Carayannis *et al. Journal of Innovation and Entrepreneurship* (2016) 5:17
DOI 10.1186/s13731-016-0045-9

Journal of Innovation and Entrepreneurship

RESEARCH Open Access

Mode 3 knowledge production: systems and systems theory, clusters and networks

Elias G. Carayannis[1*], David F. J. Campbell[2,3] and Scheherazade S. Rehman[4]

* Correspondence:
caraye@gwu.edu
[1]Department of Information Systems and Technology Management, George Washington University School of Business, Washington, DC 20052, USA
Full list of author information is available at the end of the article

Abstract

With the comprehensive term of "Mode 3," we want to draw a conceptual link between systems and systems theory and want to demonstrate further how this can be applied to knowledge in the next steps. Systems can be understood as being composed of "elements", which are tied together by a "self-rationale". For innovation, often innovation clusters and innovation networks are being regarded as important. By leveraging systems theory for innovation concepts, one can implement references between the elements of a system and clusters (innovation clusters) and the self-rationale of a system and that of networks (innovation networks). One advantage of this approach is that it makes the tools of systems theory effectively available for research on innovation. Based on original research about the European Union, also the concept of a multi-level hierarchy promises conceptual opportunities. Further integrating systems theory, we can speak of multi-level systems of knowledge (following different levels of aggregation) and multi-level systems of innovation (also following different levels of aggregation). The popular and powerful concept of the national innovation system is being chronically challenged by continuous and ongoing processes of supranational and global integration. Conceptually unlocking the national innovation systems in favor of a broader multi-level logic implies furthermore to accept the existence of national innovation systems but, at the same time, also to emphasize their global embeddedness. Our suggested catch-phrase of "Mode 3", therefore, integrates several considerations that want to relate systems theory, knowledge, and innovation more directly to each other, and this should be understood as a contribution to a dynamically evolving general discourse on the topics of knowledge and innovation.

Keywords: Clusters, Mode 3, Mode 3 knowledge production systems, Multi-level systems, Networks, Quadruple and quintuple helix innovation systems, Systems, Systems theory

Background: systems and systems theory, clusters and networks

Favoring a conceptual point of departure, the analysis is carried by three conceptual research questions. First of all, elaborate an interface between *concepts of systems* and *concepts of networks* (or innovation networks) by claiming analogies between (1) elements (parts) of a system *and* clusters and (2) and the self-rationale of a system *and* the networks. Just as the self-rationale holds together the elements of a system, a network ties together different clusters (an innovation network, thus, links different innovation clusters). Second, an application of systems theory is encouraged to the "world of knowledge," by speaking of knowledge systems. Following the logic of a

Springer Open

"multi-level" architecture, knowledge should be regarded as an aggregated concept; while innovation represents a highly aggregated term, S&T (science and technology) is already less aggregated, and R&D (research and experimental development) is even less aggregated than S&T. This implies using the concept of multi-level systems of knowledge or when an emphasis should be put on innovation, to apply the concept of multi-level systems of innovation. Through policy, the political system tries to influence the economy (economic system) and the other systems of a society. One can seriously discuss to which extent a *more narrow* economic policy is being replaced by a *broader* innovation policy. Third, the term "Mode 3" is being introduced, bridging systems theory and knowledge, thus emphasizing a knowledge systems perspective.

The article is structured into different sections. In the "Knowledge and systems and systems theory" section, we shortly refer to a first introduction and relation of "knowledge," "systems," and "systems theory," indicating opportunities of a mutual leveraging. The "What is a system?" section is devoted to a detailed discussion and review of systems theory. It focuses on how a system can be defined, referring to the concepts of "elements" and "self-rationale" of a system. Constructivist notions are emphasized, implying that social (societal) systems cannot be understood independently of an "observer," since they are not *naturally* predetermined but to a large extent "socially constructed". A further emphasis is placed on designing a conceptual bridge between the elements/self-rationale of a system and clusters/networks. Clusters and networks (and networks *of* clusters and networks) express a crucial relevance for knowledge and innovation. Through bridging elements/self-rationale and clusters/networks, the application of systems theory and systemic notions to knowledge gains additional plausibility. In the "Knowledge and knowledge systems" section, the application of systems and systems theory to knowledge and innovation is pursued in more concrete terms. Explicitly, the appropriateness of a "multi-level hierarchy" is being tested. The ramifications of such a multi-level design can either follow the logic of multi-level systems of knowledge or multi-level systems of innovation. In advanced policy terms, a political system—which operates for governing a society (and economy)—not only aims to influence the economy through economic policy but *also* through innovation policy, which reflects on the knowledge base of a society and economy. An economic policy, perhaps, does not take the knowledge base that comprehensively into account. In the context of the "Results and discussion: the knowledge systems perspective of "Mode 3"" section, under the umbrella term of "Mode 3," we again summarize our lines of arguments, by setting up a list of short propositions. In the final section (the "Conclusion: Mode 3 knowledge production in Quadruple and Quintuple Helix innovation systems" section), we explore how Mode 3 knowledge production systems relate to Quadruple and Quintuple Helix innovation systems.

Knowledge and systems and systems theory

Currently, a comprehensive spreading of an economic rationale is postulated. In that context, "markets" often are classified as an economic concept, integrating the principles of supply and demand. Furthermore, a tendency is manifested by increasingly applying the economic rationale (or rationales) to disciplines and fields lying outside of the traditional realm of economics (economy) and business. For example, explaining competition between parties based on references to "political markets" (Downs 1957) or to state another case: comprehensive evaluation exercises—such as evaluations of university research or of science and technology—are being compared by introducing the principles of a market logic to academia and thus creating academic markets (Campbell 2003, p. 109; Shapira and Kuhlmann 2003). The breakdown of East European and Soviet communism, after 1989, amplified a global proliferation of market economy and capitalism (Held et al. 1999, pp. 149–282; Yergin and Stanislaw 2002).[1]

In the "world of ideas" and concepts, however, one could propose that this dominating economic rationale is seriously challenged by the *concept or paradigm of systems* or systems theory. Perhaps, this suggests a complex conceptual relationship and interaction between the economic rationale (economics) and systems theory. This relationship could be understood not only competitively but also complimentarily, when the economic rationale and systems theory are being regarded as analytical tools that can be applied in parallel. An economic perception of market dynamics emphasizes processes of supply and demand; more specifically, modern business theories are inclined to broaden the "market-based view" with a "resource-based view," which underscores the importance of resources (including knowledge resources) for successful firm strategies in a market context (Güttel 2003, pp. 16–28, 69–83; see, for a general overview, also Barney 2002; Grant 2002; Pettigrew et al. 2002). The systems theoretical approach to markets may interpret the market as a system, operated by complex "feedback mechanisms" (coupling inputs and outputs), which, in an economic context, refer to the interaction of supply and demand. Such a *simultaneously binary economic and systemic coding of markets* might leverage important conceptual advantages. Therefore, an alternative hypothesis could stress benefits, should the supposed conceptual "economization" of the world be conceptually reframed as a spreading of systemic or systems theory notions. This points toward a polarizing question set: Economics (economic rationale) and/or systems (systems theory)? A conceptual reconciliation would propose for discussion the following equation: (economic) markets = a specific type of a system (?).

Knowledge represents an area where the application of systemic concepts (systems theory) promises particularly explanatory benefits. Modern and advanced societies and economies are being understood as knowledge-based. Knowledge is regarded as crucial for sustaining wealth and competitiveness. Global knowledge rankings of societies often correlate, at least to a certain extent, with wealth or competitiveness rankings (IMD 1996, p. 12, 2003a, b, 2004; and World Bank 2002). On the one hand, knowledge serves as an input or resource for advanced societies and economies, which increasingly depend on knowledge. On the other hand, knowledge production (knowledge creation) also generates knowledge as an output, which then is being fed back ("recycled") as a knowledge input. Mature knowledge production emphasizes high-quality knowledge, produced and used efficiently and effectively. Despite this importance of knowledge for economic performance, it is equally necessary to underscore that not all ramifications of knowledge are purely economically oriented. Non-economic aspects of knowledge stress that knowledge is crucial for enhancing a dynamic and high-quality democracy. Global freedom rankings of countries (democracies), as designed and measured by Freedom House (2003, 2004a, b), display a limited correlation tendency with knowledge rankings. This implies regarding knowledge as a key input that helps transform the quantitative spreading of market economies and democracies into economic and political systems with a “high quality” (Campbell and Schaller 2002; Campbell and Sükösd 2002, 2003). The “quantitative success” of market economies and democracies creates an intensified demand for the production and use of knowledge.

What is a system?

Systemic thinking and the application of systems theory require the employment of a definition of what a system is. Ashby (1965, p. 16), for instance, emphasizes that a system represents a set of variables, selected by an observer.[2] Maturana and Varela (1979) interpret a system as a definable set of components. Foerster (1979, p. 8) draws a distinction between “observed” and “observing” systems and was the first to introduce the term “second-order cybernetics” as a “cybernetics of cybernetics” (see also Krippendorff 1979). Foerster classifies controlled systems as “first-order cybernetics” and autonomous systems as second-order cybernetics (Umpleby 1990, p. 113). In his work on systems theory and cybernetics, Umpleby underscores the conceptual additionality, when the perspective of the observer is included. Umpleby (1990, pp. 113, 119) suggests the following propositions for first-order cybernetics: “interaction among the variables in a system” and “theories of social systems” and for second-order cybernetics: “interaction between observer and observed” and “theories of the interaction between ideas and society”. Consistently, Umpleby (1997, p. 635) can claim: “theories of social systems, when acted upon, change social systems”. In addition to this conceptual innovation of first-order and second-order cybernetics, also the systemic notions of “self-organization” and “self-organizing systems” expressed a long-lasting impact (Foerster and Zopf 1962; Roth and Schwegler 1981; Paslack 1991, pp. 91–184). Self-organization is carried by several conceptual inputs: first-order/second-order cybernetics, observed/observing systems (Foerster 1984a), autonomy, and “autopoiesis”. Autopoiesis represents a system that self-produces the components, of which the system is set up. Consequently, autopoiesis serves as a viable characterization of biologically living systems, for example cells and organisms. The term “allopoiesis”, on the other hand, implies a system, which does not reproduce itself, but produces something else; for instance, an assembly line of industrial production (Maturana 1975; Maturana et al. 1975; Maturana and Varela 1979; see also Maturana 1985). German-speaking Niklas Luhmann imported the concept of autopoiesis into his design of systems theory and applied autopoiesis to the social sciences (Luhmann 1988a, p. 295; see, furthermore: Luhmann 1988b; Gripp-Hagelstange 1995; Pfeffer 2001).

