Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation and the Environment Relate To Each Other?

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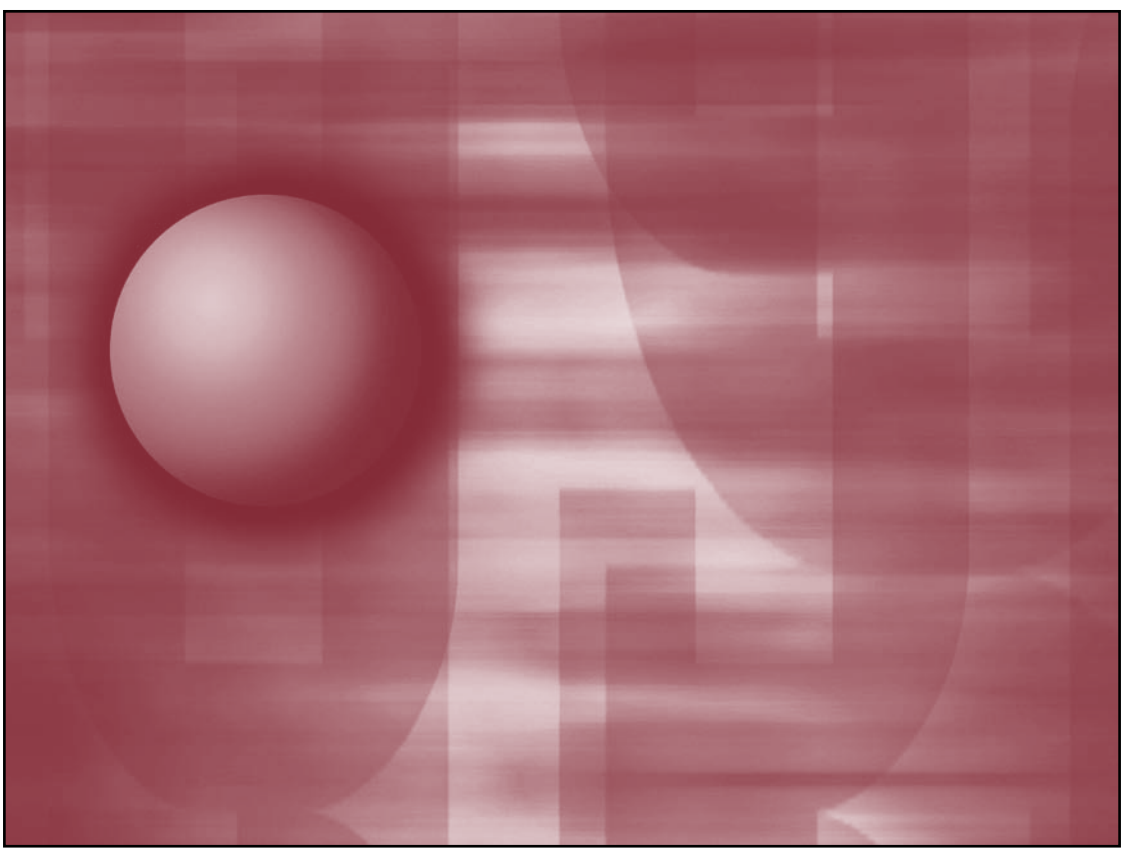

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Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation and the Environment Relate To Each Other?

A Proposed Framework for a Trans-disciplinary Analysis of Sustainable Development and Social Ecology

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ABSTRACT

This article develops an inter-disciplinary and trans-disciplinary framework of analysis that relates knowledge, innovation and the environment (natural environments) to each other. For that purpose the five-helix structure model of the Quintuple Helix is being introduced. The Triple Helix model, designed by Etzkowitz and Leydesdorff (2000), focuses on the relations of universities, industry and governments. The Quadruple Helix (Carayannis & Campbell, 2009) blends in the perspective of a media-based and culture-based public. The Quintuple Helix finally frames knowledge and innovation in the context of the environment (natural environments). Therefore, the Quintuple Helix can be interpreted as an approach in line with sustainable development and social ecology. "Eco-innovation" and "eco-entrepreneurship" should be processed in such a broader understanding of knowledge and innovation.

Keywords: *Eco-Entrepreneurship, Eco-Innovation, Mode 3, Quadruple Helix, Quintuple Helix, Social Ecology, Sustainable Development*

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1. INTRODUCTION: THE DRAFTING OF A PROPOSED FRAMEWORK FOR A TRANSDISCIPLINARY ANALYSIS OF SUSTAINABLE DEVELOPMENT AND SOCIAL ECOLOGY

This article is being guided by the following key research question: *How do knowledge, innovation and the environment (natural environment) relate to each other?* Advanced or advancing knowledge and innovation systems (across a multi-level architecture of sub-national, national and trans-national levels) could be characterized by a pluralism of knowledge and innovation modes. In fact, a certain co-evolution or congruence between advanced knowledge (innovation) systems and advanced (high-quality) democracy may be stated, postulating that advanced knowledge and innovation take over some of the structural elements of a democracy, such as pluralism and diversity.

Referring to the research question as conceptual point of departure, our final objective is to design and to propose for discussion an interdisciplinary and transdisciplinary framework of analysis for sustainable development and social ecology that exactly ties together knowledge, innovation and the environment. This model we will call the Quintuple Helix, a five-helix model that embeds the Triple Helix and the Quadruple Helix. Triple Helix focuses on knowledge production and use in context of "university-industry-government relations" (Etzkowitz & Leydesdorff, 2000). Quadruple Helix extends the Triple Helix by adding the helix of a "media-based and culture-based public" (Carayannis & Campbell, 2009). The Quintuple Helix contextualizes the Triple Helix and Quadruple Helix by further adding on the helix of the "environment" ("natural environments"). The Quintuple Helix thus offers an analytical frame or framework where knowledge and innovation, on the one hand, are being connected with the environment, on the other. By this the Quintuple Helix addresses and incorporates features of "social ecology". Furthermore, the Quintuple Helix also can be seen as a framework for interdisciplinary analysis and transdisciplinary problem-solving in relation to sustainable development, because a comprehensive understanding of the Quintuple Helix clearly implies that knowledge production and use as well as innovation must be set in context or must be contextualized by the natural environment of society.

The analytical program of work of this article will be as follows. In Chapter 2 we present an overview of key concepts on knowledge and innovation, also attempting to trace their conceptual evolution. Pivotal are innovation and the national or multi-level innovation systems. Innovation overlaps or even coincides with the application, diffusion and use of knowledge. Chapter 3 summarizes the knowledge and innovation concepts of Mode 1 and Mode 2 (Gibbons et al., 1994), Triple Helix, and reviews in detail Mode 3 and Quadruple Helix (Carayannis & Campbell, 2009). More particularly, we focus in this article section also on phenomena or trends of a continuously broader contextualization of knowledge and on the broadening of some concepts of democracy. The proposition would be to state a co-evolution (or certain congruence) between knowledge and (high-quality) democracy. In the conclusion, Chapter 4, we finally introduce the Quintuple Helix in reflection of our principal research question.

2. WHAT ARE KNOWLEDGE AND INNOVATION? OVERVIEW OF CONCEPTS AND THE EVOLUTION OF CONCEPTS

The Wikipedia definition of knowledge, also cross-referencing to the Oxford English dictionary, lists as a crucial element of knowledge "the theoretical or practical understanding of a subject". The Wikipedia definition furthermore associates knowledge to "expertise, and skills" that a person may have gained either by experience or through education.[1] Currently, there exists a general belief (indicated by numerous publications) that knowledge becomes increas-

ingly important for society, the economy and also democracy. Advancements and a sustainable development of society and the economy appear unlikely without leveraging and enhancing knowledge. This adds plausibility for using concepts such as the *knowledge-based society, the knowledge-based economy* and the *knowledge-based democracy* (Carayannis & Campbell, 2009, p. 224). Perhaps there is even a shift not only to speak of the knowledge-based society and economy, but of a *knowledge society* and a *knowledge economy per se* that is being endogenously driven by knowledge. The concept of a *knowledge democracy* consequently complements such propositions.

One could set up two conceptual axes, trying to model knowledge and different types of knowledge in greater detail (Campbell 2009). One axis may polarize "codified" (explicit) with "tacit" knowledge (see, for example, Gibbons et al., 1994, pp. 167-168). Tacit knowledge represents an experience-based knowledge, whereas codified knowledge is written down in the one or other form. The other axis could polarize knowledge that is less dependent or more dependent on the context: a possible conceptual wording would juxtapose (compare) knowledge that is "independent of users and/or appliers" with a knowledge that is "dependent of users and/or appliers". Here differing degrees of *contextualization of knowledge* become manifest and evident. The closer a knowledge places to "codified" and "user-independent", the more this knowledge is "information". Contrarily, the closer a knowledge places to the poles of tacit and user-dependent, the more various types of "competencies" are being expressed. Competencies again stretch from professional or expert knowledge (know-how) to social competencies (soft skills, intercultural competencies) and competences of the personality.[2] Higher education teaching, currently, stresses the notion of "desired learning outcomes" that become visible as competencies acquired by students. Kathleen E. Schafer (2008, p. 276) discusses prospects of a new "era of balanced leadership" in context of political leadership: this clearly would require mature social competences on the part of politicians.

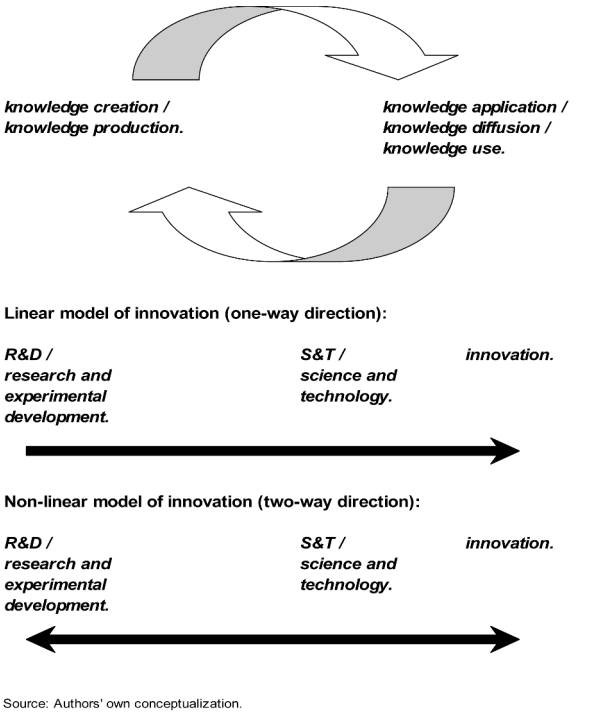
Complementary to the above depicted modeling of knowledge based on the two axes of codified/tacit and user-independent/user-dependent, an alternative modeling could focus more on aggregated features of knowledge, emphasizing systemic aspects and embedding knowledge in a larger societal context. Here several axes (or dimensions) may be discussed for a broader systemic approach (see also Carayannis & Campbell, 2009, pp. 214-215): (1) research, R&D (research and experimental development): conventionally, research is being distinguished in basic research, applied research and experimental development (OECD, 1994, p. 29; 2002, p. 30)[3]; (2) education: education can refer to primary education, secondary education and tertiary education, where tertiary education is the education being offered by universities or the higher education system (containing all HEIs, the higher education institutions) in more general; (3) innovation; (4) different spatial axes, which represent geographic, geographic-spatial or spatial-political concepts, distinguishing between the sub-national (local), national and trans-national (supranational, global) levels; (4) perhaps also other non-spatial axes would be possible, for example "creativity" and attempts of displaying and measuring creativity.

