KNOWLEDGE CREATION, DIFFUSION, AND USE IN INNOVATION NETWORKS AND KNOWLEDGE CLUSTERS

A Comparative Systems Approach across the United States, Europe and Asia

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PREFACE

Book Motivation and Scope

In this book, we attempt to address some fundamental "What" and "How" questions in both a conceptual and an applied manner.

These questions include:

1. What is knowledge in research and technology development and deployment?
2. What is the role of emerging, dynamically adaptive, and transdisciplinary knowledge and innovation systems and infrastructures (such as innovation networks of networks and knowledge clusters of clusters) in the science enterprise?
3. What are the implications and lessons learned for science and technology public sector policies and research and development private sector practices?
4. How do the emerging network-centric and cluster-based knowledge infrastructures shape and become simultaneously shaped by science and technology policies and practices?
5. How does the organizing of the science enterprise according to "Mode 3"—namely, dynamically adaptive, continually reconceptualizing, redefining, and recombining systems and their elements, functions, and borders—impact the science enterprise and become in turn shaped by its evolving dynamics?
6. What policy learning should result from our collection of transatlantic perspectives?
7. Finally, could "Mode 3" serve as a means of inferring and identifying meaningful patterns in the chaotic dynamics of the ebb and flow of knowledge or, in other words, the punctuated processes of knowledge creation, diffusion, and use within and around the science enterprise?

In this book, we have attempted to compile an eclectic configuration of perspectives and treatises of mutually complementary and reinforcing themes on science and technology (S&T) as well as on research and development (R&D).

We hope that it will prove of interest and use for S&T policymakers, R&D managers, business decision makers, and students of innovation and knowledge dynamics alike.

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"Mode 3"

Meaning and Implications from a Knowledge Systems Perspective

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Under the comprehensive umbrella term of *Mode 3* our interest is to put a conceptual link between systems and systems theory on the one hand, and their application to knowledge on the other hand. 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. Leveraging systems theory for innovation concepts, one can draw a referential line between the elements of a system and clusters (innovation clusters) and the self-rationale of a system and networks (innovation networks). One advantage of this approach is that it makes the tools of systems theory effectively available for research about innovation. Also from original research about the European Union the concept of a multilevel hierarchy promises conceptual opportunities. Further integrating systems theory, we can speak of multilevel systems of knowledge (following different levels of aggregation) and multilevel systems of innovation (also following different levels of aggregation). The popular and powerful concept of the national innovation system is being chronically challenged by ongoing processes of supranational and global integration. Conceptually unlocking the national innovation systems in favor of a broader multilevel logic implies further accepting the existence of national innovation systems, but, at the same time, emphasizing also 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 and should be understood as a contribution to the general discourse.

Favoring a conceptual point of departure, the analysis is carried by three conceptual research questions. First of all, elaborating an interface between concepts of systems and concepts of networks (or innovation networks) claims analogies between (1) elements (parts) of a system *and* clusters and (2) the self-rationale of a system *and* 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 "multilevel" 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 multilevel systems of knowledge or, when an emphasis should be put on innovation, to apply the concept of multilevel 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 chapter is structured into four major sections. In the first section we shortly refer to a first introduction and relation of knowledge, systems, and systems theory, indicating opportunities of a mutual leveraging. The second 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 can not 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 system 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 third section, the application of systems and systems theory to knowledge and innovation is pursued in more concrete terms. Explicitly, the appropriateness of a multilevel hierarchy is being tested. The ramifications of such a multilevel design can follow the logic of either multilevel systems of knowledge or multilevel systems of innovation. In advanced policy terms, a political system—which operates for governing a society—aims to influence the economy not only through economic policy but also through innovation policy, which reflects the knowledge base of a society and its economy. An economic policy, perhaps, does not take the knowledge base that comprehensively into account. In the context of the conclusion, under the umbrella term of

Mode 3, we again summarize our lines of arguments, by setting up a list of short propositions.