More formally approached, systems can be defined by referring to two important principles (Campbell 2001, p. 426):

1. *Elements*: systems consist of elements (parts)
2. *Self-Rationale*: systems have a mode of operation, a self-rationale (logic, self-logic), which organizes the self-organization and reproduction of a system and the relationship between the elements within a system and, furthermore, the relationship between the system and the other systems.

In systems theory, the distinction between the system and its environment, quasi embedding the system, is essential: the other systems also define something like an environment for the specific system (Easton 1965a, p. 24; Foerster 1984b, p. 4; Luhmann

1988a, p. 292; Willke 1989, p. 121). Related questions, therefore, are as follows: Do systems have boundaries and where are they located? Can systems overlap, and if so, how should those areas of overlapping be interpreted? Do systems network? Referring back to the self-rationale of a system, it should be emphasized that every specific system proposes a specific set of elements and a specific self-rationale. Thus, a self-rationale also distinguishes one system from the other systems and makes the borderlines more visible. At the same time, potential overlaps complicate the issue of exact borders of a system. *Society can be understood—and can be "constructed" (designed)—as being composed of different systems, and these subsystems of a society then define social (societal) systems*. The political system and the economic system are examples for such social (societal) systems. Furthermore, geographically, there can be subnational (local), national, and transnational (supranational, international, and global) systems or societies.

The focus of Lundvall on the knowledge concept of the "national systems of innovation" consequently requires Lundvall to elaborate what a system is. For a formal definition of a system, Lundvall (1992, p. 2) suggests: "Somewhat more specifically, a system is constituted by a number of elements and by the relationships between these elements". In that context, Lundvall also cites Boulding, claiming that Boulding defines a system as the opposite of chaos.[3] Also emphasizing references to knowledge, Kuhlmann (2001, p. 955) offers the following conceptualization for a system: "As a system we understand a conglomeration of actors, institutions and processes all functionally bound together, whereby certain characteristic core functions of each form the demarcation criteria against other societal (sub)systems". Already back in the late 1980s, the *Max-Planck-Institut für Gesellschaftsforschung*, in Cologne, Germany, developed an interesting approach to systems theory, focusing on key issues: understanding society in a systemic context; looking for possible synergy effects between systems theory and action theory (decision-making); analyzing the science system and technology; and assessing the possibilities of influencing or controlling developments of and in different systems (subsystems) of society (Mayntz et al. 1988; see, more specifically, Mayntz 1988; Stichweh 1988a; Stichweh 1988b; Rosewitz and Schimank 1988).

A literature search and review quickly reveals that there exist very different definitions of systems, social systems, and suggested elements of a system. David Easton, for example, stresses as possible "units of analysis": action, decision, function, and even systems can serve as units of analysis, when a system is being understood as a part (element) of a larger system (Easton 1965b, pp. 15–16). Easton was inclined to analyze politics under the premises of systems theory and to frame political life (political activities) as a system of behavior. According to Easton, a meaningful systems analysis, therefore, requires the following: (1) a "system" (e.g., political life); (2) an "environment", in which the system is embedded; (3) "response", implying internal variations of the structures and processes of a system, in response to the environment and the "internal sources"; and (4) "feedback", by tendency information-based, that influences the decision-making of actors (Easton 1965a, pp. 23–25). Easton (1965c, p. 112) claims, when referring to his "simplified model of a political system," demands on and support for a political system function as inputs and decisions and actions of a political system as outputs. Almond (1956, pp. 393–394) interprets a political system as a system of "action". Thus, the smallest unit is the "role" (rôle), representing the pattern of participation of an actor in an interactive process. Consequently, a political system can be conceptualized as a "set of interacting rôles" or as a "structure of rôles".

While these (earlier) Anglo-American systems applications in the social sciences underscored action and behavior, the systems theory of the 1980s and 1990s in the German language area emphasized an alternative focus. Luhmann (1988a, p. 299), for instance, defines "communication" as the most basic element of a social system. Willke (1989, p. 25) also underscores that communication (and not action) constitutes the basic elements of the operation mode of social systems. This implies that society cannot be understood as an aggregation of individuals, and a single individual represents a "psychological system" but not a social system (Willke 1989, pp. 18, 21). Individuals, persons, are necessary preconditions, a necessary environmental (context) condition for society, but not part of society (Luhmann 1988a, p. 299; Willke 1989, p. 24). Communication operates *between* individuals. Communication and action (behavior) are not being regarded as identical but as different entities, with communication as the more comprehensive concept, since communication also reflects on actors and acting (Willke 1989, pp. 24–25). In variance (and perhaps opposite) to Luhmann and Willke, Umpleby (1990, p. 115) states: "Social systems are composed of thinking participants whereas physical systems are not". Luhmann and Willke strongly emphasize a difference between communication (social systems) and action (e.g., Luhmann 1988a, p. 299). Contrary to that, earlier Anglo-American system thinkers, such as David Easton and Gabriel Almond, apply a more integrative approach by interpreting action (behavior) as the basic elements of a social system.

These systems theoretical differences lead to the following hypothesis: *there are no restrictions with regard to the possible design of a system and the specific configuration of its elements and self-rationale, as long as the systems design is not (self-)contradictory*. In principle, every consistent design or concept of a system can claim a certain legitimacy. Consistence refers to the internal logical construction of systems as well as the "empirical definition" of the systems terms. While the conceptual production (creation) of systems is permissive during the ex-ante phase, there operate processes of "conceptual selection" in the ex-post aftermath. Every systems design is exposed to a communicative discourse and to external assessment and evaluation and criticism. Therefore, there are general expectations that the designers of a system can offer arguments that demonstrate the plausibility of their systemic approach. Specifically, this can imply:

1. To which extent can a concept of a system convince other observers, members, and actors of a society?
2. How useful is a concept of a system, and what is its potential of application?
3. To which degree is a concept of a system open for learning and can be adapted and improved?

The number (How many systems?), and the internal and external configuration of social (societal) systems, as proposed by observers, *is not "naturally" predetermined but socially constructed.* Different observers propose different (or similar) definitions of systems, about which then these different observers, and communities, debate. Under certain circumstances, some consensus (consensuses) may be established, for example, it is useful to speak about a political, economic, education, research, S&T, and innovation system. But, realistically judged, one must also acknowledge that competition between concepts of systems and between observers represents a common situation. Dissent between observers (or members and actors of a society) can be very fundamental.

We already referred to systems theories that emphasize the importance of the observer[4] and distinguish between observed and observing systems. Restating the communication-based systems theoretical approach of Luhmann and Willke, it appears definitely legitimate to design social systems, using communication as its basic elements, which also leverages analytical advantages. However, on the other hand: evaluated from our analytical point of departure, it is not legitimate to rule out (or to *forbid*) per se a systems theoretical design, which prefers to introduce and to use basic elements other than communication. We suggested that the two essential components of a system are its elements and self-rationale. We also proposed that every (or almost every) concept of a system, based on a specific definition of elements and of a self-rationale, is legitimate, as long as the systems theoretical design is consistent and not self-contradictory. What then counts is *how convincing and how useful is a specific systems theoretical design?* A dynamically unfolding discussion of the usefulness can lead to several outcomes: either one systems theoretical concept replaces another concept or there operates a parallel co-existence (co-evolution) of different systems theoretical concepts. The co-existence paradigm may imply, depending on the application needs, systems theoretical concepts develop their specific profile of usefulness and/or convince different communities to a varying degree. Communication and communicative discourses play an important role for such evaluation processes of systemic concepts. Already, Easton (1965a, p. 33) asserted that concepts are not necessarily right or wrong but more or less useful. Should a specific conceptualization of a system convince broader communities and constituencies, then such a systemic concept enters and structures mainstream thinking and perhaps can achieve the status of a relative consensus. Again, referring to an argument made by Umpleby (1997, p. 635), the following distinction can be drawn between the natural and social sciences: different theories (concepts) in the natural sciences change our perception and interpretation, but not per se the actual behavior of the natural world. Different theories (concepts) in the social sciences, however, can change social systems and societies, if that new theory (concept) convinces enough members or key actors of a society.

Our proposed flexible designing of systems may also be more appropriate for dealing effectively with the complexities of society. Societal complexity may create ambiguities concerning the number, function (self-rationale), and boundaries of social systems. Overlaps between systems cause conceptual irritations for some systems theories that are inclined to develop exactness, despite the circumstance that in modern and advanced societies and economies, such hybrid overlapping and networking within and between systems occurs quite frequently. For a flexible systems theoretical approach, a potential overlap between systems does not really pose a problem, because the premise of constructing social systems already implies that systems boundaries can be volatile. An overlap between different systems can be accepted either as a “hybrid area” or can be solved by redefining the zone of overlapping to a new system. Networks and networking are not only important for explaining the dynamics of society (Marin and Mayntz 1991; Sabatier and Jenkins-Smith 1993; Sabatier 1999) but they also support our understanding of knowledge. Mode 1 and Mode 2 (Gibbons et al. 1994; Nowotny et al. 2003;

Nowotny et al. 2003), Science One and Science Two (Umpleby 2002), Triple Helix (Etzkowitz and Leydesdorff 2000), and the Technology Life Cycles (Tassey 2001) can be introduced as knowledge concepts that emphasize a network-style and network-based linkage of different modes of knowledge production (see also Geuna and Steinmueller 2003). *Innovation networks and clusters*—and "networks of innovation networks and clusters"—represent further knowledge-oriented concepts that stress the importance of networks. This creates a demand for conceptually bridging systems and systems theory *with* networks and clusters.