Focusing on research (R&D), the so-called "linear model of innovation" was prevailing for a long time. This linear model leverages on the fact that the universities (the HEIs) concentrate on basic research (often or mostly publicly funded), while firms concentrate on experimental development (often or mostly privately financed) (for the U.S., see National Science Board, 2008, Volume 1, Chapter 4, pp. 14-15). Applied research often is being seen to position itself "between" basic research and experimental development. This is carried by the underlying understanding that ideas, products or services start as a basic research in context of universities, and gradually diffuse time-lagged into society and the economy. Firms selectively pick up some basic research results and convert these through applied research and

experimental development into commercially profitable products or services for the market. Challenges obviously are how to design systematically interfaces and linkages between publicly funded basic university research and the privately funded firm-based commercialization of research for profitable business activities. Potential risks (or market failures) could be a private under-investment of research or of basic research (Tassey, 2001, pp. 42, 61-64). Kline and Rosenberg (1986) and Miyata (2003, p. 715) describe the linear model as a sequence of the following concepts: basic research; applied research; development; production; and marketing. This "simple linear model" Narin et al. (1997, p. 318) summarize as: "The notion that technology springs from a scientific base was originally embedded in the 'linear model' of innovation: from basic research through applied research continuing into technology and resultant economic benefit." Lundval (1992, p. 13) paraphrases this also as a "linear model of technical change". Interestingly, this linear model of innovation often is being closely associated with Vannevar Bush and his pivotal report *Science The Endless Frontier* (Bush, 1945, see the chapter on "The Importance of Basic Research"). Narin et al. (1997, 317-318) claim this implicitly and in substance this association of the linear innovation model to Bush appears correct. At the same time, however, it should be mentioned that Bush himself, in his famous text, not even mentions the word "innovation" (as can easily be verified by an electronic word search command). Currently, the linear innovation models are being challenged by non-linear innovation models that stress the importance of a simultaneously coupling of basic (university) research with the commercial R&D applications of firms in the business sectors. Kline and Rosenberg (1986) propose to introduce here a so-called "chain-linked model" (see also Miyata 2003, p. 716). The underlying concept is to cross-link mutually and directly basic university research and the applied R&D commercialization in firms, but also to foster basic business research and applied research in universities (Carayannis & Campbell, 2009, p. 209-211). In metaphoric terms, the *first-then* ("zuerst-dann") relationships in the linear model are being extended by *simultaneously-simultaneously* ("gleichzeitig-gleichzeitig") relations and network configurations in non-linear knowledge arrangements (Campbell, 1995, p. 31). Originally *"sequenced"* processes are being *"parallelized"* (Campbell and Güttel, 2005, pp. 167-168; Carayannis & Campbell, 2009, p. 217).

In a systemic (social, societal) understanding, knowledge creation and knowledge production often are associated more closely to research, basic research and the sciences, thus a function of universities (HEIs), embedded in a national or multi-level innovation system, is to focus exactly on knowledge creation and knowledge production.[4] Of course, also other organizations, such as firms, can focus and specialize on knowledge production. Knowledge creation and production are being complemented by the concepts of knowledge application, knowledge diffusion and knowledge use. This could imply to think of *two sides* of knowledge: knowledge creation and production on the one hand, and knowledge application and use on the other (see Figure 1). Knowledge application and knowledge use already overlap substantially with the concept of innovation that could be defined as: *innovation leverages knowledge for knowledge application, diffusion and use, and thus translates knowledge into application*. This definition of innovation has references to knowledge and leaves the question open (and unresolved), whether there could be an innovation without knowledge (Carayannis & Campbell, 2009, pp. 213-214). There exists basic research[5], "pure research" or "pure science"[6] that is not interested in issues of application and innovation. Whether an innovation, for example some forms of management innovations in business that are not R&D or technology-based, can qualify as an innovation without linkages to knowledge, could be debated. But there can be innovations that are not connected to basic research (for an overview on innovation, see Shavinina, 2003). S&T, science and technology, also spans to both poles of knowledge: science

Figure 1. Conceptualization of (a possible) relationship of knowledge and innovation



Source: Authors' own conceptualization.

locates more closely to knowledge creation and production, while technology associates closer to knowledge application, use and innovation. Technology may be interpreted as a type of innovation (often with a technological hardware component), interested in converting science (basic research) into commercial application and use.

The concept of the "national system of innovation" (or national innovation system) was developed by the two scholars Bengt-Åke Lundvall (1992) and Richard R. Nelson (1993). This approach contextualizes innovation in the context of societies at the level of nation states. Lundvall (1992, p. 2) offers the following key definition: "It follows that a system of innovation is constituted by elements and relationships which interact in the production, diffusion, and use of new, and economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state." For Lundvall (1992, p. 1) knowledge constitutes the "most fundamental resource" and learning the "most important process" in a modern economy. In that line of argument we might postulate the following relationship: (1) innovation leverages or translates knowledge into application and use; (2) applied or used knowledge always or often or at least potentially may also be used economically for economic purposes, for generating financial revenues and profit; (3) thus innovation also converts (potentially) knowledge creation and production into economic activities.

Lundvall (1992, pp. 3-4) acknowledges that processes of globalization and regionalization weaken the national systems: "international specialization was often reflected in a regional specialization within the countries."[7] Despite the recognition of such sub-national and trans-national innovation processes, Lundvall emphasizes that national patterns still exist and still play a key role, providing continued plausi-

bility for the concept of the national innovation system: "… we believe that national systems still play an important role in supporting and directing processes of innovation and learning." The modern nation states acted as "engines of growth" (Lundvall, 1992).[8] Stefan Kuhlmann (2001, p. 972) also stresses the dominance of nation-state-structures for the current political systems: "political systems are still nationally based, but are, in Europe, spreading increasingly both to the transnational and to the regional level". Lundvall (1992, p. 5) diagnoses that the concepts of the national innovation systems "already entered the everyday vocabulary of policymakers". This supports opportunities of and for a cross-country learning. Interestingly, depending on the level of aggregation or the level of analysis, as Lundvall (1992, p. 7) says, innovation systems might differ in their ambitions and goals: the national level emphasizes "international competitiveness of the national economy"; at the level of international organizations the efforts concentrate on "strengthening economic growth" and "avoiding international conflicts"; at the global level ambitions focus on the "long term survival of the global economy" that depend on "ecological sustainability" and a "reduction of the extreme social inequality". In the conceptual framing of Lundvall, moving bottom-up upward, the forces of learning gain in importance.

In further reflection of the concept of the *national innovation system,* now the concept of *multi-level systems of innovation* has entered the discourse.[9] Multi-level systems of innovation may be based on a geographic, spatial, geographic-political or spatial-political understanding, juxtaposing, for example, sub-national, national and trans-national levels in one framework. Kuhlmann (2001, pp. 970-971, 973) speaks of "multi-level, multi-actor systems" and of "multi-level innovation policy". Robert Kaiser and Heiko Prange (2004, pp. 395, 405-406) use the terms of a "multi-level governance system" and discuss perspectives "from national to multi-level innovation systems". In addition to such "spatial axes", a multi-level system of innovation also could be based on "non-spatial axes", or, to be more precise, on non-spatial axes of knowledge aggregation (Campbell, 2006, p. 70; Campbell & Carayannis, 2006, pp. 11-14; Carayannis & Campbell, 2009, pp. 214-216). For example: innovation may be regarded as the highest form of knowledge aggregation of research (of the axis of research). Conventionally understood, technology is broader than research, and innovation again is broader than technology (Campbell & Güttel, 2005, p. 154; Carayannis & Campbell, 2006, pp. 14-15). In that line of argument, innovation may also qualify as the broadest aggregation of knowledge of education (the axis of education). Rephrasing the above said, a multi-level innovation system could be based on several spatial and non-spatial axes that display different levels of (spatial and non-spatial) knowledge aggregation.

Earlier in this chapter we proposed for innovation the definition of *converting knowledge creation and production to knowledge application, diffusion and use*. From that logic it follows that, in principle, everything may qualify as belonging to a national (or multi-level) system of innovation that supports such processes and structures of knowledge application. How narrowly or how broadly (national) innovation systems are being defined, therefore, will differ and is interdependent with a concrete historical context. Depending on whether we believe or not believe in that an institution or structure should be associated to knowledge and innovation processes, this institution or structure would play a function for innovation and thus would be a part (or not) of the (national) innovation system. In a society, where knowledge is being associated primarily with knowledge creation and production in context of universities and higher education systems, and only few structural linkages to society and the economy, the "extension" of a national innovation system is more limited. In a society and economy, emphasizing knowledge application, diffusion and use, the national innovation system obviously "broadens" and becomes increasingly powerful. Even culture (at least partially) could belong to the innovation system. Kuhlmann (2001, pp. 954, 958, 967), for

example, speaks of "innovation cultures", thus going clearly beyond a primarily institutional approach. In the words of Lundvall (1992, pp. 12-23): "In different historical periods different parts of the economic system, or different inter-faces between subsystems, may play a more or less important role in the process of innovation".

The more knowledge application and knowledge use represent issues of interest, in a practical sense but also theoretically and conceptually, the more encompassing the national or multi-level innovation systems behave. The ultimate ratio would be that of a society or an economy that convert to a full and real knowledge society and knowledge economy, where almost everyone acts also as a knowledge worker, and with an innovation system stretching far out and into the peripheries of society. Kuhlmann (2001, p. 972) accentuates aspects of a "co-evolution" between the "political systems" and "innovation systems". The innovation system also could be understood as a system that cross-cuts into other systems of society, such as the political system, the research (R&D) system, the education system and the economic system. The political system may try to influence the economic system directly with economic policy-making. Alternatively, the political system could be inclined to impose effects on the economic system via innovation policy. Innovation policy, then, would be an economic policy that cross-references to knowledge and that leverages knowledge: "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" (Carayannis & Campbell, 2006, pp. 18, 16-19).

What results, so the proposition, are forms of an "indirect coupling" between politics and the economy. One could even hypothesize that the more advanced a society and economy progress, we should expect at least a partial conversion or transformation from economic policy to innovation policy. Represents innovation policy a further developed form of economic policy in context of the knowledge society and knowledge economy? "For an advanced, knowledge-based democracy, knowledge and innovation policies qualify as a superior next-stage development of 'old' economic policies, and the degree of conversion from economic to knowledge and innovation policies may serve as a 'maturity test' for governance and policy-making" (Carayannis & Campbell, 2007, pp. 87-88). However, we also want to stress that there are manifold opportunities for innovation policy that are not necessarily associated with economic activities.

While "innovation" could be modeled as a top-down process (systemically linking knowledge production to knowledge application), "invention", on the other hand, may be modeled as a bottom-up process. "Creativity" can move top-down as well as a bottom-up (Carayannis & Campbell, 2007, p. 85). The Wikipedia definition of creativity emphasizes the "generation of new ideas or concepts" and "new associations of the creative mind between existing ideas or concepts". [10]*This implies that the creation and production of new knowledge already qualify as examples of and for creativity*. Further propositions are (see again Figure 1): (1) *Creativity in knowledge creation and production is being linked by innovation to knowledge application and use in the wider society.* (2) *Without creativity, the knowledge input for the innovation process might face serious constraints.* (3) *In addition, creativity can also focus on improving processes of innovation on the application and use "side of knowledge".* Creativity management is interested in developing, controlling, regulating, and optimizing creativity for organizations (Dubina, 2005; 2007; 2009). The concept of the "creative knowledge environments" (CKEs) focuses on those environments and contexts that foster creativity in producing new knowledge and new innovations (Hemlin et al., 2004).[11] That line of thinking emphasizes to interpret

new knowledge as a creative knowledge.[12] Or to rephrase: new knowledge qualifies as a potential candidate for a creative knowledge. This "construction" of creativity as a new knowledge or a new production of knowledge obviously also brings "art" into play. Fiction or science fiction may serve as stimulators for creative ideas, with the potential of being later transformed, at least partially (and of course not always), into new knowledge creation and production. *We can also call this the creativity of knowledge creation.*

2.1 Summary of Chapter 2

Analyses of knowledge originally focused more on the knowledge creation and production. Universities and other HEIs were at the core, delivering basic research and educational functions. Innovation as a concept was either not mentioned literally (for example, Bush, 1945) or had a conservative connotation. Joseph Schumpeter, for example, does not make a strong connection to knowledge in his definition of innovation, as is being expressed by the following quote about innovation (taken from Miyata, 2003, p. 715): "(1) an introduction of new products (or products with improved quality); (2) new method of production; (3) new markets and distributing channels; (4) new sources of supply and inputs; (5) new organizations of an industry" (Schumpeter, 1934, p. 66).

