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Open Innovation Diplomacy and a 21st Century Fractal Research, Education and Innovation (FREIE) Ecosystem: Building on the Quadruple and Quintuple Helix Innovation Concepts and the "Mode 3" Knowledge Production System

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Abstract The traditional Triple Helix innovation model focuses on university–industry–government relations. The Quadruple Helix innovation systems bring in the perspectives of the media-based and culture-based public as well as that of civil society. The Quintuple Helix emphasizes the natural environments of society, also for the knowledge production and innovation. Therefore, the quadruple helix contextualizes the triple helix, and the quintuple helix the quadruple helix. Features of the quadruple helix are: culture (cultures) and innovation culture (innovation cultures); the knowledge of culture and the culture of knowledge; values and lifestyles; multiculturalism, multiculture, and creativity; media; arts and arts universities; and multi-level innovation systems (local, national, global), with universities of the sciences, but also universities of the arts. The *democracy of knowledge*, as a concept and metaphor, highlights

On the OID concept, see Carayannis, NATO Conference, 2010; Carayannis, BILAT Conference, Vienna, Austria, March 2011; Johns Hopkins School of Advanced International Studies Transatlantic Research Center Conference, Washington, DC, June 2011, and Springer Journal of the Knowledge Economy (JKEC), Fall 2011 (forthcoming).

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and underscores parallel processes between political pluralism in advanced democracy, and knowledge and innovation heterogeneity and diversity in advanced economy and society. The "mode 3" knowledge production system (MODE3KPS; expanding and extending the "mode 1" and "mode 2" knowledge production systems) is at the heart of the fractal research, education and innovation ecosystem. MODE3KPS universities or higher education systems are interested in integrating and combining mode 1 and mode 2. The concept of open innovation diplomacy (OID) encompasses the concept and practice of bridging distance and other divides (cultural, socioeconomic, technological, etc.) with focused and properly targeted initiatives to connect ideas and solutions with markets and investors ready to appreciate them and nurture them to their full potential. In this sense, OID qualifies as a new and novel strategy, policy-making, and governance approach in the context of the quadruple and quintuple innovation helices.

Keywords Open innovation diplomacy · Mode 3 knowledge production system · Fractal research, education and innovation (FREIE) ecosystem · Quadruple helix innovation · Quintuple helix innovation · Democracy of knowledge · Knowledge democracy · Innovation networks · Knowledge clusters · Knowledge fractals · Knowledge nuggets · Glo*C*al · Multidimensional and multi-attribute knowledge and innovation systems · Art and arts universities · Academic firm · Entrepreneurial university · Mode 3 university · Technological learning dynamics · Knowledge swings · Disjointed incrementalism · Partisan mutual adjustment · Strategic incrementalism · Strategic management of technological learning · Conceptual branding · Knowledge weavers

Introduction to Knowledge and Definition of Terms

> New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life.
>
> FRANKLIN D. ROOSEVELT
>
> November 17, 1944

Open Innovation Diplomacy,[1] Quadruple Helix Innovation,[2] "Mode 3" Knowledge Production System,[3] FREIE[4]

Our conceptual point of departure here is our article release in the International Journal of Technology Management that was published back in 2009: *"Mode 3" and "Quadruple Helix": Toward a 21st Century Fractal Innovation Ecosystem* [43]. In

[1] See Carayannis, BILAT, March 2011, SAIS TRC, June 2011 and Springer JKEC, Fall 2011.
[2] See Carayannis and Campbell, IJTM, 2009.
[3] See Carayannis and Campbell, IJTM, 2009.
[4] See Carayannis, BILAT, March 2011, SAIS TRC, June 2011 and Springer JKEC, Fall 2011.

the following, we iterate and reiterate our earlier work and focus on analytically and discursively expanding our previous propositions. With this analytical expansion, we want to reflect the discussions since. We also want to develop a more future-oriented outlook and vision, addressing the current challenges and introducing a problem solving that is interested in sustainable solutions, emphasizing a sustainable development perspective that brings together *innovation*, *entrepreneurship*, and *democracy.*

Developed and developing economies alike face increased resource scarcity and competitive rivalry. Science and technology increasingly appear as a main source of competitive and sustainable advantage for nations and regions alike. However, the key determinant of their efficacy is the quality and quantity of entrepreneurship-enabled innovation that unlocks and captures the pecuniary benefits of the science enterprise in the form of private, public, or hybrid goods. In this context, linking university basic and applied research with the market, via technology transfer and commercialization mechanisms including government–university–industry partnerships and risk capital investments, constitutes the essential trigger mechanism and driving device for sustainable competitive advantage and prosperity. In short, university researchers properly informed, empowered, and supported are bound to emerge as the architects of a prosperity that is founded on a solid foundation of scientific and technological knowledge, experience, and expertise and not in fleeting and conjectural "financial engineering" schemes. Building on these constituent elements of technology transfer and commercialization, *innovation diplomacy* encompasses the concept and practice of bridging distance and other divides (cultural, socioeconomic, technological, etc.) with focused and properly targeted initiatives to connect ideas and solutions with markets and investors ready to appreciate them and nurture them to their full potential.