How can we define the conceptual relationship between clusters and networks on the one hand and between the elements and the self-rationale of a system? There are different possibilities. One way to look at this is *clusters could be interpreted as an equivalent for the elements of a system and networks as a (partial) equivalent for the relationship between the elements of one or of several systems*. Networks may represent a specific, but crucial, subset of relations, relationships. *Through networking, the clusters/elements of a system (of different systems) relate and interact (and communicate).* A system, acting as a subsystem and being embedded by a larger system, could also be interpreted as an element or as a cluster of that meta-system. Such perspective of further aggregation emphasizes that the borderlines between elements (clusters) and systems are perhaps more in flux than originally expected. Every element or cluster of a system could be tested whether it qualifies as a micro-system (subsystem). The manifold possibilities for relations (linkages) between elements within a system or across different systems clearly underscore the dynamic capabilities of networks and networking. In Fig. 1, we summarize our preliminary conclusions through conceptually integrating the axes of *elements/self-rationale* and *clusters/networks*.

In the following, we want to propose, for discussion, possible definitions for the self-rationale of the political, economic, and knowledge systems:

1. *Self-rationale(s) of the political system*: The political system has or should express a responsibility for the overall performance of a society (and of the economy). The "governance of society" can be defined as a self-rationale of politics: through policy (policy-making) and legislation or—alternatively—steering,[5] coordination, and communication, the political system attempts to influence the dynamics of a society and economy and tries to support the performance (and self-rationales) of the other systems (Campbell 2001, p. 428). In summary, the political system is interested in effectively stimulating and coordinating the performances of the other systems and thus enhancing a synergetic performance surplus. Policy objectives can and should target the implementation, support, and supervision[6] of markets and market mechanisms. In fact, enhancing the build-up of (self-organizing) markets represents in advanced societies and economies an important policy application area for politics.[7]
2. *Self-rationale(s) of the economic system*: Phrased simply, wealth creation defines a primary function of an economy. A more sophisticated approach would have to outline specific implications and ramifications, such as: What is the relationship between wealth and competitiveness? How can the economic system perform without negatively impacting its environments? Is it possible to create wealth and to avoid, at the same time, (major) distribution inequalities of the surplus wealth?

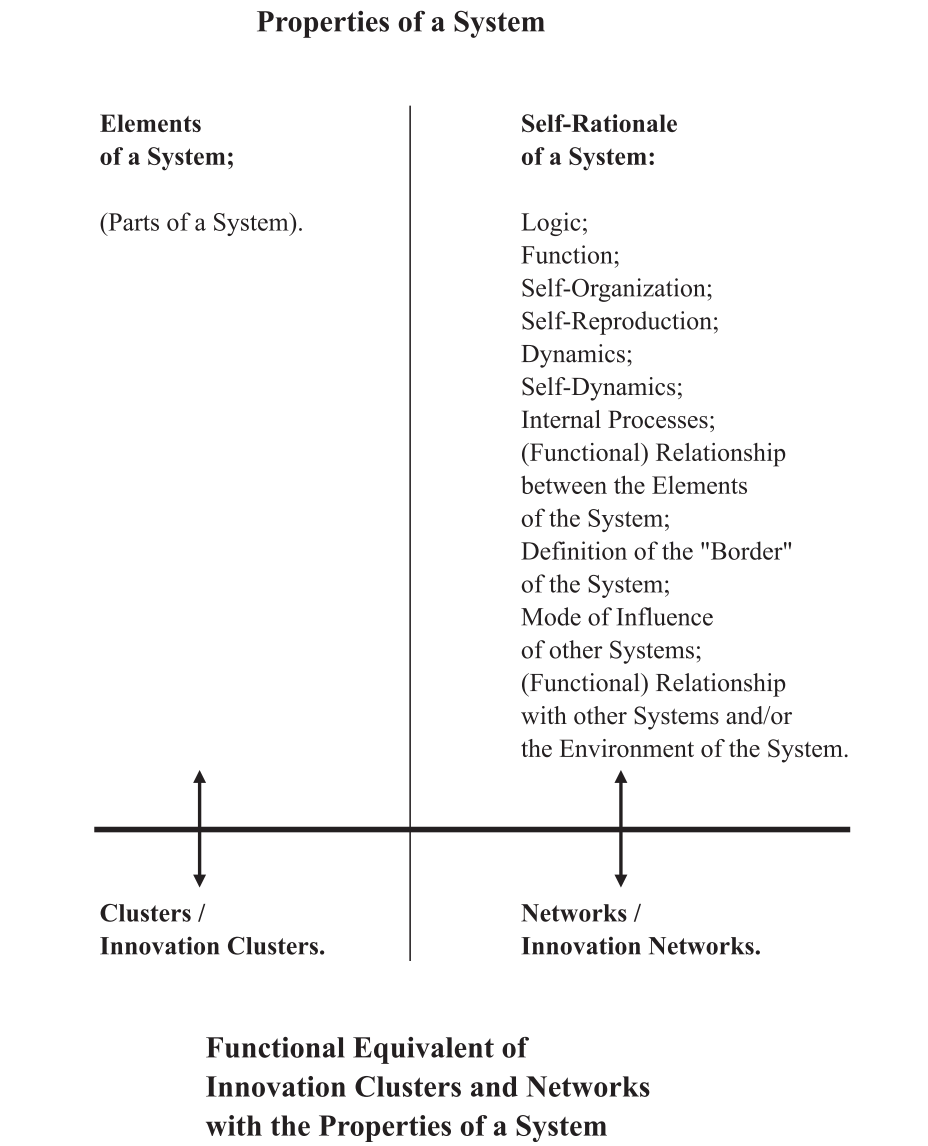

Fig. 1 A formalized definition of systems and of innovation clusters and innovation networks. Source: authors' own conceptualization

3. *Self-rationale(s) of the knowledge system*: One main function of the knowledge system is to produce (create) and to distribute knowledge. Partly, knowledge can be regarded as an input, as a resource, with the potential of enhancing processes. Understood systems theoretically, knowledge, being produced by the knowledge system, has the potential of supporting and enhancing the performance of the other systems of a society, which operate increasingly knowledge-dependent. Here, some similar interests between the political and the knowledge systems may be stated. The political system enhances the performance of a society through the governance of society: policy-making and legislation, coordination, and communication (and the support of market-building). Complementarily, the knowledge system enhances the overall performance of a society by producing and distributing knowledge "resources," which then are being used by the other systems of a society for

supporting their processes and performances. Is the innovation system understood as a subsystem of the knowledge system, then the innovation system represents for the advanced societies and economies an interface, through which politics and the economy (business) communicate and interact. The innovation system defines a crucial area for applying and testing hypotheses of modern Political Economy.

Knowledge and knowledge systems

After having elaborated on systems and systems theory, we want to focus on linking this systems perspective with knowledge. Knowledge—and consequently the "knowledge system" (or *knowledge systems*)—should be regarded as an aggregated term or concept. Referring analytically to "multi-level systems" can leverage important conceptual advantages and benefits. Conceptual "multi-level" architectures already are being used frequently for analyzing and evaluating the supranational structures of the European Union (EU). In fact, speaking about *multi-level governance* originates from research about the EU (Hooghe and Marks 2001; Bomberg and Stubb 2003, p. 9). One could also reflect about multi-level legislation of the EU.[8] Obviously, this logic of multi-levels may also be applied to other research areas and to alternative macro-political entities with a federal structure, for example, the USA. This would introduce interesting research designs, such as comparing multi-level EU and USA and to search for possible similarities and differences.

Evaluated from an analytical perspective, it appears promising to import this EU-based research concept of multi-levels and to modify it specifically, so that it fits our research interests about knowledge. The logic of multi-levels implies *there is one (or more than one) axis of further aggregation.* Aggregation can be approached either functionally (as a sequence of continuously more comprehensive concepts) and/or geographically (e.g., subnational, national, supranational, transnational). If we are interested in displaying the knowledge system in the context of the architecture of multi-level systems, then we can propose two (functional) axes: an "education" axis (OECD 2002, pp. 35–63; OECD 2003b) and a "research" axis. In the specific institutional context of universities, following the Humboldtian tradition of emphasizing a research-based teaching, obviously, education and research overlap considerably (Campbell and Felderer 1997, pp. 56–57; Etzkowitz 2003, p. 110). With the concept of corporate universities, also firms may establish and support institutions of tertiary education (Etzkowitz and Leydesdorff 2000, p. 117–118). The research axis, as proposed here, could aggregate from research, to S&T, and to innovation (see Fig. 2). A broader term for research is R&D, where research again differentiates in basic research and applied research (OECD 1994, p. 29). Basic research represents a primary competence area of universities, and experimental development, already closest market-oriented, is the primary competence of business firms in the economic markets (OECD 2003a, Table 3; National Science Board 2002, Vol. 1, p. 4–29, and Vol. 2, pp. A4–7 until A4–34). Consequently, R&D, S&T, and innovation can be regarded either as specific knowledge systems or, alternatively, as subsystems of the aggregated knowledge system (the *knowledge meta-system*).

Referring to innovation, there are two issues of further concern. (1) *Is innovation research-oriented and biased in favor of research (and disfavoring education)?* On the one hand, we conventionally associate innovation more closely to R&D (S&T) than to

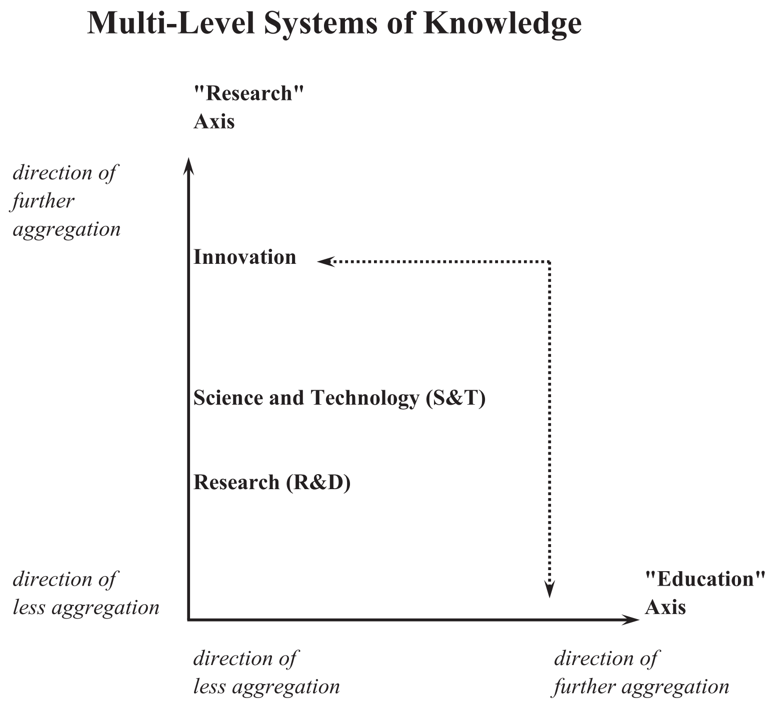

Fig. 2 Multi-level systems of knowledge. Source: authors' own conceptualization

education. However, this depends on the specific conceptual approach. Should innovation (and innovation policy) be understood broadly, then innovation clearly integrates symmetrically the two axes of research and education (see, for example, Kuhlmann 2001, p. 954).[9] (2) *Is there a knowledge concept more comprehensive than innovation?* One could claim that innovation already represents the most comprehensive knowledge concept, thus, in a final consequence, the innovation and knowledge systems overlap completely and coincide. An alternative approach would suggest regarding the knowledge concept (and knowledge system) still as broader and more comprehensive than the innovation concept (innovation system). This offers the advantage of sustaining a conceptual difference between knowledge and innovation, acknowledging that innovation could be closer associated to research than to education. Without a conceptual difference, both concepts, knowledge and innovation, would collapse to interchangeable terms.

