters. These clusters are labeled by index terms from their own citers with red tags.

The network presented in Fig. 2 has a modularity of 0.8686, which is considered very high. This suggests that the specialties in innovation policy are clearly defined in terms of co-citation clusters. The average silhouette score of 0.28 is relatively low mainly due to the numerous small clusters. The major clusters that are focused on in the review are considered sufficient from the point of view of analysts.

The areas in different colors indicate the time when co-citation links in those areas appeared for the first time. Clusters are numbered beginning from #0. The names of the clusters were extracted from highly centralized documents in the network. These documents will be reviewed when describing the clusters. Beyond the name of these clusters, the figure can be interpreted using a reductionist approach that innovation policy studies have two main theoretical backgrounds based on the actors in the reviewed literature. One such theoretical background is economics and the other is public policy. Moreover, sustainability finds an application base in the public policy domain. Foresight and open innovation studies seem in-between as expected.

After demonstrating the timeline view of these clusters, seven major clusters were explained in detail. The visualization of timelines in CiteSpace depicts clusters along

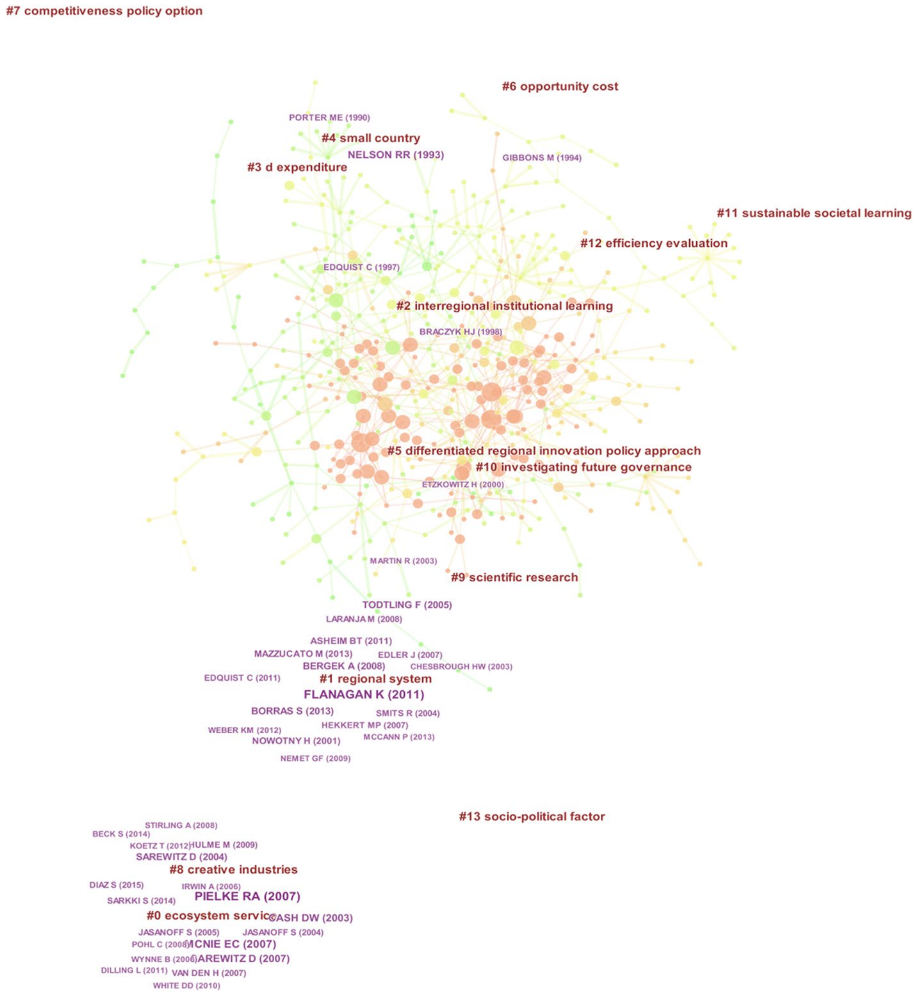

Fig. 2 Cluster view of the innovation policy network (LRF = 2, LBY = 8 and $e = 2.0$)

horizontal timelines. Each cluster is displayed from left to right. The timescale showing the date of publication is given at top of the figure. The clusters are arranged vertically in the descending order of their size, where the largest cluster is shown at the top of the figure. The colored curves represent co-citation links added in the year of the corresponding color. Large-sized nodes or nodes with red tree rings are of particular interest because they are either highly cited or have citation bursts or both. Below in each timeline the three most cited references in a particular year are displayed. The label of the most cited reference is placed in the lowest position. References published in the same year are positioned in such a way that the less cited references are shifted to the left. The new version of CiteSpace supports a function to generate labels for a cluster year by year based upon the terms identified by Latent Semantic Indexing. The year-by-year labels can be displayed in a table or