The emerging *gloCalizing*, globalizing, and localizing [35, 36], frontier of converging systems, networks, and sectors of innovation driven by increasingly complex, nonlinear, and dynamic processes of knowledge creation, diffusion, and use, confronts us with the need to re-conceptualize—if not reinvent—the ways and means that knowledge production, utilization, and renewal take place in the context of the knowledge economy and society (gloCal knowledge economy and society).

Perspectives from and about different parts of the world and diverse human, socioeconomic, technological, and cultural contexts are interwoven to produce an emerging new worldview on how specialized knowledge, which is embedded in a particular socio-technical context, can serve as the unit of reference for stocks and flows of a hybrid, *public/private*, *tacit/codified*, *tangible/virtual good* that represents the building block of the knowledge economy, society, and polity.

"Mode 1" of *knowledge production* refers primarily to basic university research (basic research performed by the higher education sector) that is being organized in a disciplinary structure. "Mode 2" focuses on knowledge application and a knowledge-based problem solving that involves the following principles: "knowledge produced in the context of application," "transdisciplinarity," "heterogeneity and organizational diversity," "social accountability and reflexivity," and "quality control" [60]. As a more far-reaching re-conceptualization of knowledge production, we postulate and introduce a new approach that we call the "mode 3" *knowledge production system* (expanding and extending the "mode 1" and "mode 2" knowledge production systems), which is at the heart of the *fractal research, education and innovation ecosystem* (FREIE) and consists of "innovation networks" and "knowledge clusters" (see definitions below) for knowledge creation, diffusion, and use [37]. This is a *multilayered*, *multimodal*, *multi-nodal*, and *multilateral* system encompassing mutually complementary and reinforcing innovation networks and knowledge clusters consisting of human and intellectual capital, shaped by social capital and underpinned by financial capital.

The "mode 3" knowledge production system is in short the nexus or hub of the emerging twenty-first century innovation ecosystem[5] where *people*,[6] *culture*,[7] and *technology*[89] [31] (forming the essential "mode 3" knowledge production system building block or "knowledge nugget") [28] meet and interact to catalyze creativity, trigger invention, and accelerate innovation across scientific and technological disciplines, public and private sectors (government, university, industry, and non-governmental knowledge production, utilization, and renewal entities as well as other civil society entities, institutions, and stakeholders), in a top-down, policy-driven as well as bottom-up, entrepreneurship-empowered fashion. One of the basic ideas of the article is: *coexistence*, *co-evolution*, and *co-specialization* of different knowledge paradigms and different knowledge modes of knowledge production and knowledge use as well as their co-specialization as a result. We can postulate a dominance of knowledge heterogeneity at the systems (national, transnational) level. Only at the subsystem (subnational) level should we expect homogeneity. This understanding we can paraphrase with the term "mode 3" knowledge production system.

Embedding concepts of knowledge creation, diffusion, and use in the context of general systems theory could prove mutually beneficial and enriching for systems theory as well as knowledge-related fields of study as this could:

(a) Reveal for systems theory a new and important field of application and
(b) At the same time, provide a better conceptual framework for understanding knowledge-based and knowledge-driven events and processes in the economy and, hence, reveal opportunities for optimizing public sector policies and private sector practices.

[5] Furthermore, see Milbergs [84].
[6] See discussion on democracy in the conclusion of this article.
[7] "*Culture* is the invisible force behind the tangibles and observables in any organization, a social energy that moves people to act. Culture is to the organization what personality is to the individual—a hidden, yet unifying theme that provides meaning, direction, and mobilization" [67].
[8] *Technology* is defined as that "which allows one to engage in a certain activity…with consistent quality of output," the "*art of science and the science of art*" [27], or "*the science of crafts*" [6].
[9] We consider the following quote useful for elucidating the meaning and role of a "knowledge nugget" as a building block of the "mode 3 innovation ecosystem": "People, culture, and technology serve as the institutional, market, and socio-economic 'glue' that binds, catalyzes, and accelerates interactions and manifestations between creativity and innovation as shown in Figure 3, along with public-private partnerships, international Research & Development (R&D) consortia, technical/business/legal standards such as intellectual property rights as well as human nature and the 'creative demon'. The relationship is highly non-linear, complex and dynamic, evolving over time and driven by both external and internal stimuli and factors such as firm strategy, structure, and performance as well as top-down policies and bottom-up initiatives that act as enablers, catalysts, and accelerators for creativity and innovation that leads to competitiveness" [31] (p. 593).