Emphasizing the research axis of knowledge, we can apply more specifically the multi-level logic by referring to *multi-level systems of innovation* (Campbell 2006) and want to propose two particular directions of further aggregation (see Fig. 3). Functionally, the aggregation may move from R&D to S&T and finally to innovation; geographically, the aggregation may take the direction from subnational (local) to national and transnational (supranational, global)—for example, Kaiser and Prange (2004, pp. 395, 405–406) discuss multi-level systems of innovation under geographical premises.[10] The concept of the national systems of innovation, prominently promoted by Bengt-Åke Lundvall, interprets and places the innovation system in the context of the nation state, focusing consequently on the nation-state level (Lundvall 1992, pp. 2–3; compare, furthermore, with Lundvall et al. 2002; Lundvall and Tomlinson 2002; Nelson 1993; Larédo and Mustar 2001; Mowery 2001; Bozeman and Dietz 2001). The existence and

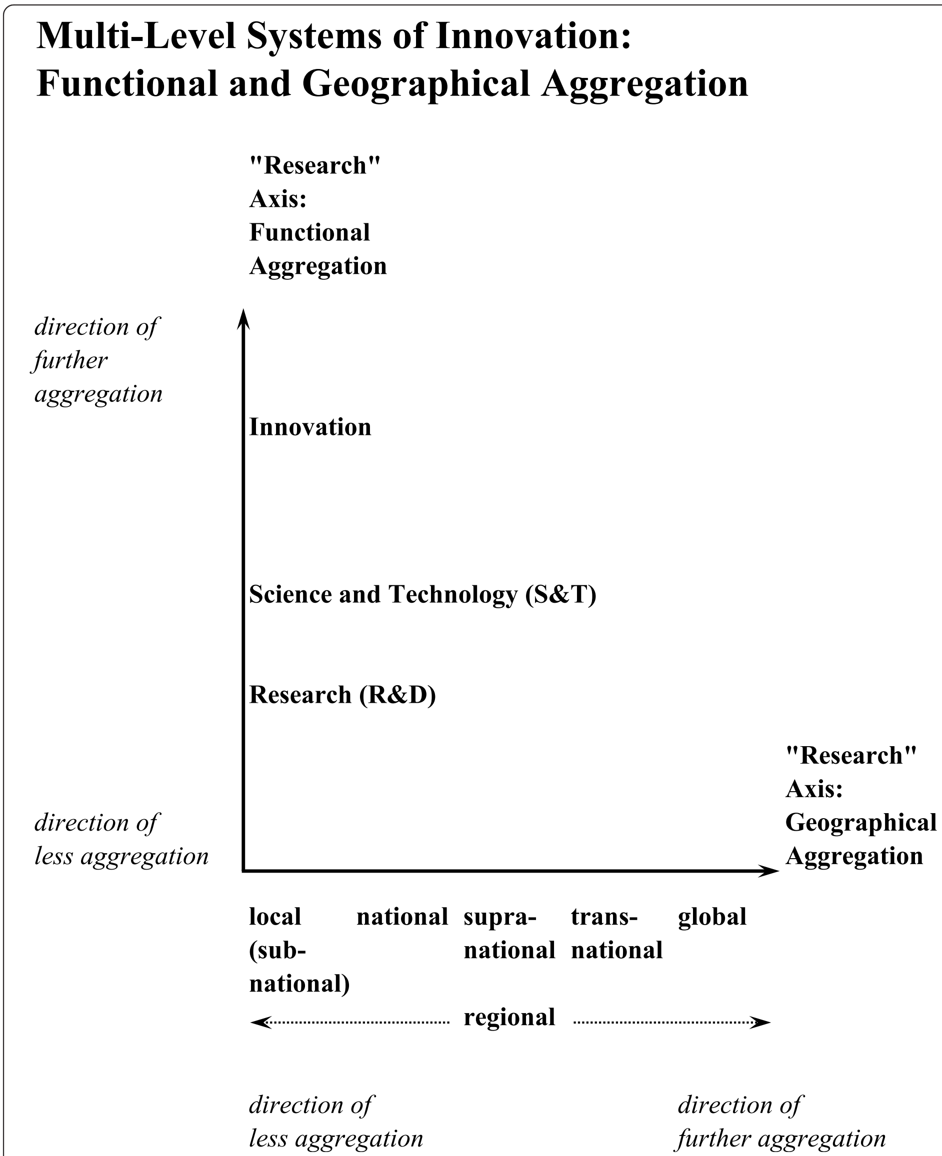

Fig. 3 Multi-level systems of innovation: functional and geographical aggregation. Source: Campbell (2004)

operation of national patterns obviously supports the plausibility of a concept, such as national innovation systems. But Lundvall (1992, pp. 3–4) also explicitly comments that the national innovation systems are exposed to and challenged by globalization and regionalization. In our opinion, Lundvall could be interpreted twofold: first, innovation processes (and innovation systems) operate, in parallel, locally, nationally, and globally; second, the national context (nation-state configuration) still represents an important reference for innovation systems. Therefore, the Lundvall inclination of explaining innovation, based on national innovation systems, can be comfortably incorporated into our proposed concept of "multi-level systems of innovation". Lundvall (1992, p. 4) emphasizes an understanding of modern Western nation states as "engines of growth". Also, Nelson (1990, p. 193) paraphrases capitalism as an "engine of progress". Discussing the objectives of innovation policy, Lundvall (1992, p. 15) underscores the government goal of supporting economic growth. Kuhlmann (2001, p. 954) defines as primary objective for a public innovation policy the enhancement of the competitiveness of an economy.

The functional aggregation of the research axis of knowledge allows for different options of how research (R&D), S&T, and innovation could be related to each other (see Fig. 4). Concerning the placement of innovation, it reflects a broad consensus to interpret innovation as the most comprehensive concept. Regarding more specifically the vis-à-vis placement of R&D and S&T, there is certainly room for an interesting debate. (1) R&D, S&T, and innovation[11]: in a conventional understanding, R&D is less aggregative than S&T. This may be made plausible by referring to empirically based indicators. Expenditure on R&D and S&T can be expressed in percentage terms of the GDP (gross domestic product). ICT (information and communication technology) certainly qualifies as a subcategory of S&T expenditure. A comparison of the advanced OECD countries clearly demonstrates that already ICT expenditure alone (only a subcategory of S&T) consummates a larger percentage proportion of GDP than all of the R&D expenditure (OECD 2003c, Table 2; World Bank 2002). (2) R&D/S&T and innovation[12]: this approach is inclined to speak of one integrated R&D and S&T system and not to see R&D and S&T as two distinct and different systems. As a consequence, R&D and S&T could be, at least partially, mutually, and conceptually *translated*: for example, basic research and science as well as experimental development and technology

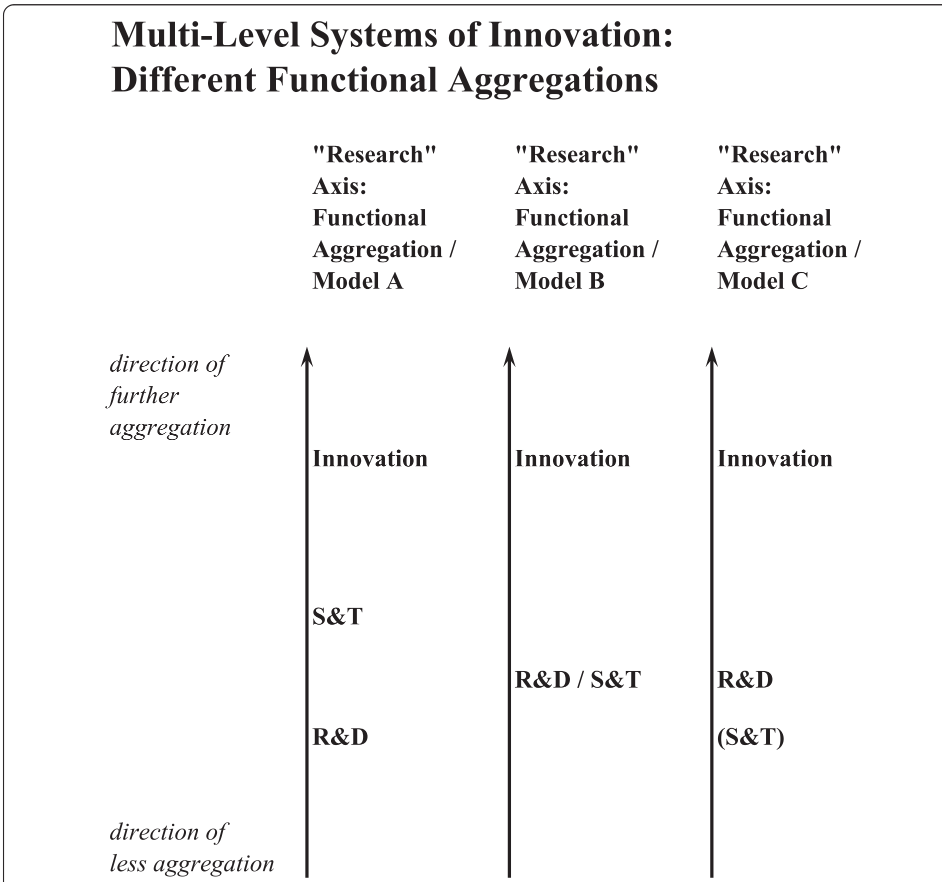

Fig. 4 Multi-level systems of innovation: different functional aggregations. Source: authors' own conceptualization

overlap. But the comprehensiveness and "conceptual stretch" of related R&D and S&T categories might deviate considerably. Phrased differently, R&D and S&T represent perhaps alternative sets of categories for re-typologizing and re-conceptualizing common knowledge structures and processes. (3) R&D (S&T) and innovation[13]: here, the emphasis focuses on the R&D and innovation systems, where the R&D system is embedded in the larger innovation system. S&T is not necessarily being designed as an independent system; thus, there arises no need for a specific or systemic placement of S&T versus R&D and innovation. Those components of S&T, which display a relevance for R&D, are incorporated as a subset (subsystem) into the R&D system. Consequently, left-over properties of S&T, which express no implications for R&D, are not configurated to an independent S&T system.