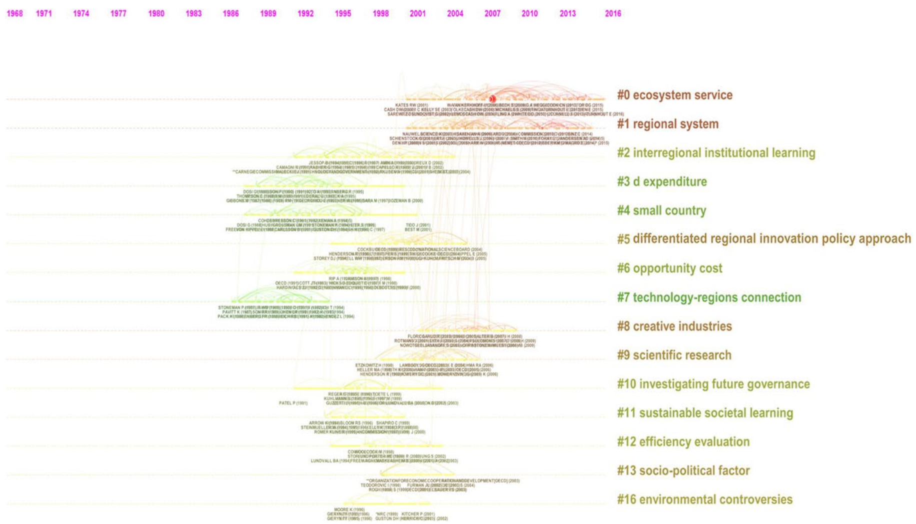

Fig. 3 Timeline view of innovation policy network (LRF = 2, LBY = 8 and $e = 2.0$)

above the corresponding timeline. The eventual timeline view of the clusters is shown in Fig. 3.

When the figure is examined, it can be seen that clusters #0 (Ecosystem service), and #1 (regional system) have the closest citation years and can be interpreted as emerging topics for the innovation policy domain.

Cluster #0 is the largest cluster, which has 72 members with a silhouette value of 0.926. It is labeled as *ecosystem service* by Log-likelihood Ratio (LLR) and *Policy* by tf–idf. The mean citation year of this cluster is 2008. Therefore, this cluster is considered to represent current discussions. Citespace listed highly central documents in the cluster and yielded 30 documents in cluster #0. Six of these documents contain a similar phrase, "ecosystem service", the title of this cluster. When all documents are analyzed, it can be seen that Hegger et al. (2012)'s study has the highest centrality score (0.11). In this study, Hegger et al. (2012) conceptualize the joint knowledge production in regional climate change adaptation projects and propose a policy framework by portraying joint knowledge production projects as policy arrangements in which the degree of success would depend upon the actors involved. The second highest score (0.08) is given to Schut et al. (2014)'s study, in which they focused on competing claims on natural resources and their management by understanding the complex dynamics and proposed a five-step strategy. Together with the environmental studies, Veld (2010)'s study is noteworthy. In this study, there is a new understanding of the knowledge economy based upon a discussion on political governance and the importance of knowledge democracy. Veld (2010) discusses the rise of media-politics as a threat to democracy. Another interesting study in the same cluster is by Turnhout et al. (2013). They discuss new roles for scientists in knowledge brokering and conclude that the new roles of science might strengthen traditional disciplinary scientific ideals (Turnhout et al. 2013). Overall, this cluster emphasizes the relationships between sustainability, environmental concerns, and knowledge democracy with an increasing need for scientists to perform new roles as knowledge brokers considered through a systemic perspective. The discussions in this cluster imply that we are at a crisis stage regarding global environmental issues, which need to be handled with a new understanding. Other studies in the cluster are listed in the "Appendix".