Later approaches emphasize the connection of innovation to knowledge by interpreting innovation as a knowledge application, diffusion and use. Now, innovation is being regarded as essential for the leveraging and "fuelling" of knowledge into the society and economy of a knowledge society and a knowledge economy. Innovation carries knowledge far into society, fills all of society with knowledge. Often (not always) this applied knowledge has roots in processes of knowledge creation and production in types and arrangements of basic research. *This inclusion of innovation into the conceptualization of knowledge has the effect that the concept of knowledge is being "broadened" and contextualized by society.* Knowledge is also a social process. Without references to society and social applications and the problem-solving potentials of knowledge, knowledge cannot be understood sufficiently anymore. Knowledge application and use feed back directly into knowledge creation and production (non-linear innovation models). Concepts such as the national systems of innovation (Lundvall, 1992; Nelson, 1993) or the multi-level innovation systems (Kuhlmann, 2001; Kaiser & Prange, 2004; Carayannis & Campbell, 2006) emphasize these aspects of a society-wide stretch of knowledge. Economic policy is being partially replaced by innovation policy (Carayannis & Campbell, 2006; 2007). Carrying such ideas consistently further, this also implies that knowledge production and knowledge application, from a systemic perspective, should not only reflect the context of society, but, in addition, also the environmental context of society. Knowledge is being contextualized by society, but also by the (natural) environments of society.

3. MODE 1, MODE 2 AND MODE 3: TRIPLE HELIX AND QUADRUPLE HELIX

The author team of Gibbons, Limoges, Nowotny, Schwartzman, Scott, and Trow (Gibbons et al., 1994)[13] distinguishes between two different modes of knowledge production. "Mode 1" focuses on the traditional role of university research in an elderly "linear model of innovation" understanding. This reflects a basic university research, interested in "first/basic principles" and "discoveries", with a disciplinary research structure, where quality is being controlled primarily by disciplinary peers or a disciplinary peer review process. These disciplinary peers exercise a strong quality gate keeper function and represent also a university (higher education) system with powerful hierarchies, built into the institutions (Gibbons et al., 1994). Success in Mode 1 (of Mode 1 university research) is defined as a quality or excellence that is approved by hierarchically established peers: "Success in Mode 1 might

perhaps be summarily described as excellence by disciplinary peers" (Gibbons et al., 1994). Mode 1 is not concerned with the application, diffusion and use of knowledge, and Mode 1 does not focus on features in relation to problem-solving for the society or the economy. Non-linear innovation models are of no major concern for Mode 1.

Mode 2 knowledge production, on the contrary, can be characterized by the following five principles: (1) "knowledge produced in the context of application"; (2) "transdisciplinarity"; (3) "heterogeneity and organizational diversity"; (4) "social accountability and reflexivity"; (5) and "quality control". Mode 2 represents a "problem solving which is organized around a particular application" and where: "Knowledge production becomes diffused throughout society. This is why we also speak of a socially distributed knowledge" (Gibbons et al., pp. 3-4). In Mode 2 the terms "discovery", "application" and "fabrication" (also fabrication of knowledge) overlap. Exploitation of Mode 2 knowledge demands, at least to a certain extent, actual participation in the knowledge production process. Prerequisites of Mode 2 were (are) the massification of tertiary higher education, followed by a considerable spill-over of higher education graduates and higher education knowledge (competencies) into society. Advancing IT technologies allowed an effective communicative link-up of those different knowledge-competent sites outside of the universities and the higher education sector. Continuous communication and negotiations between knowledge producers are crucial. Manifold network arrangements are necessary features for linking together knowledge producing sites "through functioning networks of communication" (Gibbons et al., 1994, p. 6).

The principle of transdisciplinarity underscores the primacy of problem-solving in Mode 2, for which different disciplinary knowledge may be combined or recombined in conventional or unconventional formats. The purity of disciplinary knowledge does not define a criterion of concern. Transdisciplinarity, according to Mode 2, should develop "a distinct but evolving framework to guide problem solving efforts", is not interested in establishing new academic disciplines, and represents a "problem solving capability on the move" (Gibbons et al., 1994, p. 5). Tacit knowledge (embedded in individual persons or organizations) is as valid or relevant as codified knowledge (written down or stored). In epistemic terms, researchers, in Mode 2, "do not concern themselves with the basic principles of the world but with specific ordered structures within it" (Gibbons et al., 1994, p. 24). Therefore, one may postulate that Mode 2 resembles a transdisciplinary problem-solving knowledge, where: "knowledge production in Mode 2 occurs within transient contexts of application" and with "knowledge producers with many different institutional affiliations, either simultaneously or sequentially" (Gibbons et al., 1994, p. 33). Success in Mode 2 means that knowledge was useful or that a knowledge production contributed effectively to a problem-solving in society or the economy: "In Mode 2 success would have to include the additional criteria such as efficiency or usefulness, defined in terms of the contribution the work has made to the overall solution of transdisciplinary problems", and the quality control is being exercised by the "community of practitioners" that do not follow the structure of an institutional logic of academic disciplines (Gibbons et al., 1994, p. 33). Mode 2 demands more social accountability and reflexivity, and a greater sensitivity for the impact of knowledge on society and the economy. Values of individuals and of groups must be reflected, to allow social acceptance for a particular problem-solving approach. The authors of Mode 2 (Gibbons et al., 1994) postulate that Mode 2 developed out of Mode 1. Furthermore, there is a parallel existence of Mode 2 and Mode 1 with co-evolutionary effects (see generally Gibbons et al., 1994; see furthermore Nowotny et al., 2001; 2003; Campbell & Güttel, 2005, p. 154; Campbell, 2006, pp. 71-73, 91-92).

The "Triple Helix" (three-helix) model focuses on the interaction of the state, academia and industry. In accordance with the OECD

classification of sectors the state represents the government sector, academia the higher education sector, and industry the business enterprise sector. For Etzkowitz and Leydesdorff (2000, p. 115) the "university-industry-government relations" are of a crucial importance, with universities representing a core institution in the knowledge society: "The university can be expected to remain the core institution of the knowledge sector" (Etzkowitz & Leydesdorff, 2000, pp. 117-118). Furthermore: "The Triple Helix thesis states that the university can play an enhanced role in innovation in increasingly knowledge-based societies" (Etzkowitz & Leydesdorff, 2000, p. 109). Research and teaching are central functions of universities. In context of a "second academic revolution" now a "third mission" gains in importance for universities, which assigns to universities also the function of supporting "economic development" (Etzkowitz & Leydesdorff, 2000, p. 110). The U.S. university system after 1945 was guided by the principles of a "peer review" system that allocated funds to a "scientific elite". But the third mission, finally, caused a "breakdown" of this pure peer review system or of the "best science" model, since it linked science to "new sources of legitimating such as regional development", where "science provides much of the basis for future industrial development". The advancing of economic development is being added to the agenda of universities, extending complementarily the original mission of research excellence and teaching. "Less research-intensive regions are by now well aware that science, applied to local resources, is the basis of much of their future potential for economic and social development" (Etzkowitz & Leydesdorff, 2000, pp. 116-117). In that context Etzkowitz (2003) also speaks of the "entrepreneurial university". It appears evident that the so-called third mission displays in substance a series of features similar to the above discussed concept of Mode 2.

Empirically, different Triple Helix configurations can exist. In the "etatistic model" (a strong state model) the state dominates the other sectors. This may serve as a description for the former communist regimes in the Soviet Union and Eastern Europe. In the "laissez-faire model" the different sectors and institutions are considerably separated. Earlier national systems of innovation in the West, which operated under the premises of linear models of innovation, could represent empirical examples. The "Triple Helix III" model of "tri-lateral networks and hybrid organizations" of "university-industry-government relations" may be described in the following way: "… is generating a knowledge infrastructure in terms of overlapping institutional spheres, with each taking the role of the other and with hybrid organizations emerging at the interfaces" (Etzkowitz & Leydesdorff, 2000, pp. 111-112). According to Etzkowitz and Leydesdorff (2000, p. 112), the Triple Helix III model represents currently for most countries the dominant frame of reference, the crucial benchmark for knowledge and innovation. Key here is the overlap and cross-communication between the different helices or sectors in a knowledge society and economy. In such a context also "non-linear models of innovation" can be embedded more easily. Some conclusions of Triple Helix are (Etzkowitz & Leydesdorff, 2000, pp. 118-119): (1) the nation-state no longer defines the only level for arrangements between government and industrial sectors; (2) profit represents an important driving force; (3) successful innovations change the "landscape", meaning the "opportunity structure" for institutions; (4) the "human capital factor" gains in importance; (5) tensions create a "dynamics for the system", so they do not necessarily have to be resolved; (6) the communication density within each helix is higher than across the helices, however, in connection to the advancement of systems the cross-helix communication flow should increase substantially.

Triple Helix, as a model, references explicitly to the models of Mode 1 and Mode 2, by claiming that Mode 2 describes the underlying change in the knowledge production, whereas Triple Helix could be interpreted as an "overlay" at the level of social structures: "The Triple Helix overlay provides a model at the level of social structure for the explanation of Mode 2 as an

historically emerging structure for the production of scientific knowledge, and its relation to Mode 1" (Etzkowitz & Leydesdorff, 2000, p. 118; for a summary of Triple Helix see Campbell & Güttel, 2005, p. 154; Campbell, 2006).

The "Quadruple Helix" (four-helix) model adds to government, universities (higher education) and the economy as further fourth helix the "public", more precisely being defined as the "media-based and culture-based public": "This fourth helix associates with 'media', 'creative industries', 'culture', 'values', 'life styles', and perhaps also the notion of the 'creative class' (a term, coined by Richard Florida, 2004). Plausibility for the explanatory potential of such a fourth helix are that culture and values, on the one hand, and the way how 'public reality' is being constructed and communicated by the media, on the other hand, influence every national innovation system" (Carayannis & Campbell, 2009, p. 206). This fourth helix also could be titled or described as the *media-based, culture-based and values-based public*. The Quadruple Helix is analytically broader than the Triple Helix, thus can be used for research questions outside the core focus of Triple Helix. The Quadrupe Helix reflects on phenomena such as the "media-based democracy" or a "multimedia information society" (Plasser & Plasser, 2002). Strategies and policies of knowledge and innovation may be supported by communication strategies in or through the media (mass media). Art can be seen as something to foster creativity, implying new forms of knowledge and innovation. Visions in the arts perhaps trigger, in the long run, the development of a new technology or the launch of a next technology cycle. Kuhlmann (2001) speaks of "innovation cultures", asserting that a knowledge society and knowledge economy also are being driven by cultures and values. Multi-cultural settings feed into creativity. The principle of social accountability and reflexivity of Mode 2 has the consequence that the underlying values of individuals, groups and of society as a whole must be recognized and taken into account, so that a knowledge, produced in the context of application and tailored for a problem-solving, is being socially accepted and thus can be successfully applied. Social processes of a knowledge production must be sensitive for culture and the values that influence a society. Here the Mode 2 approach and the Quadruple Helix model interplay.