Our proposed (and already earlier stated) flexibility for constructing social (societal) systems allows, in principle, for very different systems designs. In the following, we want to suggest more specifically how knowledge may relate to politics and the economy. This requires introducing a political and an economic system for the analysis of society and economic dynamics. Our interest in knowledge suggests furthermore a need for an R&D and/or S&T system and an education system. Thus, we are facing an interaction, potentially between the following systems: political system, economic system, R&D and/or S&T system, and the education system (see Fig. 5). Obviously, this represents only a selective and knowledge-oriented design of social systems, not including other systems (such as the legal system). A broader and more comprehensive systems design of society would have to incorporate a considerably larger number of systems.

In a next step, we may integrate the innovation system into this picture. We want to suggest, for discussion, a specific design, where the innovation system displays the following properties and patterns of interaction with the other systems of society (see

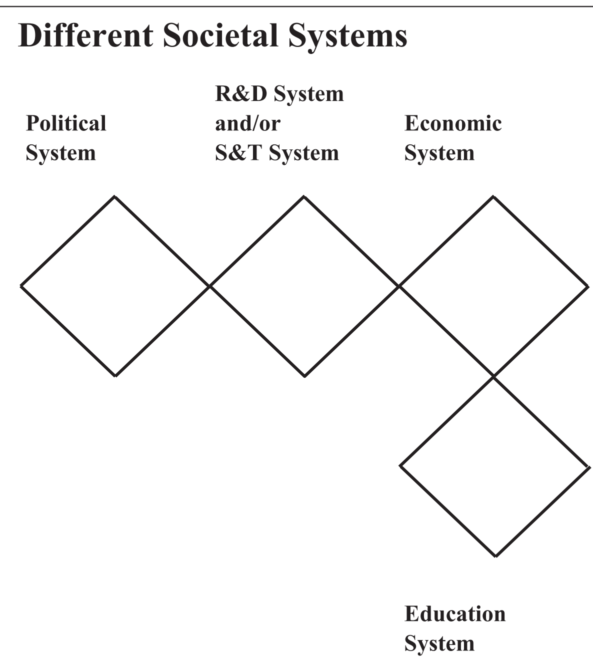

Fig. 5 Different societal systems. Source: authors' own conceptualization

Fig. 6). (1) The innovation system is more comprehensive than R&D and S&T; thus, the innovation system embodies the R&D and/or S&T systems. (2) The innovation system overlaps with the education system.[14] In addition, on the borderline of the innovation and education system—or the R&D (S&T) and education systems—the university system may be placed: this should reflect the dual research and teaching functionality of universities. (3) Furthermore, the innovation system also overlaps partially with the political and economic systems. Innovation policies may represent a common subset of the political and innovation systems. Since innovation policies emphasize particularly the enhancement of economic performance, innovation policies also can be regarded as a cross-cutting subset of the innovation and economic systems.

The political system expresses an interest in enhancing the performance of the other systems of a society. Policies represent one possibility, how politics may want to leverage an influence on processes in different social (societal) systems (see Fig. 7). Through economic policy, the political system can impact the economic system directly; through education policy, the education system; and through R&D policy, the R&D system. Through innovation policy, however, which recognizes more specifically the conditions and ramifications of knowledge, the political system also projects an indirect and "mediated," knowledge-tailored, influence on the economic system. *This understanding underscores the interpretation and valuation of the innovation system as an interface between politics and the economy*. The concept of the knowledge-based economy and society even suggests that in many contexts, an innovation policy may be more effective in supporting economic performance than traditional economic policy. In advanced societies, *the indirect*

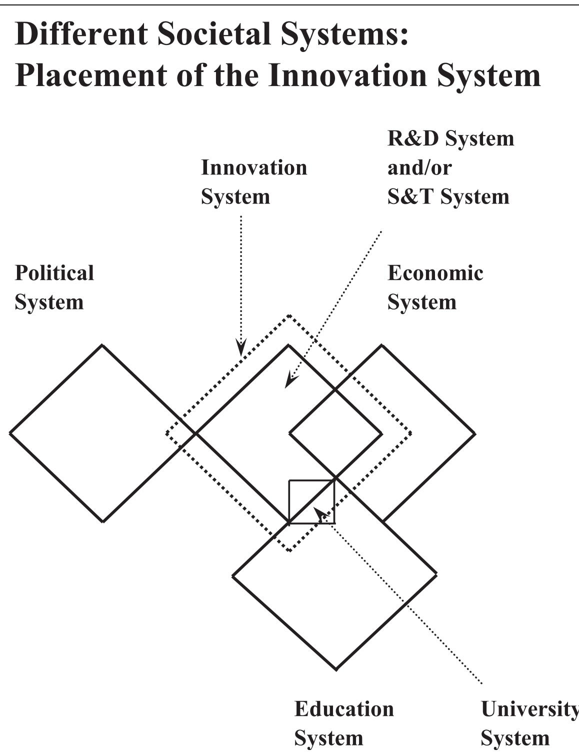

Fig. 6 Different societal systems: placement of the innovation system. Source: authors' own conceptualization

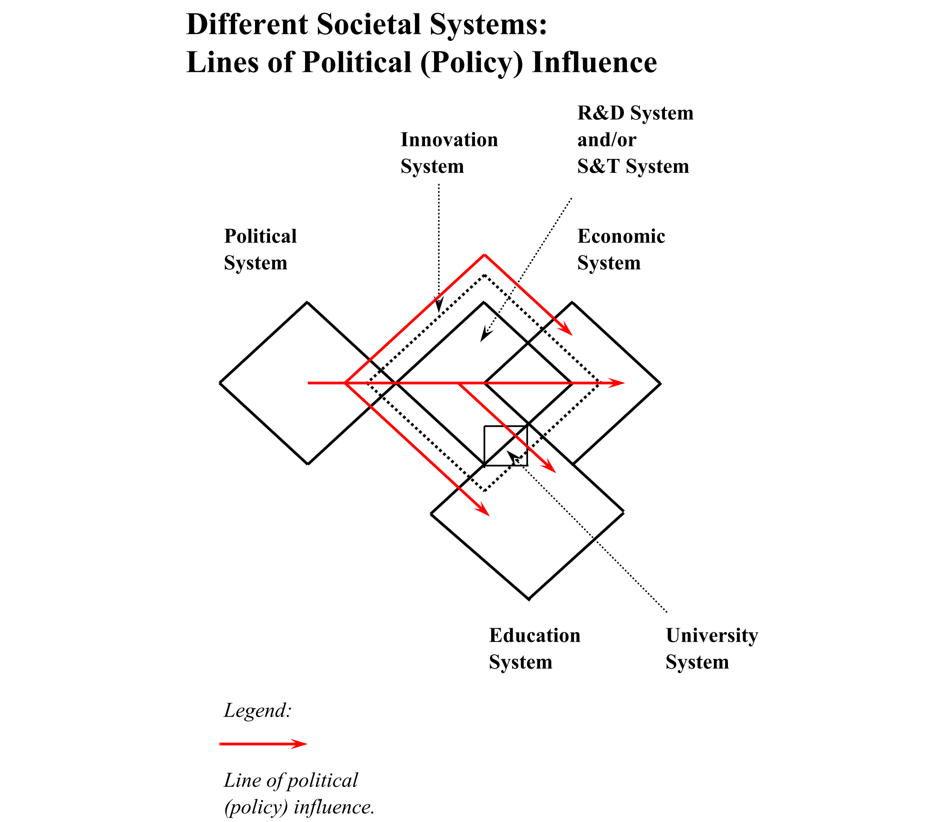

Fig. 7 Different societal systems: lines of political (policy) influence. Source: authors' own conceptualization

coupling of the political and economic systems, through the innovation system that overlaps with politics and the economy, gains considerably in importance. Discursively, this implies that for knowledge-based economies and societies, the innovation system and the innovation policy might define a crucial area for analysis under the premises of Political Economy or International Political Economy (for a general overview of Political Economy, see: Balaam and Veseth 2001; Crane and Amawi 1997; Frieden and Lake 2000).

Results and discussion: the knowledge systems perspective of "Mode 3"

Using systems theory and applying systems concepts on knowledge certainly represents an interesting approach. We want to conclude our analysis with suggesting—for discussion—propositions for a possible knowledge systems perspective, which we label ad hoc as "Mode 3". "Mode 3" focuses on linking systems theory and knowledge and the analysis of knowledge (see also Carayannis and Campbell 2006):

1. Analyzing knowledge in the context of systems and systems theory leverages conceptual advantages.
2. The knowledge-based economy, knowledge-based society, and knowledge-based democracy are concepts demonstrating how important knowledge is for understanding the dynamics of advanced societies.