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 competitively, but also complementarily, 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, Thomas, and Whittington, 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 conceptualeconomization 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; 2003b; 2004; 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. Noneconomic 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, 2004b), 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. W. Ross Ashby (1965, p. 16), for instance, emphasizes that a system represents a set of variables, selected by an observer.[2] Humberto R. Maturana and Francisco J. Varela (1979) interpret a system as a definable set of components. Heinz von 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, Stuart A. 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, the systemic notions of *self-organization* and *self-organizing systems* are expressed

as 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, Varela, and Uribe, 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; also see 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*: and systems have a mode of operation, a self-rationale (logic, self-logic) that 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: 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, Stefan 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, 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, and 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 (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"; (4) and "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," that demands on and support for a political system function as inputs; decisions and actions of a political system function as outputs. Gabriel A. Almond (1956, pp. 393–394) interprets a political system as a system of "action." Thus, the smallest unit is the role, representing the pattern of participation of an actor in an interactive process. Consequently, a political system can be conceptualized as a set of interacting roles or as a structure of roles.

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. Niklas Luhmann (1988a, p. 299), for instance, defines "communication" as the most basic element of a social system. Helmut Willke (1989, p. 25) also underscores that communication (and not action) constitutes the basic element of the operation mode of social systems. This implies that society cannot be understood as an aggregation of individuals, and that 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 opposition) 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. *Consistency* 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, 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 to what degree can it be adapted and improved?

The number of systems (How many systems?) and the internal and external configuration of social (societal) systems, as proposed by observers, *are 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, that it is useful to speak about a political, economic, education, research, science and technology (S&T), and innovation system. But to make a realistic judgment, 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 a social system using communication as its basic element, which also leverages analytical advantages. 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 that 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 its 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 coexistence (coevolution) of different systems theoretical concepts. The coexistence paradigm may imply, depending on the application needs, that 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 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 either can be accepted 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., 2002; Nowotny, Scott, and Gibbons, 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 on the other? 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 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 in a larger system, could also be interpreted as an element or as a cluster of that metasystem. Such a 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 for whether it qualifies as a microsystem (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 Figure 1.1 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. The *governance of society* can be defined as a self-rationale of politics: through policy (policymaking) 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 buildup 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

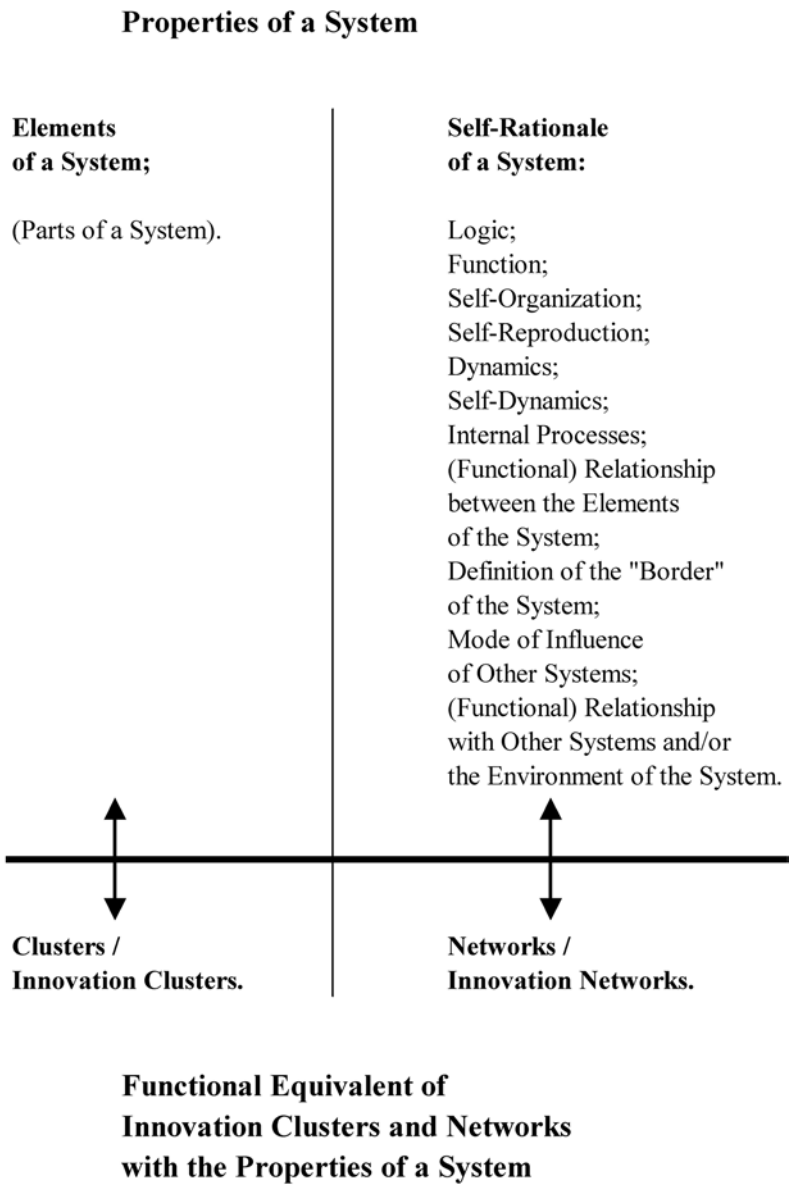

FIGURE 1-1. A Formalized Definition of Systems and of Innovation Clusters and Innovation Networks
Source: Authors' own conceptualization.