The concept of "Mode 3" (Carayannis & Campbell, 2006) is being carried by several considerations. For advanced knowledge societies and economies it is crucial to accept and to foster a pluralism of different knowledge and innovation modes (paradigms). In advanced knowledge societies and economies this pluralism is being "integrated" on the basis of a co-existence and co-evolution of a diversity of knowledge and innovation modes (paradigms), enabling a mutual cross-learning of different *"knowledges"*. (Over time, some knowledge and innovation modes may become replaced by others.) This makes knowledge more similar to democracy, allowing to speak of a "democracy of knowledge" (Carayannis & Campbell, 2009, pp. 207-208). Key features of Mode 3 are: "Crucial for the suggested 'Mode 3' approach is the idea that an advanced knowledge system may integrate different knowledge modes. Some knowledge (innovation) modes certainly will phase out and stop existing. However, what is important for the broader picture is that in fact a co-evolution, co-development and co-specialization of different knowledge modes emerges. This pluralism of knowledge modes should be regarded as essential for advanced knowledge-based societies and economies. This may point to similar features of advanced knowledge and advanced democracy" (Carayannis & Campbell, 2009, p. 206). "'Mode 3' allows and emphasizes the co-existence and co-evolution of different knowledge and innovation paradigms. In fact, a key hypothesis is: The competitiveness and superiority of a knowledge system is highly determined by its adaptive capacity to combine and integrate different knowledge and innovation modes via co-evolution, co-specialization and co-opetition knowledge stock and flow dynamics (for example, Mode 1, Mode 2, Triple Helix, linear and non-linear innovation)" (Carayannis & Campbell, 2009, p. 223).[14]

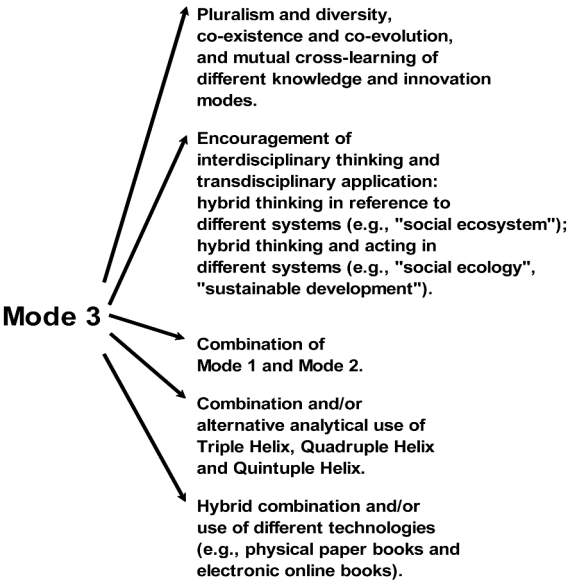
For a multi-level advanced Mode 3 knowledge system the existence and co-evolution of a pluralism and diversity of knowledge and innovation modes is pivotal. This pluralism in fact promises advantages, flexibility and appears necessary for prospects and opportunities in direction of a further development of knowledge societies and knowledge economies. Just as democracy must balance different and opposite viewpoints and is being driven by a pluralistic political spectrum of a variety of political parties, politicians and voters, also a Mode 3 knowledge society and a Mode 3 knowledge economy require and excel a diversity in knowledge and innovation. This does not rule out that some knowledge or innovation modes can phase out (historically) and are being replaced by other (new) knowledge and innovation modes. The notion of a co-evolution of knowledge (and innovation) modes rather emphasizes that despite phenomena of a "paradigm shift"[15] the general picture of a co-existence of a pluralism of modes is not being questioned (on the "structure of scientific revolutions" see also Kuhn, 1962; Umpleby, 2005).[16]*Mode 3 encourages interdisciplinary thinking and transdisciplinary application of interdisciplinary knowledge*. Hybrid thinking, parallel and simultaneously in different systems or on the basis of "transsystemic" conceptual approaches, appears to be key. One could argue that concepts such as "sustainability", "sustainable development" or " social ecology" are already *per se* interdisciplinary and transdisciplinary, should analysis be followed by application. Research questions and problem-solving in relation to ecology, the environment, environmental changes and environmental protection increasingly depend in interdisciplinary and transdisciplinary network configurations of different knowledge and innovation modes. Hybridization in Mode 3 also refers to how Mode 1 could be combined with Mode 2 or how Triple Helix may be embedded and contextualized within a wider Quadruple Helix architecture. Hybridization furthermore applies to opportunities of combining different technologies, at least for specific periods: examples for hybrid technologies may be the co-existence of physical paper books in print and electronic (online) books[17] or the co-existence of different drive motors of the coming hybrid and plug-in hybrid cars that most likely will mark a major change for land transportation with hopefully environmentally positive effects such as considerable reductions in CO_2 emissions[18] (see Figure 2).

Mode 3 claims a certain congruence of structures and processes of advanced knowledge and advanced democracy. In the following two chapters (3.1 and 3.2) we want to add some plausibility to these propositions.

3.1 The Broader Contextualization of Knowledge and the Creation of a Knowledge Democracy

There are clear indications that the conceptualization and contextualization of knowledge have become increasingly broader. Knowledge creation and production was and still is being extended to knowledge application, diffusion and use, incorporating ideas of innovation. Knowledge users out in the practical fields are just as important as knowledge producers (knowledge creators), and, depending on the specific constellation or network configuration (for example, in a non-linear innovation arrangement), the same person or institution can act as a knowledge producer and/or knowledge user. The combination of Mode 1 and Mode 2 is more extensive than a pure Mode 1 system, and this also holds true for the following combinations: Triple Helix and Quadruple Helix *over* Triple Helix, and linear and non-linear models of innovation *over* one-way linear innovation models. National systems of innovation are being reframed in context of multi-level systems of innovation. In principle, knowledge for a practical problem-solving of society or the economy has the same relevance as knowledge involved in basic research activities on the fundamental "principles of the world". Transdisciplinarity, here, means the application of interdisciplinary (or also disciplinary) knowledge. This emphasis of the application context of knowledge and the problem-solving interest of innovation imply

Figure 2. Key features and propositions of Mode 3



Source: Authors' own conceptualization.

that "knowledge production becomes diffused throughout society" (Gibbons et al., 1994, p.4). Therefore, in this particular understanding, this form of knowledge represents also a social knowledge.

Empowering citizens as knowledge producers and knowledge users can contribute to a process of "democratizing innovation" (Von Hippel, 2005). Eric von Hippel distinguishes between a "user-centered innovation" and a "manufacturer-centric innovation". The user-centered approach implies that "users of products and services" are "increasingly able to innovate for themselves". "Lead users" are the "innovating users", who can be individuals or firms. Users innovate so that they have what they cannot find on the market. Lead users often "freely reveal their innovations" to others, as being exemplified by the "open source" software movement. "Innovation communities" help to diffuse innovations more quickly. User innovations contribute in general to the social welfare of a society. Manufacturers, in fact, should search for "lead user innovations" and then should consider how these could be re-translated into new products or services, offered by commercial firms. Manufacturers may consider providing "toolkits" with their products or services, so that users can design their own customized solution or application (Von Hippel, 2005).[19]

This society-wide stretch of knowledge production and knowledge use implies that knowledge and innovation "flow through" all (at least the major sections) of society: society and the economy are "filled" with knowledge (see Figure 3). When society in general becomes knowledge-based, then this contributes to the establishment of a knowledge-based democracy or even a knowledge democracy. The Mode 3 architecture of knowledge emphasizes that Mode 2-based knowledge for problem-solving often (but of course not always) has hybridized cross-linkages to a Mode 1-based knowledge of basic research in the sciences (in context of universities), partly in a linear, partly in a non-linear framework of innovation models. It is evident that wide-spread knowledge can support

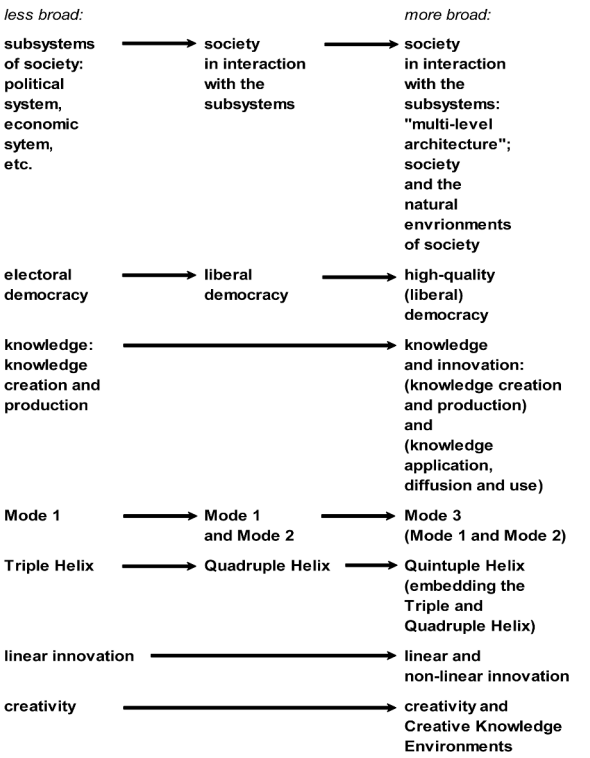
democracy and the formation of high-quality democracy. Electoral studies clearly indicate that the higher the level of educational attainment, the more likely a person will vote (for the U.S. see U.S. Census Bureau, 2008, Table 5). Education thus drives electoral participation rates. Higher education benefits people also in economic and socio-economic terms (for the U.S. see Baum and Payea, 2005, and Baum et al., 2006). Several analyses indicate positive interactions and feedback loops between education, democracy and the economy (Carmines and Stimson, 1980; Saint-Paul and Verdier, 1993). Values are sometimes being typologized and contrasted in the two groups of "materialist" and "postmaterialist" values. Postmaterialism is more sensitive for environmental issues. There is a hope that economic progress finally gives rise to postmaterialist values in the long run: "The scarcity hypothesis implies short-term changes, or period effects: Periods of prosperity lead to increased Postmaterialism, and periods of scarcity lead to Materialism. The socialization hypothesis implies that long-term cohort effects also exist: the values of a given generation tend to reflect the conditions prevailing during its preadult years" (Inglehart, 1990, pp. 75, 79). Should values diffuse and become more dominant in favor of a greater protection of the environment, then a problem-solving in Mode 2, which demands more social accountability and reflexivity, would have to recognize such a value shift. This would increase opportunities for "eco-innovation" and "eco-entrepreneurship".

3.2 The Broadening of the Concept of Democracy and of the Quality of Democracy: Democracy and the Environment

In congruence to a tendency that knowledge has been conceptualized more broadly over time, by extending knowledge from knowledge creation and production to knowledge application, diffusion and use (furthermore emphasizing a pluralism of knowledge modes, thus the metaphor of a "democracy of knowledge"), one can formulate the proposition that there is also a tendency that the concepts of democracy increased their complexity. Minimum definitions of democracy are being challenged by maximum definitions. Originally, democracies were described in terms of an "electoral democracy", focusing on political rights and on issues of elections. Robert A. Dahl (1971, pp. 2-9) explains democracy as the interplay of the two dimensions of "public contestation" ("political competition") and "participation". The "liberal democracy" already is more demanding than a pure electoral democracy, adding to the political rights the civil liberties. The country-based freedom measures, in a global comparative format, produced by Freedom House (2008, 2009a, 2009b), refer to such a liberal-democracy-understanding, since their measures focus on and combine political rights and civil liberties. In modern democratic theory the originally two dimensions of democracy of Dahl have been substantially complemented. In a review about the quality of democracy, Larry Diamond and Leonardo Morlino (2004, pp. 22-23) identify the following eight dimensions that appear crucial for a democracy and the quality of democracy: rule of law; participation; competition; vertical accountability; horizontal accountability; freedom; equality; and responsiveness.