3. Systems theory and the systemic approach represent a comprehensive paradigm, displaying a greater conceptual extension than a purely (primarily) economy-based rationale.
4. Markets can be integrated into systems theory, by interpreting markets (economic markets) as a specific type of a system. The claimed economization of the world may be reinterpreted in the context of systems theory.
5. Systems consist of elements and a self-rationale. Systems can be designed (constructed), to a maximum extent, flexible, as long as the design is consistent and not self-contradictory. Discussion then will focus on: Can a systems design convince other "observers"? Is a systems design useful and can it be practically applied? Is a systems design capable of "conceptual learning"?
6. Systems theory, in principle, is open for conceptually combining elements/self-rationale and clusters/networks.
7. There is a need for permanently testing the applicability of knowledge-based systems concepts. Through this application-orientation, the further theoretical development of knowledge systems concepts is enhanced. (Systems theory, in general, should be application-oriented.)
8. In recent years, the concept of the innovation system (national innovation system) experienced a serious proliferation and can be interpreted, de facto, as a successful application of systemic concepts. Innovation, innovation systems, and innovation policies are key terms.
9. Knowledge represents an aggregated term. Research, science and technology, and innovation are less aggregative.
10. Applying the logic of "multi-level systems" to knowledge and innovation appears promising. Consequently, one can speak of "multi-level systems of knowledge" and/or "multi-level systems of innovation".
11. Networking is important for understanding the dynamics of advanced and knowledge-based societies. Networking links together different modes of knowledge production and knowledge use and also connects (subnationally, nationally, transnationally) different sectors or systems of society. Systems theory, as presented here, is flexible enough for integrating and reconciling systems and networks, thus creating conceptual synergies.

Conclusion: Mode 3 knowledge production in Quadruple and Quintuple Helix innovation systems

Research can be understood as a form of knowledge production (knowledge creation) and innovation as a form of knowledge application (knowledge use), within a more general framework and design of knowledge (a knowledge architecture). *Ultimately, systems of knowledge production can be linked and connected with systems of innovation. For the final conclusion to our analysis here, we propose to think of ways of combining and integrating Mode 3 knowledge production systems with and in Quadruple and Quintuple Helix innovation systems*. In the following paragraphs, we again summarize the conceptual key elements that characterize Mode 3 and Quadruple and Quintuple Helix from a more advanced systems perspective.

University research, in a traditional understanding and in reference to universities in the sciences, focuses on basic research, often framed within a matrix of academic disciplines and without a particular interest in the practical use of knowledge and innovation. This model of university-based knowledge production also is being called "Mode 1" of knowledge production (Gibbons et al. 1994). Mode 1 is also compatible with the linear model of innovation, which is often being referred to Bush (1945). The linear model of innovation asserts that first, there is basic research in university context; gradually, this university research will diffuse out into society and the economy. It is then the economy and the firms that pick up the lines of university research and develop these further into knowledge application and innovation, for the purpose of creating economic and commercial success in the markets outside of the higher education system. Within the frame of linear innovation, there is a sequential "first-then" relationship between basic research (knowledge production) and innovation (knowledge application).

The Mode-1-based understanding of knowledge production has been challenged by the new concept of "Mode 2" of knowledge production, which was developed and proposed by Gibbons et al. (1994, pp. 3–8, 167). Mode 2 emphasizes a knowledge application and a knowledge-based problem-solving that involves and encourages the following principles: "knowledge produced in the context of application," "transdisciplinarity," "heterogeneity and organizational diversity," "social accountability and reflexivity," and "quality control" (see furthermore Nowotny et al. 2001, 2003, 2006). Key in this setting is the focus on a knowledge production in contexts of application. Mode 2 expresses and encourages clear references to innovation and innovation models. The linear model of innovation also has become challenged by non-linear models of innovation, which are interested in drawing more direct connections between knowledge production and knowledge application, where basic research and innovation are being coupled together not in a first-then but in an "as well as" and "parallel" (parallelized) relationship (Campbell and Carayannis 2012). Mode 2 appears also to be compatible with non-linear innovation and its ramifications.

A "Mode 3" university, higher education institution, or higher education system would represent a type of organization or system that seeks creative ways of combining and integrating different principles of knowledge production and knowledge application (for example, Mode 1 and Mode 2), by this encouraging diversity and heterogeneity and by this also creating creative and innovative organizational contexts for research and innovation. Mode 3 encourages the formation of "creative knowledge environments" (Hemlin et al. 2004). "Mode 3 universities" and Mode 3 higher education institutions and systems are prepared to perform "basic research in the context of application" (Campbell and Carayannis 2013a, p. 34). This has furthermore qualities of non-linear innovation. Governance of higher education and governance in higher education must also be sensitive, whether a higher education institution operates on the basis of Mode 1, Mode 2, or a combination of these in Mode 3. The concept of "epistemic governance" emphasizes that the underlying knowledge paradigms of knowledge production and knowledge application are being addressed by quality assurance and quality enhancement strategies, policies, and measures (Campbell and Carayannis 2013a, 2013b, 2016).

The Triple Helix innovation model concentrates on university-industry-government relations (Etzkowitz and Leydesdorff 2000). In that respect, Triple Helix represents a basic model for knowledge production and innovation application. The models of the

Quadruple Helix and Quintuple Helix innovation systems are designed to already comprehend and to refer to an extended complexity in knowledge production and knowledge application (innovation); thus, the analytical architecture of these models is conceptualized broader. To use metaphoric terms, the Quadruple Helix embeds and contextualizes the Triple Helix, while the Quintuple Helix embeds and contextualizes the Quadruple Helix (and Triple Helix). The Quadruple Helix adds as a fourth helix the "media-based and culture-based public," "civil society," and "arts, artistic research, and arts-based innovation" (Carayannis and Campbell 2009, 2012, p. 14, and 2014; see also Danilda et al. 2009, and Bast et al. 2015). *The Quadruple Helix also could be emphasized as the perspective that specifically brings in the "dimension of democracy" or the "context of democracy" for knowledge, knowledge production, and innovation*. The Quintuple Helix innovation model is even more comprehensive in its analytical and explanatory stretch and approach, adding furthermore the fifth helix (and perspective) of the "natural environments of society" (Carayannis and Campbell 2010, p. 62).

The Triple Helix is explicit in acknowledging the importance of higher education for innovation. However, it could be argued that the Triple Helix sees knowledge production and innovation in relation to economy; thus, the Triple Helix models first of all (primarily) the economy and economic activity. In that sense, the Triple Helix frames the knowledge economy. The Quadruple Helix brings in the additional perspective of society (knowledge society) and of democracy (knowledge democracy). The Quadruple-Helix-innovation-system understanding emphasizes that sustainable development of and in economy (knowledge economy) requires that there is a co-evolution of knowledge economy and knowledge society and knowledge democracy. The Quadruple Helix even encourages *the perspectives of knowledge society and of knowledge democracy* for supporting, promoting, and advancing knowledge production (research) and knowledge application (innovation). Furthermore, the Quadruple Helix is also explicit that not only universities (higher education institutions) of the sciences but also universities (higher education institutions) of the arts should be regarded as decisive and determining institutions for advancing next-stage innovation systems: the interdisciplinary and transdisciplinary connecting of sciences and arts creates crucial and creative combinations for promoting and supporting innovation. Here, in fact, lies one of the keys for future success. The concept and term of "social ecology" refers to "society-nature interactions" between "human society" and the "material world" (see, for example, Fischer-Kowalski and Haberl 2007). The European Commission (2009) identified the necessary socio-ecological transition of economy and society not only as one of the great next-phase challenges but also as an opportunity, for the further progress and advancement of knowledge economy and knowledge society. The Quintuple Helix refers to this socio-ecological transition of society, economy, and democracy, the Quintuple Helix innovation system is therefore ecologically sensitive. Quintuple Helix bases its understanding of knowledge production (research) and knowledge application (innovation) on social ecology. Environmental issues (such as global warming) represent issues of concern and of survival for humanity and human civilization. But the Quintuple Helix translates environmental and ecological issues of concern also in potential opportunities, by identifying them as possible drivers for future knowledge production and innovation (Carayannis et al. 2012). This, finally, defines also opportunities for the knowledge economy. "The Quintuple Helix supports here the formation of a win-win situation between ecology, knowledge and innovation, creating synergies between economy, society and democracy" (Carayannis et al. 2012, p. 1).

Methods

The article follows the attempt and logic of reconstructing (by this designing) key elements of the current discourses on innovation and knowledge. For that purpose, also writing skills based on "Mode 3 writing techniques" were utilized (Carayannis and Campbell 2006).

Endnotes

[1]A "quantitative" spreading of democracy implies that "quality" issues of democracy, and their evaluation, crucially gain in importance (Campbell et al. 1996, p. 5).

[2]For an interesting web reference about systems theory, see: "ASC Glossary on Cybernetics and Systems Theory" (http://pespmc1.vub.ac.be/ASC/indexASC.html).

[3]"According to Boulding (1985), the broadest possible definition of a system is 'anything that is not chaos'" (Lundvall 1992, p. 2).

[4]Can there be an observation independent of the characteristics of the observer?

[5]The systems theoretical equivalent for steering, in German, is "Steuerung" (Willke 1998, p. 2). For further readings, in that context, see also: Willke 1997; and Kuhlmann 1998.

[6]Willke (1997) titled one of his books consequently *Supervision des Staates* ("supervision by the state").

[7]This is paralleled by a skepticism against "political control" of a society, reinforced by the collapse of the planned economy system of the communist regimes in Eastern Europe and the Soviet Union (Yergin and Stanislaw 2002) and a reshuffling of the political-economic agenda in Western democracies since the 1980s, emphasizing more directly market concepts (Cooper et al. 1988).

[8]Multi-level *governance* of the EU represents a more frequently cited research objective than focusing on the EU's multi-level *legislation*.

[9]The direct Kuhlmann (2001, p. 954) quote is: "In the meantime, national and increasingly also regional governments of all these countries pursue, more or less explicitly, 'innovation policies', understood here as the integral of all state initiatives regarding science, education, research, technology policy and industrial modernization, overlapping also with industrial, environmental, labour and social policies".

[10]Interestingly, the aggregative scope of "region" (regions) is not convincingly standardized and depends on the specific discourse. In the context of the EU, a region clearly represents a subnational unit, often coinciding with the local or locality. But in comparative or international affairs research, a region also could be defined as a nation-state transcending cluster of several countries (for example, see Peters 1998, pp. 18–19).