The second cluster is cluster #1, which has 59 members and a silhouette value of 0.905. It is labeled *regional systems* by LLR, *innovation* by tf–idf. The mean citation year of this cluster is 2007 and this cluster may be considered as contemporary as the first cluster. There are 27 highly central documents in this cluster and only two of them include the "regional systems" phrase. Within the cluster, Weber and Rohracher (2012)'s study has the highest score of centrality (0.12). They highlighted the rising concerns about societal challenges in innovation policy rather than economic growth objectives and proposed a comprehensive framework to allow policies in a transformative environment by combining market failures, structural system failures, and transformational system failures. The second highest score of centrality (0.10) is given to Uyarra and Flanagan (2010)'s study, where they asserted some dangers concerning the use of regional systems of innovation as a normative concept by illustrating these issues in northwestern region of England. The third one is Kern (2012)'s study which involves a multi-level perspective to describe and analyze the complex and long-term processes. The list of the other studies involved in this cluster is given in "Appendix".

The third cluster (#2) is labelled *interregional institutional learning* by LLR and *innovation policy* by tf–idf, has 48 members, and a silhouette value of 0.917. The mean citation year of this cluster is 1997. There are two highly central documents in this cluster. Hassink and Lagendijk (2001)'s study has the highest score of centrality (0.31). They highlighted the nature and role of the learning processes between regions and proposed a model of the knowledge cycle. Through the model, they tried to help translating regional experiences into more general analytical concepts and policy prescriptions.

The fourth cluster (#3), labeled *r-d expenditure* by LLR, *japan* by tf–idf, has 46 members and a silhouette value of 0.969. The mean citation year of this cluster is 1992. There are four highly central documents in this cluster. (Sternberg 1996a, b)'s comparative studies have the two highest scores of centrality (0.24, 0.17). These studies empirically analyze the R&D expenditure trends of industrialized countries and the relationship between technology policies and the growth of regions. Davenport and Bibby (1999)'s study is interesting in this cluster with its 'small country as SME' metaphor. They emphasized that this metaphor would emphasizes the role of culture and society as a national specialty in an innovation system (Davenport and Bibby 1999). With these comparative studies and different analogies, this period may be interpreted as normal science.

The fifth cluster (#4) is labeled *small country* by LLR, *technology policy* by tf–idf. The cluster has 46 members and a silhouette value of 0.93. The mean citation year of this cluster is 1992. There are nine highly central documents in the cluster. Kaplan (1999) has the highest score of centrality in this cluster (0.13). Kaplan (1999)'s study reviews South African technology policies with the aim of analyzing the effects of the evolutionary perspective on the policy choices. This cluster also includes Metcalfe (1994)'s seminal work on evolutionary economics and technology policy; Lundvall (2001)'s study on innovation policy in the globalizing learning economy; and Sanz Menendez et al. (2000)'s study regarding the use of Foresight in science and technology policy. This period may be considered a 'pre-paradigmatic' phase, where innovation policy issues were considered with a shift from linear to systemic or traditional to evolutionary ways in a transitional manner. Studies conceptualized these issues in a comparative way.