Thus, the major purposes of this chapter could be paraphrased as:

(a) *Adding to the theories and concepts of knowledge* further discursive inputs, such as suggesting a linkage of systems theory and the understanding of knowledge and emphasizing multilevel systems of knowledge and innovation, summarized also under the term “mode 3” *knowledge production systems approach to knowledge creation, diffusion, and use* that we discuss below.
(b) This diversified and conceptually pluralized understanding should *support practical* and *application-oriented decision making* with regard to *knowledge*, *knowledge optimization*, and the *leveraging of knowledge for other purposes*, such as economic performance: knowledge-based decision making has ramifications for knowledge management of firms (global multinational corporations) and universities *as well as* for public policy (knowledge policy, innovation policy).
(c) The *exploration*, *identification*, and *understanding* of the *key triggers*, *drivers*, *catalysts*, and *accelerators* of high-quality and quantity (continuous as well as discontinuous, reinforcing as well as disruptive) innovation and sustainable entrepreneurship (financially and environmentally; see the work by the authors on the *quintuple innovation helix* in [44], pp. 58–63) that serve as the foundations of robust competitiveness within the operational framework of *open innovation diplomacy* and *Diaspora entrepreneurship and innovation networks*.

Definition of Terms

Diplomacy

The art and practice of conducting negotiations between nations
A skill in handling affairs without arousing hostility

- http://www.merriam-webster.com/dictionary/diplomacy

Diplomacy is the art and practice of conducting negotiations between representatives of groups or states. It usually refers to international diplomacy, the conduct of international relations[1] through the intercession of professional diplomats with regard to issues of peace-making, trade, war, economics, culture, environment and human rights. International treaties are usually negotiated by diplomats prior to endorsement by national politicians. In an informal or social sense, diplomacy is the employment of tact to gain strategic advantage or to find mutually acceptable solutions to a common challenge, one set of tools being the phrasing of statements in a non-confrontational, or polite manner.

- http://en.wikipedia.org/wiki/Diplomacy

Science Diplomacy

> What is “Science Diplomacy”? Science Diplomacy (SD) is the exchange of Science and Technology across borders. A valuable resource and little understood tool of awareness, understanding, and capacity building, its power is not widely known or considered often enough.

- http://mountainrunner.us/2007/04/science_diplomacy.html

Cultural Diplomacy

> *Cultural diplomacy* specifies a form of diplomacy that carries a set of prescriptions which are material to its effectual practice; these prescriptions include the unequivocal recognition and understanding of foreign cultural dynamics and observance of the tenets that govern basic dialogue.
> Milton C. Cummings Jr. draws out the meaning of these cultural dynamics in his description of cultural diplomacy as “…the exchange of ideas, information, art, lifestyles, values systems, traditions, beliefs and other aspects of cultures….”

- http://en.wikipedia.org/wiki/Cultural_diplomacy

Economic Diplomacy

> Berridge and James (2003) state that “economic diplomacy is concerned with economic policy questions, including the work of delegations to conferences sponsored by bodies such as the WTO” and include “diplomacy which employs economic resources, either as rewards or sanctions, in pursuit of a particular foreign policy objective” also as a part of the definition.
> Rana (2007) defines economic diplomacy as “the process through which countries tackle the outside world, to maximize their national gain in all the fields of activity including trade, investment and other forms of economically beneficial exchanges, where they enjoy comparative advantage; it has bilateral, regional and multilateral dimensions, each of which is important”.

- http://en.wikipedia.org/wiki/Economic_diplomacy

Innovation Diplomacy

> Science, despite its international characteristics, is no substitute for effective diplomacy. Any more than diplomatic initiatives necessarily lead to good science. These seem to have been the broad conclusions to emerge from a three-day meeting at Wilton Park in Sussex, UK, organised by the British Foreign Office and the Royal Society, and attended by scientists, government officials and politicians from 17 countries around the world. The definition of science diplomacy varied widely among participants. Some saw it as a subcategory of "public diplomacy", or what US diplomats have recently been promoting as "soft power" ("the carrot rather than the stick approach", as a participant described it).
> Others preferred to see it as a core element of the broader concept of "innovation diplomacy", covering the politics of engagement in the familiar fields of international scientific exchange and technology transfer, but raising these to a higher level as a diplomatic objective.

- http://scidevnet.wordpress.com/category/science-diplomacy-conference-2010/

> Science and innovation together have a role that can be used to promote global equality and sustainable development," Seabra da Cruz said. He pointed out how Brazil's surging capacity in science and technology has provided a new channel for establishing relations with other countries, particularly emerging economies such as China and India, and those in other parts of the developing world:

> The big challenge to us and other emerging economies is to find ways of using scientific knowledge to enhance our competitiveness and create a new international division of labour. Without linking scientific knowledge to innovation policy, it is impossible to have sustainable development." As an example of innovation diplomacy in action, he pointed to how technical knowledge can be exchanged between countries about the best ways of using cheap, sustainable sources of energy—as Brazil is doing with its experience in biofuels—helping to improve relations between the providers of such knowledge and those that receive it. "This is an example of where we can exchange information about best social and innovation practices—which are all likely to involve science to a greater or lesser degree—and also provide an immediate and relatively easy way of making innovation work for diplomacy." He admitted that, as with science diplomacy, innovation diplomacy presents a number of challenges. Diplomats need to be well informed on innovation-related issues, embassies need to develop "observatories" that monitor the innovation landscape of the countries in which they are based, and ways need to be found to engage a country's scientific and technological diaspora.