Another question is, whether democracy represents a concept only of the political system or, alternatively, a concept that extends to society and thus also focuses on the interfaces of the political system with society and the economy? For Guillermo O'Donnell (2004, p. 13) the human beings (as "agents") are endowed with the following characteristics: they have (in principle) the autonomy to make decisions; they have the cognitive ability to reason; and they have a responsibility for their own actions. Already at this point it appears to be evident why people (human beings), in a society enriched with knowledge and never-ending knowledge flows, are better prepared to act as conscious "agents" who reflect their democracy politically and who are engaged in a political decision-making. O'Donnell (2004) defines the following two key dimensions for de-

Figure 3. Trends in the broadening of concepts



Source: Authors' own conceptualization.

mocracy and the quality of democracy: "human rights" (for example political rights, civil rights and social rights) and "human development". O'Donnell (2004, p. 55) uses the metaphor of a "nexus of these three currents", where *democracy, human rights* and *human development* are intertwined. The conceptual formula of O'Donnell for the quality of democracy thus may be paraphrased as (Campbell, 2008, p. 41): "quality of democracy = (human rights) + (human development)". By incorporating human development, O'Donnell (2004, pp. 11-12) carries his understanding of democracy and the quality of democracy already far out into society, because he draws a direct intellectual line to the Human Development Reports and the Human Development Index (HDI), which is being regularly and annually released by the United Nations Development Program (UNDP). Interpreting O'Donnell freely and referring to his approach as a theoretical point of departure, one could set up the hypothesis that, at least in principle, the HDI qualifies as a measure for human development in a comparative global format (see, for example, UNDP, 2009, pp. 171-175). O'Donnell emphasizes that human development actually transforms the human rights from rights into real freedoms.[20]

The "Democracy Ranking of the Quality Ranking" applies, as underlying model of democracy, a broad conceptualization of democracy and the quality of democracy, which is even more encompassing than the approach of O'Donnell.[21] The conceptual formula of the "Democracy Ranking" is: "quality of democracy = (freedom & other characteristics of the political system) + (performance of the non-political dimensions)". In addition to the

political system, the performance of the non-political dimensions also is being factored in. With this focus on performance, the "Democracy Ranking" attempts to be "neutral" with regard to a left/right or liberal/conservative axis, not favoring either left or right values, ideologies or policies, but looks more closely on the output of performance that should be empirically accessible and indicator-based for reasons of measurment. In Western political thought, traditionally, freedom often is more closely associated with the right or conservatism, and equality with the left (Harding et al., 1986, p. 87). The non-political dimensions, in context of the "Democracy Ranking", are: gender, economy, knowledge, health, and the environment (Campbell, 2008, pp. 30-41; Campbell & Barth, 2009, pp. 216-218; Campbell & Pölzlbauer, 2009, pp. 3-8; Campbell & Sükösd, 2002).

For the "Democracy Ranking" the concept of democracy goes beyond the boundaries of the political system and includes the intersections between politics and society, but also the performance of society, which is being interpreted as a responsibility of politics. The "Democracy Ranking" reflects also explicitly on the embeddedness of society in the context of the natural environment (environments), more directly of course the impact of society on nature. Environmentally sensitive behavior of people and society would factor into the "Democracy Ranking" as a good quality environment. O'Donnell (see again 2004, p. 55) refers to the three-current understanding of democracy, human rights and human development. The "Democracy Ranking" applies a four-current understanding that links together democracy, human rights, human development, and the (natural) environment of society. Here an interplay is being constructed between the quality of democracy and the quality of the environment. Those cross-references between the political system, society, the economic system, and the environment indicate that the "Democracy Ranking" model reveals socio-ecological features of sustainable development. While the industrialized nations or the advanced OECD countries often rank high with regard to the quality of their human rights or their economic and socio-economic performance, they often also pollute the environment considerably more than many of the so-called less or least developed countries (LDCs, LLDCs). In an age of a growing importance of global interwovenness and global responsibility, this for a large part negative impact of the industrialized countries on the environment should be taken more strictly into account. In the "Human Development Report 2007/2008" (UNDP, 2007, pp. 21-47), devoted most importantly to the issue of fighting climate change, clearly a link is being drawn between increased CO_2 emissions (and other greenhouse gases) and rising temperatures. The "world is warming" because of "human-induced climate change". Above all the industrialized countries and regions cause most of the global CO_2 emissions, thus they express a negative balance of "deep carbon footprints" (on the concept of the "Ecological Footprint" see also Monfreda et al., 2004).

There are different initiatives, interested in measuring the quality of the environment. For example, the "Environmental Sustainability Index" (ESI) focuses on the "ability of nations to protect the environment over the next several decades". For that purpose 76 different data sets were aggregated into 21 "indicators of environmental sustainability", referring to the following features: "natural resource endowments, past and present pollution levels, environmental management efforts, and the capacity of a society to improve its environmental performance" (Esty et al., 2005, p. 1). The Environmental Sustainability Index was published for the last time for 2005. The follow-up product is the Environmental Performance Index (EPI), which, so far, was released for 2006 and 2008. The EPI framework focuses on offering a "composite index of current national environmental protection efforts". There are two key core objectives: "reducing environmental stresses to human health (the Environmental Health objective)" and "protecting ecosystems and natural resources (the Ecosystem Vitality objective)". For that purpose the EPI applies

25 indicators that are being aggregated to three distinct levels (policy categories, objectives, and the final index) (Esty et al., 2008).[22]

3.3 Summary of Chapter 3

Schumpeter's concept of the built-in "creative destruction" mechanism of a capitalist economy can be explained, in a modern knowledge-based language, with the need of managing simultaneously different technology life cycles and the conversion from "old" to "new" technology life cycles (on technology life cycles, see Tassey, 2001; Campbell, 2006). Technology life cycles link "knowledge waves" to the growth (growth and decline) cycles and long-term performance and competitiveness of an economy. Technology life cycles drive an economy and demand permanent change. Every technology life cycle has an "expiration date", but always new technology cycles are being created. Several technology life cycles, at different stages of market maturity, operate in parallel. Therefore, innovation and innovativeness represent crucial characteristics of firms in a market economy. Economic performance depends on entrepreneurs, who leverage the momentum and dynamics of technology life cycles.[23]

Schumpeter (1976, pp. 82-83) provides the following famous quote on the *creative destruction:* "Capitalism, then, is by nature a form or method of economic change and not only never is but never can be stationary. And this evolutionary character of the capitalist process is not merely due to the fact that economic life goes on in a social and natural environment which changes and by its change alters the data of economic action; this fact is important and these changes (wars, revolutions and so on) often condition industrial change, but they are not its prime movers. Nor is the evolutionary character due to a quasi-automatic increase in population and capital or to the vagaries of monetary systems of which exactly the same thing holds true. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates. …This process of Creative Destruction is the essential fact about capitalism".

The concept of Mode 3 is more inclined to emphasize the co-existence and co-evolution of different knowledge and innovation modes. Mode 3 even accentuates such a pluralism and diversity of knowledge and innovation modes as being necessary for advancing societies and economies. This pluralism supports processes of a mutual cross-learning from the different knowledge modes. Between Mode 1 and Mode 2 manifold creative arrangements and configurations are possible, linking together basic research and problem-solving. Individual knowledge and innovation modes may phase out and become replaced in context of a "paradigm shift" (see again Kuhn, 1962). There also may be some cyclical patterns, indicating how dominant or non-dominant certain modes are during certain periods, captured by the phrase of "knowledge swings" (Carayannis & Campbell, 2009, p. 225). This, however, does not alter the general pattern of a co-existence and co-evolution of a continuous and continuing diversity of knowledge and innovation modes. The Quadruple Helix model adds to the "university-industry-government relations" the fourth helix of a "media-based and culture-based public" that also includes values and different value systems.

For the advanced knowledge societies and knowledge economies we can set up for discussion the following propositions about possible "evolutionary" effects (described by the concepts of Mode 3 and Quadruple Helix): (1) the pluralism of the knowledge and innovation modes suggests features similar to and in congruence with the political pluralism and diversity of democracy. The notion of a "democracy of knowledge" (Carayannis & Campbell, 2009, pp. 207-208) describes these phenomena. (2) The hybrid coupling of Mode 1 basic research and Mode 2 problem-solving leads to a society-wide diffusion of good-quality knowledge. Knowledge is being broadly contextualized by society. Innovation carries

knowledge application, diffusion and use far out into society and the economy. Knowledge producers and knowledge users are cross-linked in heterogeneous networks, with shifting functions and continuous reconfigurations. The same persons and institutions can act simultaneously as knowledge producers and knowledge users. This society-wide flow of knowledge (claimed by Mode 3 and Quadruple Helix) also supports citizenry and political citizenship for a high quality democracy. Here knowledge society, knowledge economy and knowledge democracy meet and overlap. (3) Over time, concepts of democracy have become more complex and demanding. Broader conceptualizations of democracy transcend the boundaries of the political system and integrate the interplay of politics, society and the economy. In such a wider understanding the co-evolution of human rights and human development is crucial (for example, see O'Donnell, 2004). A next step in broadening the concept of democracy would be to blend together the co-evolution of human rights, human development and of the environment. Cross-linking human rights, human development and the environment already bridges analytically into sustainable development, clearly including features of social ecology.

It is not easy to balance Schumpeter's concept of "creative destruction", contextualized in a modern interpretation in the framework of the technology life cycles, with the pluralism and co-evolution approach of Mode 3 and the Quadruple Helix. Of course one could attempt to juxtapose the two spheres of (1) pluralistic knowledge and innovation modes and (2) the dynamics of the technology life cycles, where technology life cycles departure from specific knowledge and innovation modes. But some conceptual tensions between these two different understandings still remain. Schumpeter's model emphasizes more the aspects of competition or of a radically competitive capitalist economic system. Mode 3 and Quadruple Helix are more in favour of stressing the opportunities of co-evolutionary learning. In that sense Mode 3 and Quadruple Helix indicate a path of sustainable development for an economic system, interested in advancing a market economy that is socially and environmentally sensitive, thus recognizing and implementing criteria of "social ecology". Here is sufficient space and are sufficient opportunities for "eco-innovation" and "eco-entrepreneurship". Mode 3 and Quadruple Helix may help converting the "creative destruction" (at least partially) into a "creative learning" and a "creative co-evolution".

4. CONCLUSION: SUSTAINABLE DEVELOPMENT, SOCIAL ECOLOGY AND THE QUINTUPLE HELIX

Society could be designed or understood to consist of different subsystems (or systems).[24] The political system or the economic system are such examples. Politics and the economy are being embedded by society, thus society, in this understanding, is more comprehensive than politics and the economy. For every societal subsystem the other subsystems of society or society as a whole represent "social environments" (societal environments). In a spatial (spatial-political) multi-level architecture, societies could be located at different levels of aggregation, ranging from sub-national (local, regional) to national and trans-national (supranational, global). Society again is being contextualized by the "natural environment" (the natural environments).