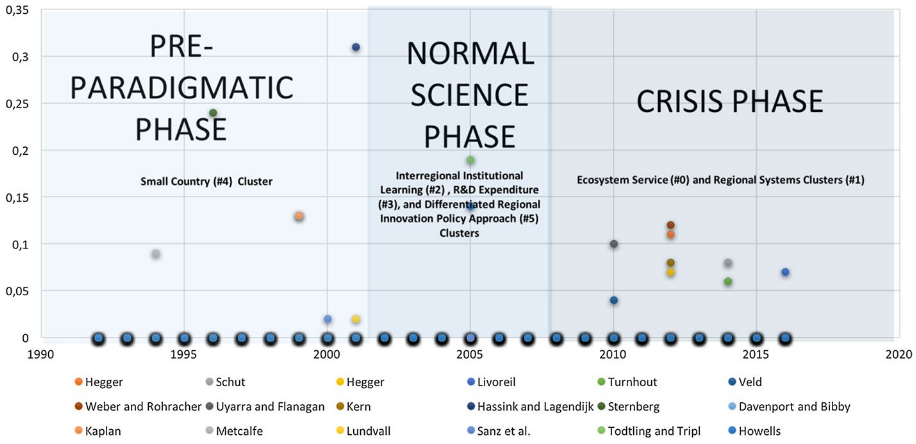

Fig. 4 Phase transition for innovation policy studies

Finally, labeled *differentiated regional innovation policy approach* by LLR, *innovation* by tf–idf, the sixth cluster (#5) has 43 members and a silhouette value of 0.867. The mean citation year of this cluster is 2000. There are seven highly central documents in the cluster. Todtling and Trippl (2005)'s study has the highest centrality score (0.19) in this cluster. They discussed the transition of innovation studies to regional policy and refuted the claim that there was an 'ideal model' concept for innovation policy development. Another study by Howells (2005) also focused on regional economic development. Other studies listed below may be accepted as an extension for a more localized version of national innovation systems. From these studies in sixth cluster it may be said that the national innovation system concept was explained by the regional systems approach. This cluster may be considered part of normal science.

Discussion and conclusion

Scientific change is a challenging task for researchers, because of the complex nature of scientific domains. Several paradigm shifts have been observed through the evolution of the innovation policy domain. So far, our analysis has indicated that three such shifts can be distinguished (Fig. 4). Although it is hard to distinguish transitions between different phases easily, especially for social science domains, some clear changes are evident between the pre-paradigmatic, normal science, and crisis phase. Our study has described the transition in innovation policy domain by applying co-citation analysis with an evolutionary perspective. The interdisciplinary characteristics of innovation policy make this evaluation process even harder for experts because of the interactions between different domains and concepts. After analyzing the largest six clusters in detail, the findings may be summarized based on mean citation years and qualitative assessments of the articles with an inferential perspective as in Fig. 4.

Based upon the findings of co-citation analysis and the interpretations of the high-central papers, the timeline is divided into three phases. The figure uses different shades of the same color to show the nebulous borders surrounding the phases due to the transitional nature of scientific evolution as there is no clear cut shifts from one phase to another. The small country cluster is interpreted as the pre-paradigmatic phase, because the studies here were understood as conceptualizing the paradigm by using analogies. In this stage, analogies were made about small states as SMEs. The normal science phase may include Interregional Institutional learning, R&D expenditure, and Innovation Policy Approach clusters, because of the applications of the paradigm to different fields for testing. However, this should not suggest that after 2008 there was no normal science uses. The cut-off values between phases are not clear, only hypothetical. The ecosystem service and regional systems clusters are included in the crisis phase. Increasing data and computational capability forces scholars to grapple with the systemic perspective by using big data and network perspectives as well as finding new ways to explain the evolutionary paradigm in complex systems. Especially in the environmental perspective, biodiversity and sustainability studies were undertaken in this cluster and the discussion was concentrated upon preparing policy models for these topics. A significant issue in this cluster was the discussion on knowledge democracy with high centrality. Considering the transformations pushing society towards a more networked structure, codifying and disseminating knowledge may evolve in a more participative and inclusive manner.

Building upon this background, this paper has demonstrated that at the present time there are evidences of a new paradigm change. The signals of this shift can be observed through the introduction of concepts such as responsible innovation, innovation for wellbeing, ideology-free policy processes, governmentrepreneurship, and evidence-based policy making. Furthermore, novel concepts are also observed in broader socio-economic contexts of innovation domain such as the emergence of collaborative consumption and the sharing economy. It is anticipated that these transformations will lead to a more de-centralized and distributed innovation policy-making structure for a network society, and thus a paradigm shift in innovation policy. These perspectives may lead to more democratic and participatory policy models. For future studies, the applicability of de-centralized and distributed perspectives on innovation policy development can be considered as an important area of research. Moreover, following the rapid progress in information and communication technologies, analogy-based creative thinking may be applied to create new physical or virtual platforms.

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Appendix

See Table 1.