More specifically, innovation diplomacy leverages entrepreneurship and innovation as key drivers, catalysts, and accelerators of economic development and envisions in particular the development of efforts and initiatives along the following axes concerning in particular the socioeconomic condition and dynamics in Greece currently:

1. *Re-engineer mindsets, attitudes, and behaviors* to help people—and especially the younger ones—realize the true nature and potential of innovation and entrepreneurship as a way of life and the most powerful lever for and pathway to sustainable growth and prosperity with positive spillover effects staunching the brain drain, reduced cynicism and increased optimism and trust in the future and each other, reduced criminality and social unrest, higher assimilation of migrant groups, etc.
2. *Engage in sustained, succinct, and effective dialog with stakeholders and policy makers within the involved countries* to pursue the reform and as needed reinvention of institutions, policies, and practices that can make flourish entrepreneurship and innovation in areas such as related laws, rules and regulations, higher education, public and private research and development, civil society movements and non-governmental organizations, etc.
3. *Identify, network, and engage purposefully and effectively with the Diaspora professional and social networks around the world* to trigger, catalyze, and accelerate their involvement and intervention in a focused and structured manner to help with goals 1 and 2 above as well as help establish, fund, and manage entrepreneurship- and innovation-promoting and -supporting initiatives and institutions such as business plan competitions, angel and other risk capital financing of new ventures, mentoring of, and partnering with said ventures to ensure their survival, growth, and success both within a given country and in the global markets. Of particular interest and importance would be communities of practice and interest among the Diaspora entrepreneurship and innovation networks.

To fully leverage the potential of systems (and systems theory), one should also demonstrate how a system design can be brought in line with other available concepts, such as innovation networks and knowledge clusters. With regard to clusters, at least three types of clusters can be listed:

1. *Geographic (spatial) clusters*: In that understanding, a cluster represents a certain geographic, spatial configuration, either tied to a location or a larger region. Geographic, spatial proximity, for example for the exchange of tacit knowledge, is considered as crucial. While "local" clearly represents a subnational entity, a "region" could be either subnational or transnational.
2. *Sectoral clusters*: This cluster approach is carried by the understanding that different industrial or business sectors develop specific profiles with regard to knowledge production, diffusion, and use. One could even add that sectoral clusters even support the advancement of particular "knowledge cultures." In innovation research, the term "innovation culture" already is being acknowledged [69] (p. 958).
3. *Knowledge clusters*: Here, a cluster represents a specific configuration of knowledge, and possibly also of knowledge types. However, in geographic (spatial) and sectoral terms, a knowledge cluster is not predetermined. In fact, a knowledge cluster can crosscut different geographic locations and sectors, thus operating

globally and locally (across a whole multilevel spectrum). Crucial for a knowledge is if it expresses an innovative capability, for example produces knowledge that excels (knowledge-based) economic performance. A knowledge cluster, furthermore, may even include more than one geographic and/or sectoral clusters.

Networks emphasize *interaction*, *connectivity* and *mutual complementarity*, and *reinforcement*. Networks, for example, can be regarded as the internal configuration that ties together and determines a cluster. Networks also can express the relationship between different clusters. *Innovation networks* and *knowledge clusters* thus resemble a *matrix*, indicating the interactive complexity of knowledge and innovation. Should the (proposed) conceptual flexibility of systems (and systems theory) be fully leveraged, it appears important to demonstrate how systems relate conceptually to knowledge clusters and innovation networks as they are key in understanding the nature and dynamics of knowledge stocks and flows. What we suggest is to link the two basic components (attributes) of systems ("elements/parts" and "rationale/self-rationale") [12] (p. 426) with clusters and networks [37] (pp. 9–10). What results is the formation of two pairs of theoretical equivalents (see Fig. 1):[10]

1. *Elements and clusters*: The elements (parts) of a system can be regarded as an equivalent to clusters (knowledge clusters).
2. *Rationale and networks*: The rationale (self-rationale) of a system can be understood as an equivalent to networks (innovation networks).

The rationale of a system holds together the system elements and expresses the relationship between different systems. It could be argued that, at least partially, this rationale manifests itself ("moves through") as networks. At the same time, elements of a system might also manifest themselves as clusters. Perhaps, networks could be affiliated with the functions of a system and clusters with the structures of systems. This would help indicating to us, should we be interested in searching for structures and functions of knowledge and innovation systems, what exactly to look for. This, obviously, does not imply to claim that structures and functions of knowledge (innovation) systems only fall into the conceptual boxes of "clusters" and "networks." However, clusters and networks should be regarded as crucial subsets for the elements and rationales of systems.