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?

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 theoretical knowledge, being produced by the knowledge system, has the potential of supporting and enhancing the performance of the other systems of a society, which are 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: policymaking 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 used by the other systems of a society to support their processes and performances. If the innovation system is 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 aggregate term or concept. Referring analytically to "multilevel systems" can leverage important conceptual advantages and benefits. Conceptual multilevel architectures already are being used frequently for analyzing and evaluating the supranational structures of the European Union (EU). In fact, speaking about *multilevel governance* originates from research about the EU (Hooghe and Marks, 2001; Bomberg and Stubb, 2003, p. 9). One could also reflect about multilevel legislation of the EU.[8] Obviously, this logic of multilevels may also be applied to other research areas and to alternative macropolitical entities with a federal structure, for example, the United States. This would introduce interesting research designs, such as comparing multilevel EU and U.S. and to search for possible similarities and differences.

Evaluated from an analytical perspective, it appears promising to import this EU-based research concept of multilevels and to modify it specifically, so that it fits our research interests about knowledge. The logic of multilevels implies that *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., subnationally, nationally, supranationally, or transnationally). If we are interested in displaying the knowledge system in the context of the architecture of multilevel systems, then we can propose two (functional) axes: an education axis (OECD, 2002, pp. 35–63; 2003b) and a research axis. In the specific institutional context of universities,

following the Humboldtian tradition of emphasizing 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, pp. 117–118). The research axis, as proposed here, could aggregate from research, to science and technology (S&T), and to innovation (see Figure 1.2). A broader term for research is research and experimental development (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, pp. 4–29, and vol. 2, pp. A4-7 to 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 metasystem*).

Referring to innovation, there are two issues of further concern: (1) *Is innovation research-oriented and biased in favor of research (and disfavoring education)?*

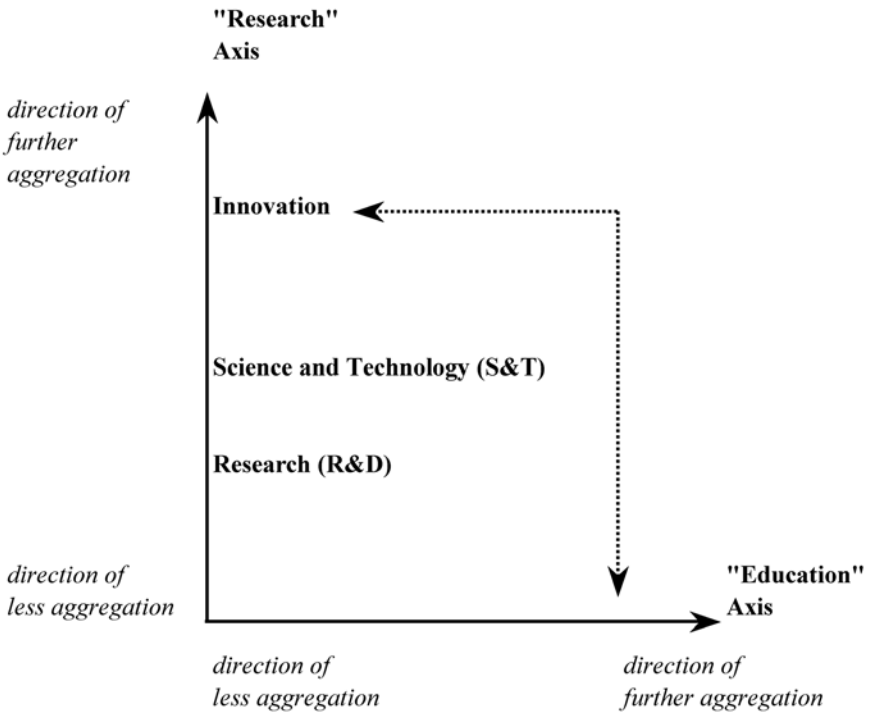

FIGURE 1-2. Multilevel Systems of Knowledge
Source: Authors' own conceptualization.