Table 1 Members of CLUSTERS (centrality > 0)

CLUSTER #0

1. 0.11 Hegger, D (2012) conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action
2. 0.08 Schut, M (2014) towards dynamic research configurations: a framework for reflection on the contribution of research to policy and innovation processes
3. 0.07 Hegger, D (2012) towards successful joint knowledge production for global change and sustainability: lessons from six Dutch adaptation projects
4. 0.07 Livoreil, B (2016) biodiversity knowledge synthesis at the european scale: actors and steps
5. 0.06 Kowalczewska, K (2012) the usability of scenario studies: the case of the eururalis from the users' perspective
6. 0.06 Meyer, R (2011) the public values failures of climate science in the US
7. 0.06 Munoz-Erickson, TA (2014) co-production of knowledge-action systems in urban sustainable governance: the kasa approach
8. 0.06 Nesshover, C (2016) challenges and solutions for networking knowledge holders and better informing decision-making on biodiversity and ecosystem services
9. 0.06 Nesshover, C (2016) the network of knowledge approach: improving the science and society dialogue on biodiversity and ecosystem services in Europe
10. 0.06 Nursey-Bray, MJ (2014) science into policy? discourse, coastal management and knowledge
11. 0.06 Pregernig, M (2014) framings of science-policy interactions and their discursive and institutional effects: examples from conservation and environmental policy
12. 0.06 Stenseke, M (2016) the intergovernmental science-policy platform on biodiversity and ecosystem services and the challenge of integrating social sciences and humanities
13. 0.06 Turnhout, E (2014) 'measurementality' in biodiversity governance: knowledge, transparency, and the intergovernmental science-policy platform on biodiversity and ecosystem services (IPBES)
14. 0.06 Wesselink, A (2013) technical knowledge, discursive spaces and politics at the science-policy interface
15. 0.06 Young, JC (2014) improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another
16. 0.04 Bonie, M (2015) framing global biodiversity: ipbes between mother earth and ecosystem services
17. 0.04 Goldberger, JR (2008) non-governmental organizations, strategic bridge building, and the "scientization" of organic agriculture in kenya
18. 0.04 Morin, JF (2017) boundary organizations in regime complexes: a social network profile of IPBES
19. 0.04 Veld, RJI (2010) towards knowledge democracy
20. 0.04 Waylen, KA (2014) expectations and experiences of diverse forms of knowledge use: the case of the uk national ecosystem assessment
21. 0.03 Giebels, D (2013) ecosystem-based management in the wadden sea: principles for the governance of knowledge
22. 0.03 Giebels, D (2015) using knowledge in a complex decision-making process—evidence and principles from the danish houting project's ecosystem-based management approach
23. 0.03 Hauck, J (2014) transdisciplinary enrichment of a linear research process: experiences gathered from a research project supporting the European biodiversity strategy to 2020

24 .0.03 Kowarsch, M (2016) an evaluation of the IPCC WG iii assessments

25. 0.03 Seijger, C (2013) understanding interactive knowledge development in coastal projects
26. 0.03 Turnhout, E (2013) new roles of science in society: different repertoires of knowledge brokering

Table 1 (continued)

27. 0.03 Wyborn, C (2015) connectivity conservation: boundary objects, science narratives and the co-production of science and practice
28. 0.01 Gorg, C (2016) governance options for science-policy interfaces on biodiversity and ecosystem services: comparing a network versus a platform approach
29. 0.01 Pellizzoni, L (2010) risk and responsibility in a manufactured world
30. 0.01 Sarkki, S (2014) balancing credibility, relevance and legitimacy: a critical assessment of trade-offs in science-policy interfaces

CLUSTER #1

1. 0.12 Weber, KM (2012) legitimizing research, technology and innovation policies for transformative change combining insights from innovation systems and multi-level perspective in a comprehensive ‘failures’ framework
2. 0.1 Uyarra, E (2010) from regional systems of innovation to regions as innovation policy spaces
3. 0.08 Kern, F (2012) using the multi-level perspective on socio-technical transitions to assess innovation policy
4. 0.08 Niosi, J (2010) building national and regional innovation systems: institutions for economic development
5. 0.08 Uyarra, E (2010) what is evolutionary about ‘regional systems of innovation’? implications for regional policy
6. 0.07 Cagnin, C (2012) orienting european innovation systems towards grand challenges and the roles that fta can play
7. 0.07 Kasa, S (2010) navigation in new terrain with familiar maps: masterminding sociospatial equality through resource-oriented innovation policy
8. 0.07 Koschatzky, K (2010) a new challenge for regional policy-making in Europe? chances and risks of the merger between cohesion and innovation policy
9. 0.05 Brown, R (2014) inside the high-tech black box: a critique of technology entrepreneurship policy
10. 0.05 Herstad, SJ (2010) national innovation policy and global open innovation: exploring balances, tradeoffs and complementarities
11. 0.05 Huggins, R (2010) regional competitive intelligence: benchmarking and policy-making
12. 0.05 Liagouras, G (2010) what can we learn from the failures of technology and innovation policies in the European periphery?
13. 0.05 Manjon, JVG (2012) innovation systems and policy design: the european experience
14. 0.05 Matti, C (2017) multi level policy mixes and industry emergence: the case of wind energy in Spain
15. 0.05 Pinto, H (2010) knowledge production in european regions: the impact of regional strategies and regionalization on innovation
16. 0.05 Wang, Y (2012) exploring the impact of open innovation on national systems of innovation—a theoretical analysis
17. 0.05 Weber, KM (2017) moving innovation systems research to the next level: towards an integrative agenda
18. 0.05 Wesseling, JH (2016) explaining variance in national electric vehicle policies
19. 0.03 Breznitz, D (2010) the limits of capital: transcending the public financer-private producer split in industrial R&D
20. 0.03 Inkinen, T (2010) intermediaries in regional innovation systems: high-technology enterprise survey from northern Finland
21. 0.03 Kivimaa, P (2006) the challenge of greening technologies—environmental policy integration in finnish technology policies