This equation formula (between elements/clusters and rationales/networks) might need further conceptual and theoretical development. But it lays open a convincing route for better understanding knowledge and innovation through tying together two strong conceptual traditions (systems theory with clusters and knowledge). A further ramification of networks, as we will demonstrate later on, could also imply understanding (at least the large-scale) knowledge strategies as complex network configurations.

As a new input for discussion, we wish to introduce the concept of the "mode 3" *knowledge creation, diffusion, and use system*, and we define below the essential elements or building blocks of "mode 3." The notion "mode 3" was coined by Carayannis (late fall of 2003) and was as a concept jointly developed by Carayannis and Campbell [37].

[10] Of course there may also be *systems of clusters* and *networks* or *clusters* and *networks of systems*.

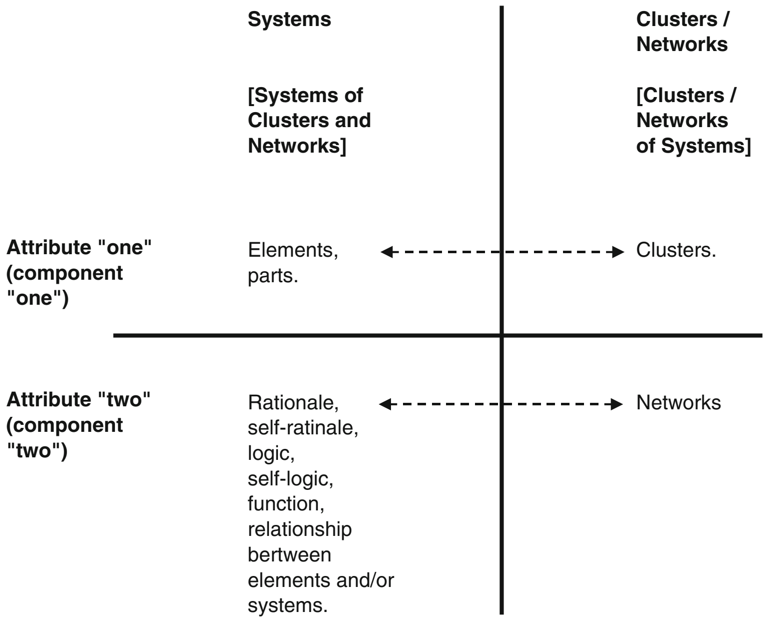


Fig. 1 Theoretical equivalents between conceptual attributes of systems and clusters/networks. Source: Authors' own conceptualization based on [43] (p. 204)

In the following, we list some of the key definitions which refer to “mode 3” and associated concepts (see also [39, 43]).

- The “mode 3” systems approach for knowledge creation, diffusion, and use

  “Mode 3” is a multilateral, multi-nodal, multimodal, and multilevel systems approach to the conceptualization, design, and management of real and virtual, “knowledge stock” and “knowledge flow,” modalities that catalyze, accelerate, and support the creation, diffusion, sharing, absorption, and use of co-specialized knowledge assets. “Mode 3” is based on a system-theoretic perspective of socioeconomic, political, technological, and cultural trends and conditions that shape the co-evolution of knowledge with the “knowledge-based and knowledge-driven, gloCal economy and society.[11]
- Innovation networks

  Innovation networks[12] are real and virtual infrastructures and infra-technologies that serve to nurture creativity, trigger invention, and catalyze innovation in a public and/or private domain context (for instance, government–university–industry public–private research and technology development co-opetitive partnerships).[13,14]

[11] Carayannis and von Zedtwitz [35].

[12] Networking is important for understanding the dynamics of advanced and knowledge-based societies. Networking links together different modes of knowledge production and knowledge use and also connects (subnationally, nationally, transnationally) different sectors or systems of society. Systems theory, as presented here, is flexible enough for integrating and reconciling systems and networks, thus creating conceptual synergies.

[13] Carayannis and Alexander [33].

[14] Carayannis and Alexander [29].

- Knowledge clusters
  Knowledge clusters are agglomerations of co-specialized, mutually complementary, and reinforcing knowledge assets in the form of "knowledge stocks" and "knowledge flows" that exhibit self-organizing, learning-driven, dynamically adaptive competences and trends in the context of an open systems perspective.
- Twenty-first century FREIE
  A twenty-first century FREIE is a multilevel, multimodal, multi-nodal, and multi-agent system of systems. The constituent systems consist of innovation meta-networks (networks of innovation networks and knowledge clusters) and knowledge meta-clusters (clusters of innovation networks and knowledge clusters) as building blocks and organized in a self-referential or chaotic[15] fractal[16] [61] knowledge and innovation architecture [27], which in turn constitute agglomerations of human, social, intellectual, and financial capital stocks and flows as well as cultural and technological artifacts and modalities, continually co-evolving, co-specializing, and co-opeting. These innovation networks and knowledge clusters also form, reform, and dissolve within diverse institutional, political, technological, and socioeconomic domains including government, university, industry, and non-governmental organizations and involving information and communication technologies, biotechnologies, advanced materials, nanotechnologies, and next-generation energy technologies.