On the one hand, we conventionally associate innovation more closely to R&D (S&T) than to 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; therefore, 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 into interchangeable terms.

Emphasizing the "research axis" of knowledge, we can apply more specifically the multilevel logic by referring to *multilevel systems of innovation* (Campbell, see Chapter 5, this volume) and propose two particular directions of further aggregation (see Figure 1.3). Functionally, the aggregation may move from R&D to S&T and finally to innovation; and 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 multilevel 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 with Lundvall et al., 2002; Lundvall and Tomlinson, 2002; Nelson, 1993; Larédo and Mustar, 2001; Mowery, 2001; Bozeman and Dietz, 2001). The existence and 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 in two ways: 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 multilevel systems of innovation. Lundvall (1992, p. 4) emphasizes an understanding of modern Western nation-states as "engines of growth." Also Richard R. 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 the primary objective for a public innovation policy the enhancement of the competitiveness of an economy.

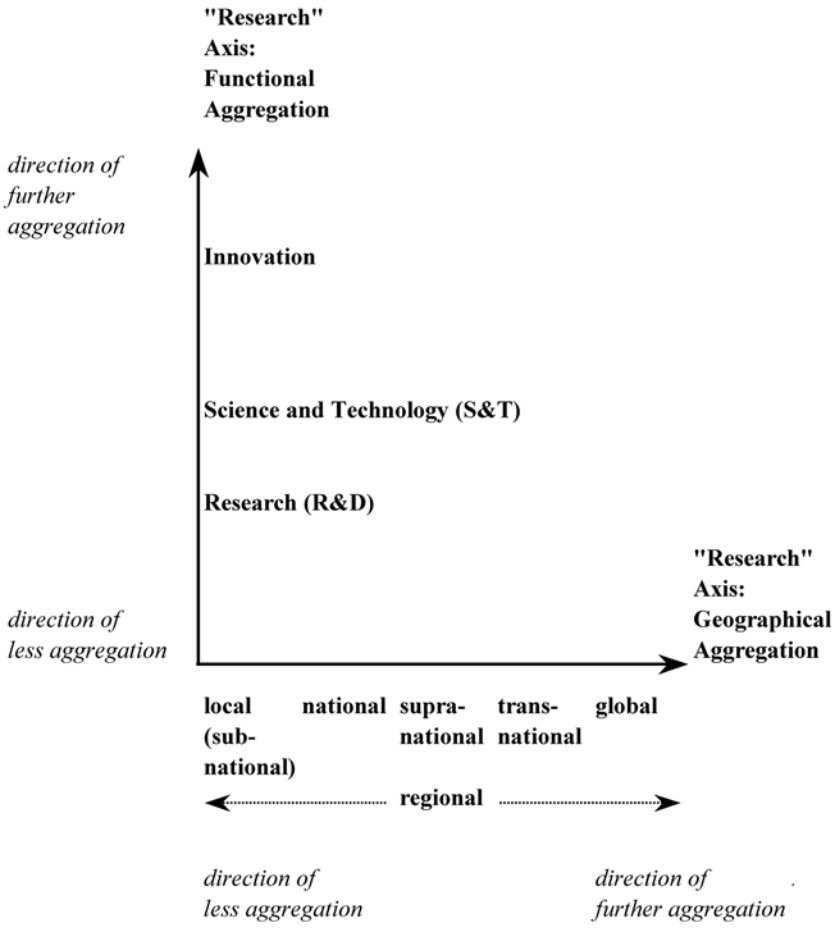

FIGURE 1-3. Multilevel Systems of Innovation: Functional and Geographical Aggregations
Source: Campbell (2004).

The functional aggregation of the "research axis" of knowledge allows for different options of how research (R&D), science and technology (S&T), and innovation could be related to each other (see Figure 1.4). 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, 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) consumes a larger percentage of GDP than all of the R&D expenditure (OECD, 2003c, Table 2; World Bank, 2002).

2. *R&D S&T, 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 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 retypologizing and reconceptualizing common knowledge structures and processes.
3. *R&D (S&T), 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, and thus there arises no need for a specific or systemic placement of S&T versus R&D and innovation.