In everyday language, when not further specified, the term environment normally is being associated with the natural environment. The planet earth has a natural environment. The concept of a natural environment may also be applied to other planets (or moons). "Ecology" refers to the interdisciplinary analysis of either interactions between living organisms or interactions between living organisms and their environments. Based on those interaction patterns, the sum of living organisms and of the non-living environment define an "ecosystem".[25] "Sustainability" can focus either on the relationship of society to the economy (e.g.,

socio-economic regimes or configurations) and/or the relationship of society with the natural environments (Winiwarter & Knoll, 2007, pp. 306-307; Adams, 2006, pp. 1-3). Concerning biological systems, "biodiversity" represents an indicator for sustainability (see Vadrot, 2008, pp. 62-79). The Human Development Index of the Human Development Reports (UNDP, 2007; 2009) can be interpreted as a measure of "sustainable development" of societies or of countries in global comparison. A key quote on sustainable development pinpoints on a definition of the so-called Brundtland Commission that states that sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987a, 1987b; see also Winiwarter & Knoll, 2007, p. 305).

Referring to our analysis in the previous sections of the article, we could also define sustainable development as a co-evolution of the different systems of society, based on knowledge and a mutual cross-learning that is socially and environmentally sensitive and that is receptive for concepts of a quality of democracy. "Social ecology" looks at the "society-nature interactions" between "human society" ("culture", the "cultural (symbolic) sphere of causation") and the "material world" ("nature", the "natural (biophysical) sphere of causation"). The "biophysical structures" or "biophysical structures of society" mark an area of overlap between culture (the cultural) and nature (the natural), and between these "biophysical structures" and nature a metabolism (or a "social metabolism", with potential of a "socio-metabolic transition"), in context of specific "metabolic profiles", occurs (see Fischer-Kowalski, 1998; Fischer-Kowalski & Hüttler, 1999; Fischer-Kowalski & Haberl, 2007; Haberl et al., 2004, 2009; see also Hopwood et al., 2005; Kates et al., 2001).[26] "Sociometabolic regimes represent dynamic equilibria of society-nature interactions and are characterized by typical patterns of material and energy flows (metabolic profiles)" (Krausmann et al., 2008, p. 1). Sustainable development and social ecology represent areas and fields for interdisciplinary analysis and transdisciplinary problem-solving. "Sustainability science is emerging as a transdisciplinary effort to come to grips with the much-needed symbiosis between human activity and the environment" (Rapport, 2007, p. 77).

The originally natural sciences-based biological concept of the "ecosystem" may also be reinterpreted by the social sciences and redesigned to fit the purpose of a "social or societal ecosystem". A societal ecosystem would embed the crucial "elements" (for example actors, institutions, structures and processes) as well as their complex interaction patterns that characterize an ecosystem, but would also stretch into the contextualization by the social (societal) environments of the other systems (subsystems) of society, and is finally contextualized by the natural environment of the whole society. A societal ecosystem also (at least potentially) interacts with its social and natural environments. An example for a societal ecosystem would be the "innovation ecosystem" that focuses on the complexity of innovation and innovation systems, framed by societal and natural environments (Carayannis & Campbell, 2009; see, furthermore, Milbergs, 2004, 2005a, 2005b). For the "innovation ecosystem" the non-linear models of innovation are of a key importance. The concepts of "biological ecosystems" and of "social ecosystems" (societal ecosystems) demonstrate the whole interdisciplinary stretch of "ecology", underpinning the intellectual and academic challenge of cross-referring and cross-relating ideas between the social sciences and natural sciences, but also highlights the benefit of interdisciplinary inquiry for transdisciplinary application. Social ecosystems and biological ecosystems could be covered and integrated by a transdisciplinary framework based on "social ecology".

When the relationship and interplay of society and the economy are being regarded as a (possible) criterion for sustainable development, then it appears plausible that Guillermo O'Donnell's (2004) conceptualization of the quality of democracy, tying together and integrating human rights and human development, also qualifies as a sustainable-development-

approach. We could claim here an overlap (at least partial overlap) between the concepts of the quality of democracy and of sustainable development. Is sustainable development a route to high-quality democracy? Or does the quality of a democracy manifest itself in patterns of sustainable development? Broader conceptualizations or definitions of democracy that do not limit democracy to the political system but are interested in integrating the political system, society and the economy in the one or other configuration and under the "umbrella" of democracy, potentially reflect aspects of sustainable development. Between so-called maximum definitions of democracy and sustainable development manifold theoretical windows of congruence open up. Should a conceptualization of a democracy or the quality of a democracy be designed so broadly as to reflect also the (natural) environmental context of society, then such a framing would not only be compatible with a sustainable development framework in general, but would also incorporate features of "social ecology". Therefore, a concept of knowledge democracy (quality of democracy) that links together the political system, society, the economy and environment allows the application of concepts of social ecology in a framework of sustainable development.

The earlier chapters of this article arrived at the following conclusions or suggested the following propositions for discussion:

1. *The broadening and "societal contextualization" of the concept of knowledge and of knowledge by incorporating innovation:* Traditional concepts of knowledge focused more on knowledge creation and production, for example basic university research in the context of higher education systems. Later concepts also included knowledge application, diffusion and use, emphasizing that innovation could be regarded as using knowledge for application and problem-solving. Innovation-oriented knowledge diffused and still diffuses far out into society, and is being characterized as a "social" ("societal") knowledge, contextualized by society. Key in that context is also the concept of the "national system of innovation" (Lundvall, 1992; Nelson, 1993). The whole spectrum of knowledge stretches from the creation and production of new knowledge, to innovation, the application and use of knowledge, frequently in non-linear models of innovation. Creativity refers either to new knowledge or to new innovation. Interestingly, for the global level of innovation systems, Lundvall (1992, p. 7) claims that non-economic aspects, such as "ecological sustainability" and a reduction of "extreme social inequality", gain importance. In context of this broadening and society-wide stretch of knowledge, two theories (models) on knowledge and innovation are pivotal: Triple Helix (Etzkowitz & Leydesdorff, 2000) looks at the dynamic interaction of the "helices" of "university-industry-government relations". In the Mode 1 and Mode 2 approach (Gibbons et al., 1994) the basic university research (Mode 1) is being supplemented by a knowledge (Mode 2) that focuses on a problem-solving for society and the economy.
2. *A possible (partial) congruence and co-evolution of knowledge and democracy:* Here, two developments run in parallel that have features of a congruence and co-evolution.
   2.1. *The pluralization of knowledge:* Advanced and further advancing (multi-level) knowledge and innovation systems can be characterized by a pluralism and diversity of knowledge and innovation modes. This pluralism is in fact necessary for promoting the continued development of knowledge societies and knowledge economies. Based on such a dynamics, a "democracy of knowledge" emerges, with pluralistic knowledge and innovation modes, with possible co-evolutionary effects of a cross-learning. Advanced

knowledge takes over structural elements of a democracy, i.e. behaves like a pluralistic democracy. "Mode 3" (Carayannis & Campbell, 2006; 2009) emphasizes this pluralism and co-evolution of different and diverse knowledge and innovation modes.[27] Cross-learning between knowledge modes in Mode 3 potentially softens the sharp edges of the "creative destruction" in the economic-technological vision of Schumpeter (1976), and moves the systems in favor of a "creative learning" and a "creative co-evolution". Mode 3 stresses hybrid combinations and possibilities of combination between Mode 1 and Mode 2 or between basic research, on the one hand, and applied research and experimental, on the other.[28] For Mode 3 it is crucial that Mode 2 problem-solving in the twentieth and twenty-first centuries (and most likely also beyond) is cross-connected with types of a Mode 1 basic research.[29] "Quadruple Helix" (Carayannis and Campbell, 2009) adds to the "university-industry-government relations" of the Triple Helix model the fourth helix of a "media-based and culture-based public" that also includes culture and values. This spreading of knowledge also helps building a knowledge democracy with political citizens that have the knowledge of making informed decisions.

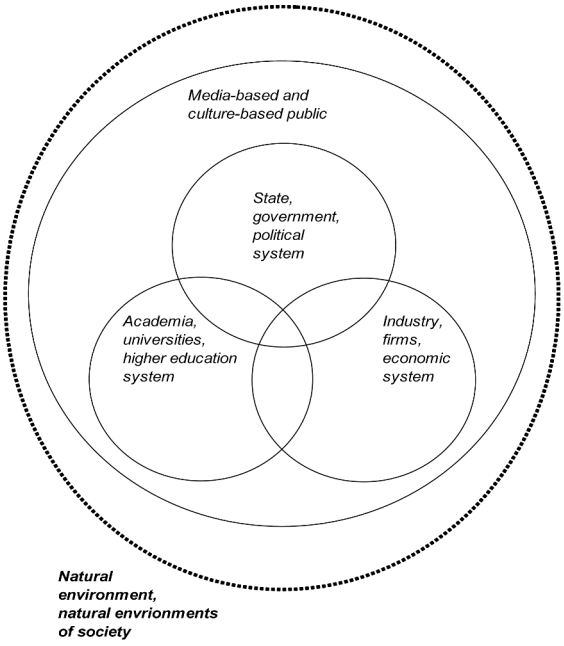
2.2. *The broadening of democracy:* Theories of democracy have become increasingly complex over time. Concepts on liberal democracy are more demanding than the simpler versions of an electoral democracy. Some approaches emphasize that democracy is not just a description of the political system, but also cross-refers to society, the economy and other subsystems of society. O'Donnell (e.g., 2004) defines the quality of democracy out of an interplay of "human rights" and "human development". The "Democracy Ranking" model of quality of democracy (e.g., Campbell, 2008) goes even further, adding also the (natural) environment or the support of the natural environment to its conceptualization. Where a model of democracy cross-cuts human rights, human development and environmental development, there are clearly references to "social ecology". A high-quality democracy is more complex than a medium-quality liberal democracy. High-quality democracies depend on a pluralized and advanced knowledge and innovation to perform. *The diversity of a democracy obviously supports the diversity of knowledge. Here the new complexity of knowledge and of democracy meet and come together.* High-quality democracy is a knowledge-based democracy, a knowledge democracy.

How do knowledge, innovation and the environment (natural environment) relate to each other? Societies or democracies (high-quality democracies), based on a co-evolution of the subsystems of society or of the subsystems in interaction with the whole of society, where mutual learning and a "positive" learning interaction take place, follow the rationale of sustainable development. Advanced and pluralized knowledge, with a co-evolution and mutual learning processes between different knowledge and innovation modes, also adopts the rationale of sustainable development. For the purpose of further discussion and analysis we lastly want to propose and introduce the five-helix model of the "Quintuple Helix", where the environment or the natural environments represent the fifth helix (see Figure 4). The Triple Helix focuses on "university-industry-government relations". The Quadruple Helix frames the Triple Helix in context of a "media-based and culture-based public". The Quintuple Helix finally embeds

the Quadruple Helix (and the Triple Helix) in context of the environment or the natural environments.[30] Depending on the analytical point of departure or on the practical interest of application and decision-making, either a Triple Helix, Quadruple Helix or a Quintuple Helix model could be more appropriate.