Mode 3, Quadruple Helix, Quintuple Helix, Democracy of Knowledge, Schumpeter's Creative Destruction, and the Co-evolution of Different Knowledge Modes

In the following chapters, we present in greater detail different aspects of advanced knowledge and innovation. Crucial for the suggested "mode 3" approach is the idea that an advanced knowledge system may integrate different knowledge modes. Some

[15] Carayannis [27] discusses chaos theory and fractals in connection to technological learning and knowledge and innovation system architectures: "Chaos theory is a close relative of catastrophe theory, but has shown more potential in both explaining and predicting unstable non-linearities, thanks to the concept of self-similarity or fractals [*patterns within patterns*] and the chaotic behavior of attractors (Mandelbrot) as well as the significance assigned to the role that initial conditions play as determinants of the future evolution of a non-linear system [61]. There is a strong affinity with strategic incrementalism, viewed as a third-order (triple-layered), feedback-driven system that can exhibit instability in any given state as a result of the operational, tactical, and strategic technological learning…that takes place within the organization in question."

[16] "A *fractal* is a geometric object which is rough or irregular on all scales of length, and so which appears to be 'broken up' in a radical way. Some of the best examples can be divided into parts, each of which is similar to the original object. Fractals are said to possess infinite detail, and some of them have a self-similar structure that occurs at different levels of magnification. In many cases, a fractal can be generated by a repeating pattern, in a typically recursive or iterative process. The term *fractal* was coined in 1975 by Benoît Mandelbrot, from the Latin *fractus* or 'broken'. Before Mandelbrot coined his term, the common name for such structures (the Koch snowflake, for example) was *monster curve*. Fractals of many kinds were originally studied as mathematical objects. *Fractal geometry* is the branch of mathematics which studies the properties and behavior of fractals. It describes many situations which cannot be explained easily by classical geometry, and has often been applied in science, technology, and computer-generated art. The conceptual roots of fractals can be traced to attempts to measure the size of objects for which traditional definitions based on Euclidean geometry or calculus fail" (http://en.wikipedia.org/wiki/Fractal).

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. We could state that competitiveness and sustainability of the glo*C*al knowledge economy and society increasingly depend on the elasticity and flexibility of promoting a co-evolution and, by this, also a cross-integration of different knowledge (innovation) modes. This heterogeneity of knowledge modes should create hybrid synergies and additionalities.

The "triple helix" model of knowledge, developed by Henry Etzkowitz and Loet Leydesdorff [53] (pp. 111–112), stresses three "helices" that intertwine and, by this, generate a national innovation system: academia/universities, industry, and state/government. Etzkowitz and Leydesdorff are inclined to speaking of "university–industry–government relations" and networks, also placing a particular emphasis on "tri-lateral networks and hybrid organizations" where those helices overlap. In extension of the triple helix model, we suggest a "quadruple helix" model (see Fig. 2). Quadruple helix, in this context, means to add to the above stated helices a "fourth helix" that we identify twofold as the "media-based and culture-based public" as well as the "civil society" (see, furthermore, [43], pp. 206–207) [47, 49, 75]. This should emphasize that a broader understanding of knowledge production and innovation application requires that also the public becomes more integrated into advanced innovation systems. The public uses and applies knowledge, so public users are also part of the innovation system. In an advanced knowledge society and knowledge economy, knowledge flows out into all spheres of society. When we speak of the "public" in context of the quadruple helix, we mean, in more particular, the media-based and culture-based public and civil society. But also other aspects are being addressed: culture (cultures) and innovation culture (innovation cultures)[17]; the *knowledge of culture* and the *culture of knowledge* [45]; values and lifestyles; multiculturalism, multiculture, and creativity; media; arts and arts universities; and multilevel innovation systems (local, national, global), with universities of the sciences but also universities of the arts. These diverse and heterogeneous settings of culture should help in fostering creativity, which is so necessary and essential for creating and producing new knowledge and new innovations. "We can also call this the creativity of knowledge creation" [44] (p. 48). In organizational and institutional terms, this encourages developing "creative knowledge environments". Hemlin et al. [64] define such contexts in the following way: "Creative knowledge environments (CKEs) are 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".[18] Richard Florida [57] coined the notion of the "creative class" (a term, coined by Richard) [57]. 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"

[17] On "innovation culture," see also [69] (pp. 954, 958, 962).

[18] For a further possible application of the Creative Knowledge Environments, see [101].