[11]Typologized as model A in Fig. 4.

[12]Typologized as model B in Fig. 4.

[13]Typologized as model C in Fig. 4.

[14]Alternatively, one could also suggest that the education system (similarly as in the case R&D and S&T) does not only overlap with innovation but is completely covered by the innovation system.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
EGC and DFJC are the main conceptual architects of the article. SSR extended the analytical architecture of EGC and DFJC. All authors read and approved the final manuscript.

Author details
[1]Department of Information Systems and Technology Management, George Washington University School of Business, Washington, DC 20052, USA. [2]Alpen-Adria-University of Klagenfurt, Faculty for Interdisciplinary Studies (iff), Institute of Science Communication and Higher Education Research (WIHO), Schottenfeldgasse 29, A-1070 Vienna, Austria. [3]Unit for Quality Enhancement (UQE), University of Applied Arts Vienna, Oskar Kokoschka-Platz 2, A-1010 Vienna, Austria. [4]School of Business and Elliott School of International Affairs, George Washington University, 1957 E Street, NW, Washington, DC 20052, USA.

Received: 30 March 2016 Accepted: 7 April 2016
Published online: 29 April 2016

References
Almond, G. A. (1956). Comparative political systems. *The Journal of Politics, 18*, 391–409.
Ashby, W. R. (1965 [1952]). *Design for a brain*. London: Chapman and Hall.
Balaam, D. N., & Veseth, M. (Eds.). (2001). *Introduction to political economy*. Upper Saddle River, NJ: Prentice Hall.
Barney, J. B. (2002). *Gaining and sustaining competitive advantage*. Upper Saddle River, NJ: Prentice Hall.
Bast, G., Carayannis, E. G., & Campbell, D. F. J. (Eds.). (2015). *Arts, research, innovation and society*. New York, NY: Springer. http://www.springer.com/business+%26+management/technology+management/book/978-3-319-09908-8.
Bomberg, E., & Stubb, A. (2003). Introduction, 3-18. In E. Bomberg & A. Stubb (Eds.), *The European Union: how does it work?* Oxford: Oxford University Press.
Boulding, K. E. (1985). *The world as a total system*. Beverly Hills: Sage.
Bozeman, B., & Dietz, J. S. (2001). Research policy trends in the United States: civilian technology programs, defense technology and the deployment of the national laboratories. In P. Larédo & P. Mustar (Eds.), *Research and innovation policies in the new global economy. An international comparative analysis* (pp. 47–78). Cheltenham: Edward Elgar.
Bush, V. (1945). *Science: the endless frontier*. Washington, D.C.: United States Government Printing Office. http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm#transmittal.
Campbell, D. F. J. (2001). Politische Steuerung über öffentliche Förderung universitärer Forschung? Systemtheoretische Überlegungen zu Forschungs- und Technologiepolitik. *Österreichische Zeitschrift für Politikwissenschaft, 30*, 425–438.
Campbell, D. F. J. (2003). The evaluation of university research in the United Kingdom and the Netherlands, Germany and Austria. In P. Shapira & S. Kuhlmann (Eds.), *Learning from Science and Technology Policy Evaluation. Experiences from the United States and Europe* (pp. 98–131). Cheltenham: Edward Elgar.
Campbell, D. F. J. (2004). *Multi-level systems of innovation: functional and geographical aggregation. Early unpublished conceptual drawing. Vienna*.
Campbell, D. F. J. (2006). The university/business research networks in science and technology: knowledge production trends in the United States, European Union and Japan. In E. G. Carayannis & D. F. J. Campbell (Eds.), *Knowledge creation, diffusion and use in innovation networks and knowledge clusters* (pp. 67–100). Westport, Connecticut: Praeger.
Campbell, D. F. J., & Carayannis, E. G. (2012). Lineare und nicht-lineare Knowledge Production: innovative Herausforderungen für das Hochschulsystem. *Zeitschrift für Hochschulentwicklung, 7*(2), 64–72. http://www.zfhe.at/index.php/zfhe/article/view/448.
Campbell, D. F. J., & Carayannis, E. G. (2013a). *Epistemic governance in higher education. Quality enhancement of universities for development. SpringerBriefs in Business*. New York, NY: Springer. http://www.springer.com/business+%26+management/organization/book/978-1-4614-4417-6.
Campbell, D. F. J., & Carayannis, E. G. (2013b). Epistemic governance and epistemic innovation policy. In E. G. Carayannis, I. N. Dubina, N. Seel, D. F. J. Campbell, & D. Uzunidis (Eds.), *Encyclopedia of creativity, invention, innovation and entrepreneurship. New York, NY* (pp. 697–702).
Campbell, D. F. J., & Carayannis, E. G. (2016). Epistemic governance and epistemic innovation policy. *Technology, Innovation and Education, 2*, 2. http://technology-innovation-education.springeropen.com/articles/10.1186/s40660-016-0008-2.
Campbell, D. F. J., & Felderer, B. (1997). *Evaluating academic research in Germany. Patterns and policies. Vienna, Institute for Advanced Studies (IHS): Political Science Series No. 48*. http://www.ihs.ac.at/publications/pol/pw_48.pdf.
Campbell, D. F. J., & Schaller, C. (Eds.). (2002). *Demokratiequalität in Österreich. Zustand und Entwicklungsperspektiven*. Opladen: Leske + Budrich.
Campbell, D. F. J., & Sükösd, M. (Eds.). (2002). *Feasibility study for a quality ranking of democracies*. Vienna: Global Democracy Ranking.
Campbell, D. F. J., & Sükösd, M. (Eds.). (2003). *Global quality ranking of democracies: pilot ranking 2000*. Vienna: Global Democracy Ranking. http://democracyranking.org/wordpress/ranking/2000/data/folder_a4-e-03.pdf.
Campbell, D. F. J., Liebhart, K., Martinsen, R., Schaller, C., & Schedler, A. (1996). Vorwort, 5. In D. F. J. Campbell, K. Liebhart, R. Martinsen, C. Schaller, & A. Schedler (Eds.), *Die Qualität der österreichischen Demokratie. Versuche einer Annäherung*. Vienna: Manz.
Carayannis, E. G., & Campbell, D. F. J. (Eds.). (2006). *Knowledge creation, diffusion and use in innovation networks and knowledge clusters: a comparative systems approach across the United States, Europe and Asia*. Westport, Connecticut: Praeger.

Carayannis, E. G., & Campbell, D. F. J. (2009). "Mode 3" and "Quadruple Helix": toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management, 46*(3/4), 201–234. http://www.inderscience.com/search/index.php?action=record&rec_id=23374&prevQuery=&ps=10&m=or.

Carayannis, E. G., & Campbell, D. F. J. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. *International Journal of Social Ecology and Sustainable Development, 1*(1), 41–69.

Carayannis, E. G., & Campbell, D. F. J. (2012). *Mode 3 knowledge production in Quadruple Helix Innovation Systems. 21st-century democracy, innovation, and entrepreneurship for development. SpringerBriefs in Business*. New York, NY: Springer. http://www.springer.com/business+%26+management/book/978-1-4614-2061-3.

Carayannis, E. G., & Campbell, D. F. J. (2014). Developed democracies versus emerging autocracies: arts, democracy, and innovation in quadruple helix innovation systems. *Journal of Innovation and Entrepreneurship, 3*, 12. http://innovation-entrepreneurship.springeropen.com/articles/10.1186/s13731-014-0012-2.

Carayannis, E. G., Barth, T. D., & Campbell, D. F. J. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of Innovation and Entrepreneurship, 1*(1), 1–12. http://www.innovation-entrepreneurship.com/content/pdf/2192-5372-1-2.pdf.

Cooper, B., Kornberg, A., & Mishler, W. (Eds.). (1988). *The resurgence of conservatism in Anglo-American democracies*. Durham: Duke University Press.

Crane, G. T., & Amawi, A. (Eds.). (1997). *The theoretical evolution of international political economy*. Oxford: Oxford University Press.

Danilda, I., Lindberg, M., & Torstensson, B.-M. (2009). *Women Resource Centres. A quattro helix innovation system on the European agenda. Paper*.

Downs, A. (1957). *An economic theory of democracy*. New York: Harper.

Easton, D. (1965a). Political life as a system of behavior. In D. Easton (Ed.), *A framework for political analysis* (pp. 23–34). Englewood Cliffs: Prentice-Hall.

Easton, D. (1965b). Theory and behavioral research. In D. Easton (Ed.), *A framework for political analysis* (pp. 1–22). Englewood Cliffs: Prentice-Hall.

Easton, D. (Ed.). (1965c). *A framework for political analysis*. Englewood Cliffs: Prentice-Hall.

Etzkowitz, H. (2003). Research groups as "quasi-firms": the invention of the entrepreneurial university. *Research Policy, 32*, 109–121.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy, 29*, 109–123.

European Commission. (2009). *The world in 2025. Rising Asia and socio-ecological transition*. Brussels: European Commission.

Fischer-Kowalski, M., & Haberl, H. (Eds.). (2007). *Socioecological transitions and global change. Trajectories of social metabolism and land use*. Cheltenham: Edward Elgar.

Foerster, H. V. (1979). Cybernetics of cybernetics. In K. Krippendorff (Ed.), *Communication and control in society* (pp. 5–8). New York: Gordon and Breach.

Foerster, H. V. (Ed.). (1984a). *Observing systems*. Seaside, California: Intersystems Publications.

Foerster, H. V. (1984b). On self-organizing systems and their environments. In H. V. Foerster (Ed.), *Observing systems* (pp. 2–24). Seaside, California: Intersystems Publications.

Foerster, H. V., & Zopf, G. W., Jr. (Eds.). (1962). *Principles of self-organization*. Oxford: Pergamon Press.

Freedom House. (2003). *Freedom in the world 2003: the annual survey of political rights and civil liberties*. Washington, D. C., New York: Freedom House.

Freedom House. (2004a). *Freedom in the world 2004: global freedom gains amid terror, uncertainty*. Washington, D.C., New York: Freedom House.

Freedom House. (2004b). *Freedom in the world country ratings (1972 through 2003)*. Washington, DC, New York: Freedom House.