The Quintuple Helix model is interdisciplinary and transdisciplinary at the same time: the complexity of the five-helix structure implies that a full analytical understanding of all helices requires the continuous involvement of the whole disciplinary spectrum, ranging from the natural sciences (because of the natural environment) to the social sciences and humanities (because of society, democracy and the economy). The Quintuple Helix also is transdisciplinary, since it can be used as a frame of reference for decision-making in connection to knowledge, innovation and the (natural) environment. The Quintuple Helix can be proposed as a framework for transdisciplinary (and interdisciplinary) analysis of sustainable development and social ecology. With the adding of the "fifth helix of the (natural) environment/environments" to knowledge creation, production, application, diffusion and use, knowledge and innovation (advanced and pluralized Mode 3 knowledge and innovation systems) are transformed to a knowledge and innovation that is sensitive or at least potentially sensitive for "social ecology": knowledge and innovation, contextualized by society, meets the context of society, the environment. Therefore, the Quintuple Helix has the potential to serve as an analytical framework for sustainable development and social ecology, by conceptually relating knowledge and innovation to the environment. Sustainable knowledge is a knowledge that reflects on the performance and quality of the environment, the natural environment. The Quintuple Helix furthermore outlines what sustainable development might

Figure 4. The five-helix model of the Quintuple Helix



Source: Authors' own conceptualization based on Etzkowitz and Leydesdorff (2000, p. 111) and on Carayannis and Campbell (2009, p. 207).

mean and imply for "eco-innovation" and "eco-entrepreneurship" in the current situation and for our future.

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REFERENCES

Adams, W. M. (2006, January 29-21). The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century. In *Proceedings of the IUCN Renowned Thinkers Meeting.* Madrid: The World Conservation Union (IUCN). Retrieved from http://cmsdata.iucn.org/downloads/iucn_future_of_sustainability.pdf

Baum, S., & Payea, K. (2005). *Education Pays 2005 Update*. Washington, DC: College Board. Retrieved from http://www.collegeboard.com/prod_downloads/press/cost05/education_pays_05.pdf

Baum, S., Payea, K., & Steele, P. (2006). *Education Pays 2006 Second Update*. Washington, DC: College Board. Retrieved from http://www.collegeboard.com/prod_downloads/press/cost06/education_pays_06.pdf

Bomberg, E., & Stubb, A. (2003). Introduction . In Bomberg, E., & Stubb, A. (Eds.), *The European Union: How Does it Work?* (pp. 3–18). Oxford, UK: Oxford University Press.

Brandenburger, A. M., & Nalebuff, B. (1997). *Co-Opetition*. New York: Doubleday.

Bush, V. (1945). *Science the Endless Frontier*. Washington, DC: National Science Foundation.

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 Carayannis, E. G., & Campbell, D. F. J. (Eds.), *Knowledge Creation, Diffusion, and Use in Innovation Networks and Knowledge Clusters. A Comparative Systems Approach across the United States, Europe and Asia* (pp. 67–100). Westport, CT: Praeger.

Campbell, D. F. J. (2008). *The Basic Concept for the Democracy Ranking of the Quality of Democracy*. Vienna, Austria: Democracy Ranking.

Campbell, D. F. J. (2009). "Externe Umwelten". Außensichten auf das iff . In Arnold, M. (Ed.), *iff. Interdisziplinäre Wissenschaft im Wandel* (pp. 101–134). Vienna, Austria: LIT.

Campbell, D. F. J., & Barth, T. D. (2009). Wie können Demokratie und Demokratiequalität gemessen werden? Modelle, Demokratie-Indices und Länderbeispiele im globalen Vergleich. *SWS-Rundschau*, *49*(2), 208–233.

Campbell, D. F. J., & Güttel, W. H. (2005). Knowledge Production of Firms: Research Networks and the "Scientification" of Business R&D. *International Journal of Technology Management*, *31*(1/2), 152–175. doi:10.1504/IJTM.2005.006629

Campbell, D. F. J., & Pölzlbauer, G. (2009). *The Democracy Ranking 2008/2009 of the Quality of Democracy: Method and Ranking Outcome*. Vienna, Austria: Democracy Ranking.

Campbell, D. F. J., & Sükösd, M. (Eds.). (2002). *Feasibility Study for a Quality Ranking of Democracies*. Vienna, Austria: Global Democracy Award.

Carayannis, E. G., & Campbell, D. F. J. (2006). "Mode 3": Meaning and Implications from a Knowledge Systems Perspective . In Carayannis, E. G., & Campbell, D. F. J. (Eds.), *Knowledge Creation, Diffusion, and Use in Innovation Networks and Knowledge Clusters. A Comparative Systems Approach across the United States, Europe and Asia* (pp. 1–25). Westport, CT: Praeger.

Carayannis, E. G., & Campbell, D. F. J. (2007). A "Mode 3" Systems Approach for Knowledge Creation, Diffusion, and Use: Towards a Twenty-First-Century Fractal Innovation Ecosystem . In Carayannis, E. G., & Ziemnowicz, C. (Eds.), *Rediscovering Schumpeter. Creative Destruction Evolving into "Mode 3"* (pp. 717–111). Houndmills, UK: Palgrave Macmillan.

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. doi:10.1504/IJTM.2009.023374

Carayannis, E. G., & Ziemnowicz, C. (Eds.). (2007). *Re-Discovering Schumpeter: Creative Destruction Evolving into "Mode 3"*. London: Palgrave Macmillan.

Carmines, E. G., & Stimson, J. A. (1980). The Two Faces of Issue Voting. *The American Political Science Review*, *74*(1), 78–91. doi:10.2307/1955648

Cullell, J. V. (2004). Democracy and the Quality of Democracy. Empirical Findings and Methodological and Theoretical Issues Drawn from the Citizen Audit of the Quality of Democracy in Costa Rica . In O'Donnell, G., Cullell, J. V., & Iazzetta, O. M. (Eds.), *The Quality of Democracy. Theory and Applications* (pp. 93–162). South Bend, IN: University of Notre Dame Press.

Dahl, R. A. (1971). *Polyarchy. Participation and Opposition*. New Haven, CT: Yale University Press.

Diamond, L., & Morlino, L. (2004). The Quality of Democracy. An Overview. *Journal of Democracy*, *15*(4), 20–31. doi:10.1353/jod.2004.0060

Dubina, I. N. (2005). Managing Creativity: Theoretical Approaches to Employees' Creativity Development and Regulation. *International Journal of Management Concepts and Philosophy*, *1*(4), 334–349. doi:10.1504/IJMCP.2005.008532

Dubina, I. N. (2007). Optimally Managing Creativity in Organisations . In Carayannis, E. G. (Ed.), *Managing Creative and Innovative People: The Art, Science and Craft of Fostering Creativity, Triggering Invention and Catalyzing Innovation* (pp. 143–170). Westport, CT: Praeger.

Dubina, I. N. (2009). *Управление творчеством персонала в условиях инновационной эконо* [Creativity Management in the Innovation Economy]. Moscow, Russia: Academia.

Esty, D. C., Levy, M., Kim, C. H., de Sherbinin, A., Srebotnjak, T., & Mara, V. (2008). *2008 Environmental Performance Index*. New Haven, CT: Yale Center for Environmental Law and Policy.

Esty, D. C., Levy, M., Srebotnjak, T., & de Sherbinin, A. (2005). *2005 Environmental Sustainability Index: Benchmarking National Environmental Stewardship*. New Haven, CT: Yale Center for Environmental Law & Policy.

Etzkowitz, H. (2003). Research Groups as "Quasi-Firms": The Invention of the Entrepreneurial University. *Research Policy*, *32*, 109–121. doi:10.1016/S0048-7333(02)00009-4

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. doi:10.1016/S0048-7333(99)00055-4

Fischer-Kowalski, M. (1998). Society's Metabolism. The Intellectual History of Materials Flow Analysis, Part I, 1860-1970. *Journal of Industrial Ecology*, *2*(1), 61–78. doi:10.1162/jiec.1998.2.1.61

Fischer-Kowalski, M., & Haberl, H. (Eds.). (2007). *Socioecological Transitions and Global Change. Trajectories of Social Metabolism and Land Use*. Cheltenham, UK: Edward Elgar.

Fischer-Kowalski, M., & Hüttler, W. (1999). Society's Metabolism. The Intellectual History of Materials Flow Analysis, Part II, 1970-1998. *Journal of Industrial Ecology*, *2*(4), 107–136. doi:10.1162/jiec.1998.2.4.107

Florida, R. (2004). *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community, and Everyday Life*. Cambridge, MA: Basic Books.

Freedom House. (2008). *Methodology*. Washington, DC: Author.

Freedom House. (2009a). *Freedom in the World Comparative and Historical Data. Country Ratings and Status, FIW (Freedom in the World) 1973-2009*. Washington, DC: Author.

Freedom House. (2009b). *Map of Freedom in the World. 2009 Edition*. Washington, DC: Author.

Gibbons, M., Limoge, 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.

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Martinez-Alier, J., & Winiwarter, V. (2009). A Socio-metabolic Transition towards Sustainability? Challenges for Another Great Transformation. *Sustainable Development*, 17.

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Weisz, H., & Winiwarter, V. (2004). Progress towards Sustainability? What the Conceptual Framework of Material and Energy Flow Accounting (MEFA) Can Offer. *Land Use Policy*, *21*(3), 199–213. doi:10.1016/j.landusepol.2003.10.013

Harding, S., Phillips, D., & Fogarty, M. (1986). *Contrasting Values in Western Europe. Unity, Diversity and Change. Studies in the Contemporary Values of Modern Society*. Houndmills, UK: MacMillan.

Hemlin, S., Allwood, C. M., & Martin, B. R. (Eds.). (2004). *Creative Knowledge Environments: The Influences on Creativity in Research and Innovation*. Camberley, UK: Edward Elgar.

Hooghe, L., & Marks, G. (2001). *Multi-Level Governance and European Integration*. Lanham, MD: Rowman & Littlefield Publishers.

Hopwood, B., Mellor, M., & O'Brien, G. (2005). Sustainable Development: Mapping Different Approaches. *Sustainable Development*, *13*, 38–52. doi:10.1002/sd.244

Inglehart, R. (1990). *Culture Shift in Advanced Industrial Society*. Princeton, NJ: Princeton University Press.

Kaiser, R., & Prange, H. (2004). The Reconfiguration of National Innovation Systems – The Example of German Biotechnology. *Research Policy*, *33*, 395–408. doi:10.1016/j.respol.2003.09.001

Kates, R. W. (2001). Environment and Development: Sustainability Science. *Science*, *292*(5517), 641–642. doi:10.1126/science.1059386

Kline, S. J., & Rosenberg, N. (1986). An Overview of Innovation . In Landau, R., & Rosenburg, N. (Eds.), *The Positive Sum Strategy*. Washington, DC: National Academy Press.

Krausmann, F., Fischer-Kowalski, M., Schandl, H., & Eisenmenger, N. (2008). The Global Sociometabolic Transition: Past and Present Metabolic Profiles and Their Future Trajectories. *Journal of Industrial Ecology*, *12*(5), 637–656. doi:10.1111/j.1530-9290.2008.00065.x

Kuhlmann, S. (2001). Future Governance of Innovation Policy in Europe – Three Scenarios. *Research Policy*, *30*, 953–976. doi:10.1016/S0048-7333(00)00167-0

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press.

Lundvall, B.-A. (Ed.). (1992). *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

Meglic, J., Kern, T., Urh, B., Balkovec, J., & Roblek, M. (2009). Influence of Polyvalence Professionals on Product Development Process Efficiency. *Strojarstvo*, *51*(2), 105–121.

Milbergs, E. (2004). *Measuring Innovation for National Prosperity*. Washington, DC: Center for Accelerating Innovation.

Milbergs, E. (2005a). *Innovation Ecosystems and Prosperity*. Washington, DC: Center for Accelerating Innovation.

Milbergs, E. (2005b). *Setting the Stage for Innovation. Accelerating Innovation 2005 Conference*. Washington, DC: Center for Accelerating Innovation.