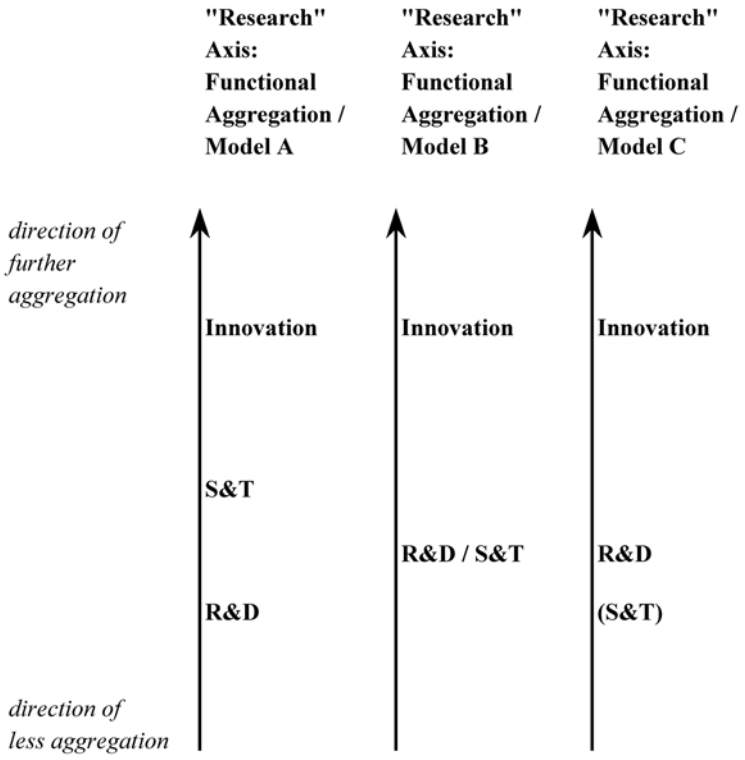

FIGURE 1-4. Multilevel Systems of Innovation: Different Functional Aggregations
Source: Authors' own conceptualization.

> Those components of S&T that display a relevance to R&D, are incorporated as a subset (subsystem) into the R&D system. Consequently, leftover 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 Figure 1.5). 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

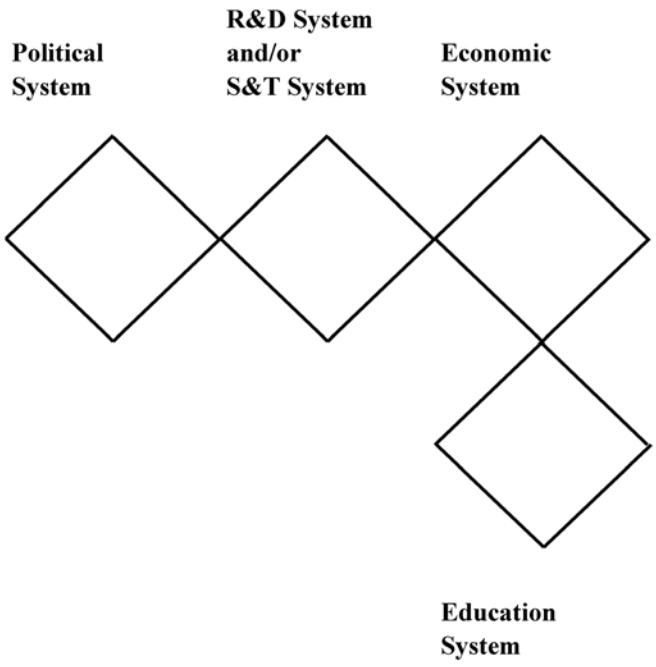

FIGURE 1-5. Different Societal Systems
Source: Authors' own conceptualization.

displays the following properties and patterns of interaction with the other systems of society (see Figure 1.6):