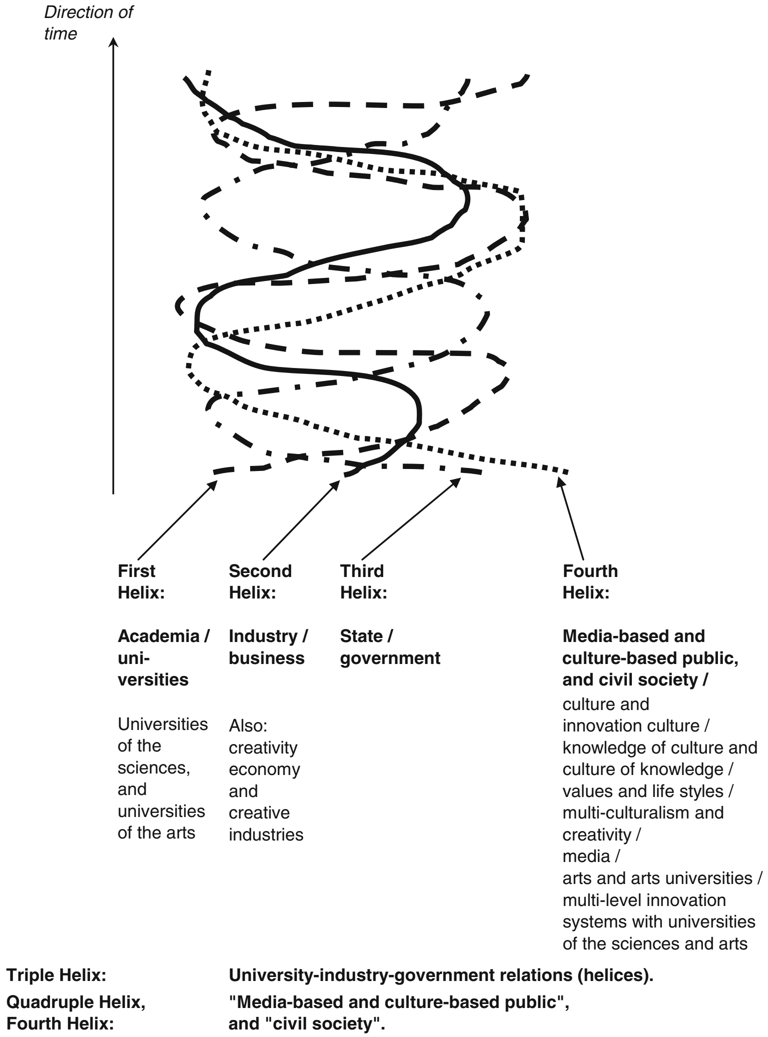


Fig. 2 The conceptualization of the “quadruple helix” innovation system. Source: Authors' own conceptualization based on [53] (p. 112), [43] (p. 207; 2010, p. 62), [49]

is being constructed and communicated by the media, on the other, influence every national and every multilevel innovation system. The proper “innovation culture” is here key for promoting an advanced knowledge-based economy. Through public discourses, transported through and interpreted by the media, it is crucial for a society to assign top priorities to innovation and knowledge (research, technology, education).

The creative industries are part of an economy, in context of the quadruple helix. It is reasonable, however, not only to speak of the creative industries but also to envision more comprehensively a “creativity economy,” where creativity is relevant for all sectors of the economy as well as all sectors of society. An advanced knowledge economy is a knowledge economy, innovation economy, and a creativity economy at the same time. The more mature and advanced a knowledge economy, innovation economy, and knowledge society are, the more creativity is being demanded. As Dubina et al. [52] state: "The more advanced and mature a knowledge economy (creativity economy) and knowledge society (creativity society) are, the more knowledge, innovation and creativity can be absorbed and are even being demanded for further progress. *The creativity economy creatively interrelates technological innovations with social innovations*" (see Fig. 3).

In the multilevel innovations systems, which are being carried and driven by advanced knowledge production in the context of the quadruple helix innovation model, research activities of the universities of the sciences (natural sciences, life sciences, social sciences, and humanities) are essential. However, what counts here are not only the sciences but also the arts. The sciences are a manifestation of knowledge, but also the arts, at least partially, can be understood as a manifestation of knowledge. In the context of higher education and the universities, we are often inclined to speak of "scientific research." But there exist also important forms of "artistic research." Artistic research, in fact, represents an innovative conceptualization of a new form of art creation and art practice, possibly also a new form of knowledge creation. "'Artistic research' is a new practice in the arts in which artists themselves act as researchers and present their findings in the form of artwork. This practice is firmly established at European universities but has so far provoked little public response. What distinguishes artistic research from 'mere' art, and what contributions can it make to the art world?" [7] (cover page; see also [82, 83]; furthermore, see [103]). Artistic research and research in the arts can engage in interdisciplinary and transdisciplinary network arrangements with research in the sciences. Artistic research and universities of the arts should be regarded as being of a crucial importance for multilevel innovation systems in advanced knowledge economies that are also creativity economies (see also [118]). Artistic research, research in the arts, and arts universities, in hybrid, pluralized, and heterogeneous combinations with universities of the sciences and research in the sciences, add to the creativity of new knowledge production and new innovations. In the sciences, there is often the understanding of a spectrum from basic (pure) research to applied research. Also for the arts, one may propose a spectrum of (pure) basic artistic research to the (applied) practice of arts (see Fig. 4).[19]

The triple helix may be regarded as a "core model" for innovation, resulting from interactions in knowledge production referring to universities (higher education), industries (economy), and governments (multilevel). The triple helix is being contextualized by the broader innovation model of the quadruple helix, which is blending in features of the public, for example civil society and the media-based and culture-based public. The quintuple helix innovation model, finally, contextualizes the quadruple helix (and triple helix). The quintuple helix brings in the perspective of the natural environments of society and the economy for knowledge production and the innovation systems. "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" [44] (p. 61). A sustainable balance between the paths of development of society and the

[19] Figure 4 should be seen here as a suggestion, as an input for discussion. The conceptual feasibility of Fig. 4 still would have to be tested.