Miyata, Y. (2003). An Analysis of Research and Innovative Activities of Universities in the United States . In Shavinina, L. V. (Ed.), *The International Handbook on Innovation* (pp. 715–738). Amsterdam, The Netherlands: Pergamon. doi:10.1016/B978-008044198-6/50049-8

Monfreda, C., Wackernagel, M., & Deumling, D. (2004). Establishing National Natural Capital Accounts Based on Detailed Ecological Footprint and Biological Capacity Assessments. *Land Use Policy*, *21*(3), 231–246. doi:10.1016/j.landusepol.2003.10.009

Narin, F., Hamilton, K. S., & Olivastro, D. (1997). The Increasing Linkage between U.S. Technology and Public Science. *Research Policy*, *26*, 317–330. doi:10.1016/S0048-7333(97)00013-9

National Science Board. (2008). Science and Engineering Indicators 2008. Volumes 1 and 2. Arlington, VA: National Science Foundation.

Nelson, R. R. (1990). Capitalism as an Engine of Progress. *Research Policy*, *19*, 193–214. doi:10.1016/0048-7333(90)90036-6

Nelson, R. R. (Ed.). (1993). *National Innovation Systems. A Comparative Analysis*. Oxford, UK: Oxford University Press.

Nowotny, H., Scott, P., & Gibbons, M. (2001). *Rethinking science. Knowledge and the public in an age of uncertainty*. Cambridge, UK: Polity Press.

Nowotny, H., Scott, P., & Gibbons, M. (2003). Mode 2 Revisited: The New Production of Knowledge. *Minerva*, *41*, 179–194. doi:10.1023/A:1025505528250

O'Donnell, G. (2004). Human Development, Human Rights, and Democracy . In O'Donnell, G., Cullell, J. V., & Iazzetta, O. M. (Eds.), *The Quality of Democracy. Theory and Applications* (pp. 9–92). South Bend, IN: University of Notre Dame Press.

OECD. (1994). *The Measurement of Scientific and Technological Activities. Proposed Standard Practice for Surveys of Research and Experimental Development. Frascati Manual 1993*. Paris: OECD.

OECD. (2002). *The Measurement of Scientific and Technological Activities. Proposed Standard Practice for Surveys on Research and Experimental Development. Frascati Manual 2002*. Paris: OECD.

Palmberg, C., & Luukkonen, Y. (2006). The Different Dynamics of the Biotechnology and ICT Sectors in Finland . In Carayannis, E. G., & Campbell, D. F. J. (Eds.), *Knowledge Creation, Diffusion and Use in Innovation Networks and Knowledge Clusters* (pp. 158–182). Westport, CT: Praeger.

Plasser, F., & Plasser, G. (2002). *Global Political Campaigning. A Worldwide Analysis of Campaign Professionals and Their Practices*. Westport, CT: Praeger.

Rapport, D. J. (2006). Sustainability Science: An Ecohealth Perspective. *Sustainability Science*, *2*, 77–84. doi:10.1007/s11625-006-0016-3

Saint-Paul, G., & Verdier, T. (1993). Education, Democracy and Growth. *Journal of Development Economics*, *42*, 399–407. doi:10.1016/0304-3878(93)90027-K

Schafer, K. E. (2008). Have We Succeeded? Political Leadership Lessons from the United States . In Zimmer, A., & Jankowitsch, R. M. (Eds.), *Political Leadership. Annäherungen aus Wissenschaft und Praxis* (pp. 263–278). Berlin: Polisphere.

Schumpeter, J. A. (1934). *The Theory of Economic Development*. Cambridge, MA: Harvard University Press.

Schumpeter, J. A. (1976). *Capitalism, Socialism and Democracy*. New York: Harper Perennial.

Shavinina, L. V. (Ed.). (2003). *The International Handbook on Innovation*. Amsterdam, The Netherlands: Pergamon Elsevier Science.

Tassey, G. (2001). R&D Policy Models and Data Needs . In Feldman, M. P., & Link, A. N. (Eds.), *Innovation Policy in the Knowledge-Based Economy* (pp. 37–71). Boston: Kluwer Academic Publishers.

Umpleby, S. A. (2005). What I Learned from Heinz von Foerster About the Construction of Science. *Kybernetes*, *34*(1/2), 278–294. doi:10.1108/03684920510575843

UNDP. (2007). *Human Development Report 2007/2008. Fighting Climate Change: Human Solidarity in a Divided World*. New York: United Nations Development Program.

UNDP. (2009). *Human Development Report 2009. Overcoming Barriers: Human Mobility and Development*. New York: United Nations Development Program.

United Nations. (1987a). *Report of the World Commission on Environment and Development (42/187)*. New York: United Nations.

United Nations. (1987b). *Report of the World Commission on Environment and Development: "Our Common Future*. New York: United Nations.

U.S. Census Bureau. (2008). *Voting and Registration in the Election of November 2008*. Washington, DC: Author.

Vadrot, A. (2008). *"Der Wille zur Wahrheit als der Wille zur Macht". Die theoretischen Implikationen der Schnittstelle zwischen Politik und Wissenschaft in der Biodiversitätspolitik. (Magisterarbeit.)*. Vienna: University of Vienna.

Von Hippel, E. (1988). *The Sources of Innovation*. Oxford, UK: Oxford University Press.

Von Hippel, E. (2005). *Democratizing Innovation. Cambridge, MA: MIT Press Winiwarter, V., & Knoll, M. (2007). Umweltgeschichte*. Köln, Germany: Böhlau.

ENDNOTES

1 See: http://en.wikipedia.org/wiki/Knowledge (retrieved: October 18, 2009)

2 In that understanding, emotional competence may cross-cut social competences and personality.

3 The OECD is the "Organization for Economic Co-operation and Development".

4 In the context of this article, we use "knowledge creation" and "knowledge production" as interchangeable terms. A possible distinction may emphasize that knowledge creation is more fundamental and basic (more overlapping with basic research) than the knowledge production.

5 We want to quote, how the OECD (1994, p. 29) defines basic research: "Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and

observable facts, without any particular application or use in view." This definition the OECD repeats unchanged in 2002 (OECD, 2002, p. 30).

6 Etzkowitz and Leydesdorff (2000, p. 116) use the term of "pure science" for describing the post-1945 university system in the U.S., which largely behaved according to the principles that were formulated and postulated by Vannevar Bush (1945). Etzkowitz and Leydesdorff (2000, p. 116) speak in this context also of an "ideology of pure research".

7 In a different book section, Lundvall (1992, p. 15) says: "As pointed out, we do not assume the process of innovation to be exclusively localized inside national borders. On the contrary, we recognize that the process of innovation has increasingly become multinational and transnational reflecting, for example, R&D cooperation between big firms based in different nations."

8 Nelson (1990) describes or paraphrases *capitalism as an engine of growth*. As Nelson (1990, p. 193) states at the beginning of his article: "Economists, from Marx, to Schumpeter, have touted capitalism as an engine of technical progress. But what kind of an engine is it? How does it work? What are the strengths and weaknesses?"

9 We can speculate, to which extent research about the European Union (EU) and concepts such as a *multi-level governance* of the EU (Hooghe and Marks, 2001; Bomberg and Stubb, 2003, p. 9) helped inducing and creating the concept of *multi-level systems of innovation* (Carayannis and Campbell, 2006, p. 11).

10 See: http://en.wikipedia.org/wiki/Creativity (retrieved: October 29, 2009)

11 Hemlin et al. provide the following definition for CKEs (quoted from the slide page number 3 of a power point presentation: http://www.spp.gatech.edu/conference2006/PPTs/Hemlin_7E.pdf, retrieved November 16, 2009): Creative knowledge environments = "… those environments, contexts and surroundings, the characteristics of which are such that they exert a positive influence on human beings engaged in creative work aiming to produce new knowledge or innovations, whether they work individually or in teams, within a single organization or in collaboration with others".

12 Consequently, the influential book *The New Production of Knowledge* (Gibbons et al., 1994) also could have been titled as *The Creative Production of Knowledge*.

13 The full names of the whole research team are: Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, and Martin Trow.

14 On the concept of "co-opetition" (forms or network configurations of a simultaneous cooperation and competition) see Brandenburger and Nalebuff (1997).

15 Modes of knowledge and innovation may be reinterpreted as "paradigms" or as being paradigm-based.

16 According to Wikipedia (http://en.wikipedia.org/wiki/Thomas_Kuhn, retrieved: November 12, 2009) the concept of a "paradigm shift" is being referred to Kuhn, however, was not literally created by Kuhn.

17 At least one potential quality of print books will be to serve as a different backup medium (in paper) for the electronic e-books. University libraries again often are challenged of not exactly knowing, where to store the masses of print publications in the long run.

18 Current hybrid cars combine a combustion engine with an electric motor. Next generation automobiles might be hybrid plug-in hydrogen cars that link an electric motor with a fuel cell. Such cars could either be externally charged directly with electricity or could convert, in the fuel cell, hydrogen and oxygen to electricity (and heat) for the electric motor. Hydrogen cars powered by fuel cells emit only water (water vapour). Is the electricity for the plug-in device or the hydrogen for the fuel cell generated in a clean way, this next generation technology might contribute to a substantial reduction of carbon dioxide emissions of the land-bound traffic and would help balancing the current effects of a global warming of the world climate. Several analysts believe that some of the Japanese and German car companies are (at least for the moment) the global leaders in hydrogen technology.

19 Two key books of Eric von Hippel, "The Sources of Innovation" (1988) and "Democratizing Innovation" (2005), are electronically available as a free download (http://web.mit.edu/evhippel/www/books.htm). Print versions must be purchased. This illustrates how a print medium and an electronic medium of the same publication can be combined in an innovative, creative and effective way, and furthermore might indicate a promising hybrid strategy for publishers in the future.

20 As an interesting example for a citizen audit on the quality of democracy, which was carried out in recent years, see Cullell (2004) on Costa Rica.

21 The general website address of the "Democracy Ranking" is: http://www.democracyranking.org/en

22 See also: http://epi.yale.edu/Home

23 For an analysis of the different dynamics in the biotechnology and ICT sectors in Finland, Christopher Palmberg and Terttu Luukkonen (2006, pp. 160-161, 167-169) apply the concept of the "competence block". Here the "entrepreneur" is crucial. Palmberg and Luukkonen define the entrepreneur as: "*Entrepreneurs*, or innovators, who *identify* profitable inventions and introduce them in the market. … The task of the *entrepreneur* is to identify those ideas that have the greatest potential commercial value and therefore to contribute to turning inventions into innovations in the market."

24 A system could be defined as consisting of "elements/parts" and the "rationale/self-rationale" of these system elements (Carayannis and Campbell, 2009, p. 204). Of course, alternative definitions for a system also are possible.

25 See also: http://en.wikipedia.org/wiki/Ecology (retrieved: November 06, 2009).

26 See also: http://www.uni-klu.ac.at/socec/inhalt/1860.htm

27 Government/opposition cycles of the political system find a partial equivalent in the so-called concept of "knowledge swings", referring to the possibility of a sequential patterning of which modes of knowledge or innovation are dominant in which periods of time (Carayannis & Campbell, 2009, p. 225).

28 This also leads to the question whether Mode 3 encourages that professionals carry hybrid competences, and thus qualify as "polyvalence professionals" (see, for example, Meglic et al., 2009).

29 In earlier historical periods also variations of a Mode 2 problem-solving existed, but with less or no cross-connections to a sciences-based Mode 1 knowledge. In that line of thinking, Mode 2 might be "older" than Mode 1 (see also Etzkowitz & Leydesdorff, 2000, p. 116).

30 At this point we leave it open, what in the logical continuation of such a conceptual sequence a Sextuple Helix (six-helix model) or a Septuple Helix (seven-helix model) possibly may or could be.

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