Table 1 (continued)

22. 0.02 Ahlqvist, T (2012) innovation policy roadmapping as a systemic instrument for forward-looking policy design
23. 0.02 Kuhlmann, S (2003) changing governance in European research and technology policy—possible trajectories and the European research area
24. 0.02 Kuhlmann, S (2003) scenarios of technology and innovation policies in Europe: investigating future governance
25. 0.02 Radaelli, CA (2012) the eu's Lisbon strategy evaluating success, understanding failure foreword
26. 0.02 Sharif, N (2010) rhetoric of innovation policy making in Hong Kong using the innovation systems conceptual approach
27. 0.02 Steward, F (2012) transformative innovation policy to meet the challenge of climate change: sociotechnical networks aligned with consumption and end-use as new transition arenas for a low-carbon society or green economy

CLUSTER #2

1. 0.31 Hassink, R (2001) the dilemmas of interregional institutional learning
2. 0.31 Hassink, R (2001) towards regionally embedded innovation support systems in south Korea? Case studies from Kyongbuk-Taegu and Kyonggi

CLUSTER #3

1. 0.24 Sternberg, RG (1996) government R&D expenditure and space: empirical evidence from five industrialized countries
2. 0.17 Sternberg, R (1996) technology policies and the growth of regions: evidence from four countries
3. 0.09 Lynn, LH (1998) the commercialization of the transistor radio in japan: the functioning of an innovation community
4. 0.02 Davenport, S (1999) rethinking a national innovation system: the small country as 'sme'

CLUSTER #4

1. 0.13 Davenport, S (1999) rethinking a national innovation system: the small country as 'sme'
2. 0.13 Kaplan, DE (1999) on the literature of the economics of technological change. Science and technology policy in South Africa
3. 0.09 METCALFE, JS (1994) evolutionary economics and technology policy
4. 0.09 Van der Meulen, B (1998) science policies as principal-agent games—institutionalization and path dependency in the relation between government and science
5. 0.07 Park, YT (1999) technology diffusion policy: a review and classification of policy practices
6. 0.02 DALPE, R (1994) effects of government procurement on industrial-innovation
7. 0.02 Lundvall, BA (2001) innovation policy in the globalizing learning economy
8. 0.02 METCALFE, JS (1995) technology systems and technology policy in an evolutionary framework
9. 0.02 Sanz Menendez, L (2000) foresight as a tool for science and technology policy

CLUSTER #5

1. 0.19 Todtling, F (2005) one size fits all? towards a differentiated regional innovation policy approach
2. 0.14 Howells, J (2005) innovation and regional economic development: a matter of perspective?
3. 0.14 Lehrer, M (2004) rethinking the public sector: idiosyncrasies of biotechnology commercialization as motors of national R&D reform in Germany and Japan
4. 0.09 Kaiser, R (2004) the reconfiguration of national innovation systems—the example of German biotechnology
5. 0.05 Koschatzky, K (2005) the regionalization of innovation policy: new options for regional change?
6. 0.05 Laranja, M (2008) policies for science, technology and innovation: translating rationales into regional policies in a multi-level setting
7. 0.05 Lehrer, M (2004) pushing scientists into the marketplace: promoting science entrepreneurship

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