Frieden, J. A., & Lake, D. A. (Eds.). (2000). *International political economy. Perspectives on global power and wealth*. Boston: Bedford.

Geuna, A., & Steinmueller, W. E. (Eds.). (2003). *Science and innovation. Rethinking the rationales for funding and governance*. Cheltenham: Edward Elgar.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge. The dynamics of science and research in contemporary societies*. London: Sage.

Grant, R. M. (2002). *Contemporary strategy analysis. Concepts, techniques, applications*. Oxford: Blackwell Publishing.

Gripp-Hagelstange, H. (1995). *Niklas Luhmann. Eine Einführung*. München: Wilhelm Fink.

Güttel, W. H. (2003). *Die Identifikation strategischer immaterieller Vermögenswerte im Post-Merger-Integrationsprozess. Ressourcen- und Wissensmanagement bei Mergers-and-Acquisitions*. München: Rainer Hampp.

Held, D., McGrew, A., Goldblatt, D., & Perraton, J. (1999). *Global transformations. Politics, economics and culture*. Cambridge: Polity Press.

Hemlin, S., Allwood, C. M., & Martin, B. R. (2004). *Creative knowledge environments. The influences on creativity in research and innovation*. Cheltenham: Edward Elgar.

Hooghe, L., & Marks, G. (2001). *Multi-level governance and European integration*. Lanham: Rowman & Littlefield Publishers.

IMD, International Institute for Management Development. (1996). *The world competitiveness yearbook 1996*. Lausanne: IMD.

IMD, International Institute for Management Development. (2003a). *The world competitiveness scoreboard 2003*. Lausanne: IMD. http://www02.imd.ch/documents/wcy/content/ranking.pdf.

IMD, International Institute for Management Development. (2003b). *IMD world competitiveness yearbook 2003. Overall rankings (1999–2003)*. Lausanne: IMD. http://www02.imd.ch/documents/wcy/content/pastranking.pdf.

IMD, International Institute for Management Development. (2004). *IMD world competitiveness yearbook 2004*. Lausanne: IMD. http://www02.imd.ch/documents/wcy/wcyBookTour.pdf.

Kaiser, R., & Prange, H. (2004). The reconfiguration of national innovation systems—the example of German biotechnology. *Research Policy, 33*, 395–408.

Krippendorff, K. (Ed.). (1979). *Communication and control in society*. New York: Gordon and Breach.

Kuhlmann, S. (1998). *Politikmoderation. Evaluationsverfahren in der Forschungs- und Technologiepolitik*. Nomos: Baden-Baden.
Kuhlmann, S. (2001). Future governance of innovation policy in Europe—three scenarios. *Research Policy, 30*, 953–976.
Larédo, P., & Mustar, P. (Eds.). (2001). *Research and innovation policies in the new global economy. An international comparative analysis*. Cheltenham: Edward Elgar.
Luhmann, N. (1988a). Neuere Entwicklungen in der Systemtheorie. *Merkur, 42*, 292–300.
Luhmann, N. (1988b). *Soziale Systeme. Grundriss einer allgemeinen Theorie*. Suhrkamp: Frankfurt am Main.
Lundvall, B.-Å. (1992). *National systems of innovation. Towards a theory of innovation and interactive learning*. London: Pinter Publishers.
Lundvall, B.-Å., & Tomlinson, M. (2002). International benchmarking as a policy learning tool. In M. J. Rodrigues (Ed.), *The New Knowledge Economy in Europe. A Strategy for International Competitiveness and Social Cohesion* (pp. 203–231). Cheltenham: Edward Elgar.
Lundvall, B.-Å., Johnson, B., Andersen, E. S., & Dalum, B. (2002). National systems of production, innovation and competence building. *Research Policy, 31*, 213–231.
Marin, B., & Mayntz, R. (Eds.). (1991). *Policy networks: empirical evidence and theoretical considerations*. Boulder: Westview Press.
Maturana, H. R. (1975). The organization of the living: a theory of the living organization. *International Journal of Man—Machine Studies, 7*, 313–332.
Maturana, H. R. (1985). *Erkennen: Die Organisation und Verkörperung von Wirklichkeit*. Vieweg: Braunschweig.
Maturana, H. R., & Varela, F. J. (1979). *Autopoiesis and cognition. The realization of the living*. Boston: Reidel.
Maturana, H. R., Varala, F. J., & Uribe, R. (1975). Autopoiesis: the organization of living systems, its characterization and a model. *Biosystems, 5*, 187–196.
Mayntz, R. (1988). Funktionelle Teilsysteme in der Theorie sozialer Differenzierung. In R. Mayntz, B. Rosewitz, U. Schimank, & R. Stichweh (Eds.), *Differenzierung und Verselbständigung. Zur Entwicklung gesellschaftlicher Teilsysteme* (pp. 11–44). Frankfurt am Main: Campus.
Mayntz, R., Rosewitz, B., Schimank, U., & Stichweh, R. (Eds.). (1988). *Differenzierung und Verselbständigung. Zur Entwicklung gesellschaftlicher Teilsysteme*. Frankfurt am Main: Campus.
Mowery, D. C. (2001). The United States national innovation system after the Cold War. In P. Larédo & P. Mustar (Eds.), *Research and Innovation Policies in the New Global Economy. An International Comparative Analysis* (pp. 15–46). Cheltenham: Edward Elgar.
National Science Board. (2002). *Science and engineering indicators 2002. Volume 1 and volume 2*. Arlington, VA: National Science Foundation.
Nelson, R. R. (1990). Capitalism as an engine of progress. *Research Policy, 19*, 193–214.
Nelson, R. R. (1993). *National innovation systems. A comparative analysis*. Oxford: Oxford University Press.
Nowotny, H., Scott, P., & Gibbons, M. (2001). *Re-thinking science. Knowledge and the public in an age of uncertainty*. Cambridge: Polity Press.
Nowotny, H., Scott, P., & Gibbons, M. (2003). Mode 2 revisited: the new production of knowledge. *Minerva, 41*, 179–194.
Nowotny, H., Scott, P., & Gibbons, M. (2006). Re-thinking science: mode 2 in societal context. In E. G. Carayannis & D. F. J. Campbell (Eds.), *Knowledge creation, diffusion, and use in innovation networks and knowledge clusters. A comparative systems approach across the United States, Europe and Asia* (pp. 39–51). Westport, Connecticut: Praeger.
OECD (1994). The measurement of scientific and technological activities. Proposed standard practice for surveys of research and experimental development. Frascati Manual 1993. Paris.
OECD (2002). Education policy analysis. Paris
OECD (2003a). Basic science and technology statistics. Paris
OECD (2003b). Education at a glance. OECD Indicators
OECD (2003c). Main science and technology indicators. Paris
Paslack, R. (1991). *Urgeschichte der Selbstorganisation*. Vieweg: Braunschweig.
Peters, B. G. (1998). *Comparative politics. Theory and methods*. London: Macmillan.
Pettigrew, A., Thomas, H., & Whittington, R. (Eds.). (2002). *Handbook of strategy and management*. London: Sage.
Pfeffer, T. (2001). *Das "zirkuläre Fragen" als Forschungsmethode zur Luhmannschen Systemtheorie*. Heidelberg: Carl-Auer-Systeme Verlag.
Rosewitz, B., & Schimank, U. (1988). Verselbständigung und politische Steuerbarkeit gesellschaftlicher Teilsysteme. In R. Mayntz, B. Rosewitz, U. Schimank, & R. Stichweh (Eds.), *Differenzierung und Verselbständigung. Zur Entwicklung gesellschaftlicher Teilsysteme* (pp. 295–329). Frankfurt am Main: Campus.
Roth, G., & Schwegler, H. (Eds.). (1981). *Self-organizing systems. An interdisciplinary approach*. Frankfurt am Main: Campus.
Sabatier, P. A. (1999). *Theories of the policy process*. Boulder: Westview Press.
Sabatier, P. A., & Jenkins-Smith, H. C. (Eds.). (1993). *Policy change and learning: an advocacy coalition approach*. Boulder: Westview Press.
Shapira, P., & Kuhlmann, S. (Eds.). (2003). *Learning from science and technology policy evaluation. Experiences from the United States and Europe*. Cheltenham: Edward Elgar.
Stichweh, R. (1988a). Differenzierung des Wissenschaftssystems. In R. Mayntz, B. Rosewitz, U. Schimank, & R. Stichweh (Eds.), *Differenzierung und Verselbständigung. Zur Entwicklung gesellschaftlicher Teilsysteme* (pp. 45–115). Frankfurt am Main: Campus.
Stichweh, R. (1988b). Inklusion in Funktionssysteme der modernen Gesellschaft. In R. Mayntz, B. Rosewitz, U. Schimank, & R. Stichweh (Eds.), *Differenzierung und Verselbständigung. Zur Entwicklung gesellschaftlicher Teilsysteme* (pp. 261–293). Frankfurt am Main: Campus.
Tassey, G. (2001). R&D policy models and data needs. In M. P. Feldman & A. N. Link (Eds.), *Innovation policy in the knowledge-based economy* (pp. 37–71). Boston: Kluwer Academic Publishers.
Umpleby, S. A. (1990). The science of cybernetics and the cybernetics of science. *Cybernetics and Systems: An International Journal, 21*, 109–121.
Umpleby, S. A. (1997). Cybernetics of conceptual systems. *Cybernetics and Systems: An International Journal, 28*, 635–652.
Umpleby, S. A. (2002). Should knowledge of management be organized as theories or as methods? In R. Trappl (Ed.), *Cybernetics and systems 2002. Volume 1* (pp. 492–497). Vienna: Austrian Society for Cybernetic Studies.

Willke, H. (1989). *Systemtheorie entwickelter Gesellschaften. Dynamik und Riskanz moderner gesellschaftlicher Selbstorganisation*. München: Juventa Verlag Weinheim.
Willke, H. (1997). *Supervision des Staates*. Suhrkamp: Frankfurt am Main.
Willke, H. (1998). *Systemtheorie III: Steuerungstheorie*. Stuttgart: Lucius & Lucius Verlagsgesellschaft.
World Bank (2002). World development indicators 2002. Washington, DC
Yergin, D., & Stanislaw, J. (2002). *The commanding heights. The battle for the world economy*. New York: Simon & Schuster.