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

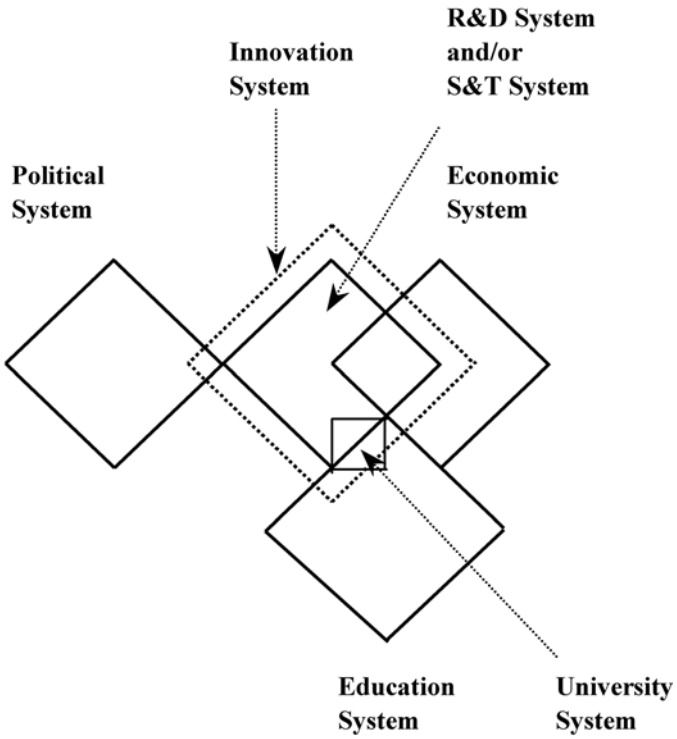

FIGURE 1-6. Different Societal Systems: Placement of the Innovation System
Source: Authors' own conceptualization.

may want to leverage an influence on processes in different social (societal) systems (see Figure 1.7). 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

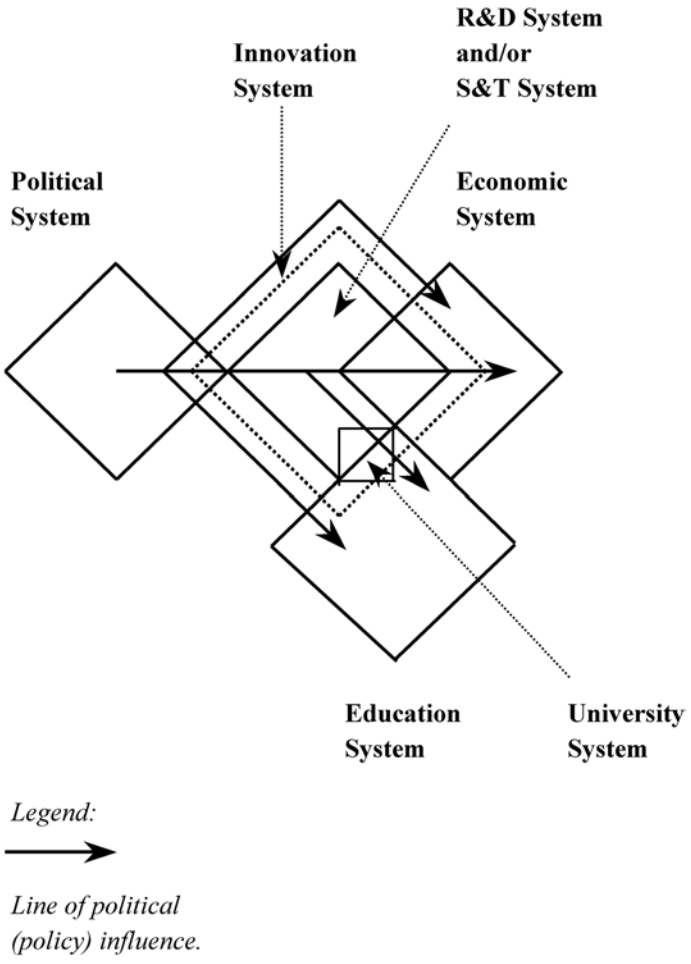

FIGURE 1-7. Different Societal Systems: Lines of Political (Policy) Influence
Source: Authors' own conceptualization.

more effective in supporting economic performance than traditional economic policy. In advanced societies *the indirect 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).

CONCLUSION: 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 by 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:

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 whether a systems design can convince other "observers," whether it can be usefully and practically applied, and whether it is capable of "conceptual learning."
6. Systems theory, in principle, is open to 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 theoretical development of knowledge systems concepts will be further 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 multilevel systems to knowledge and innovation appears promising. Consequently, one can speak of "multilevel systems of knowledge and/or multilevel 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 to integrate and reconcile systems and networks, thus creating conceptual synergies.

NOTES

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. Helmut 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, Kornberg, and Mishler, 1988).

8. Multilevel *governance* of the EU represents a more frequently cited research objective than focusing on the EU's multilevel *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 Figure 1.4.

12. Typologized as Model B in Figure 1.4.

13. Typologized as Model C in Figure 1.4.

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

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