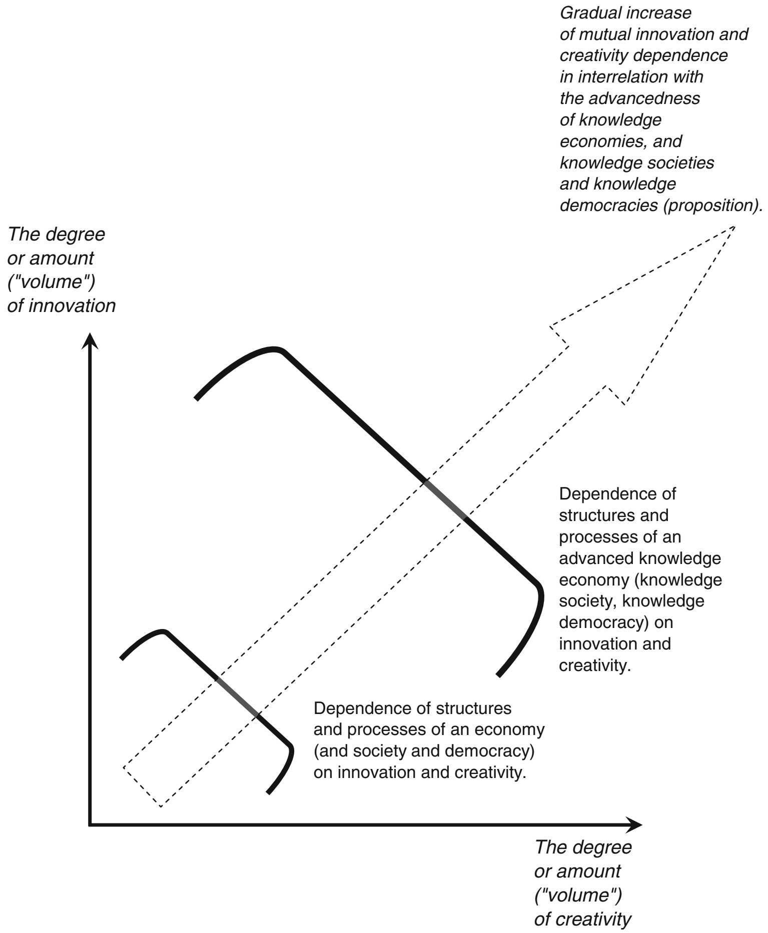
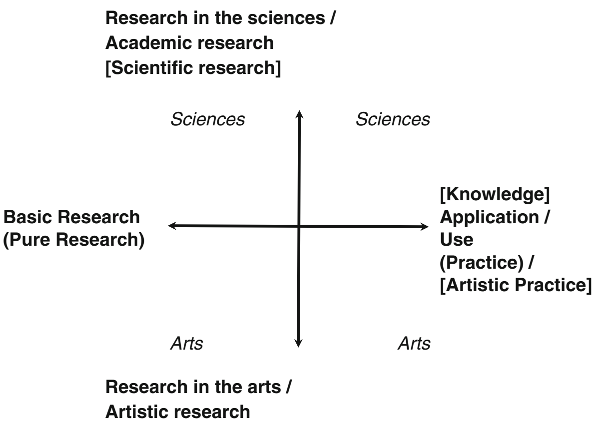


Fig. 3 The increasing cross-interrelation of innovation and creativity in advanced knowledge economies, knowledge societies, and knowledge democracies. Source: Authors' own conceptualization based on [52]

Fig. 4 Research and knowledge application in the sciences and the arts. Source: Authors' own conceptualization



economy, with their natural environments, is essential for the further progress of human civilizations. The quintuple helix, however, also emphasizes that the natural environments should be conceptualized as drivers for the further advance of knowledge production and innovation systems. Thus, the quintuple helix model appears to be compatible with the interests, also analytical interests, of social ecology (on social ecology, see [56]). The quadruple helix contextualizes the triple helix, and the quintuple helix contextualizes the quadruple helix (see Fig. 5). Depending on the interests and the analytical interests, it could be equally appropriate to frame a research question either in reference to the triple helix, quadruple helix, or quintuple helix innovation models. However, even when an analysis or assessment is being carried out in a triple helix framework, also, at one point, the contexts of quadruple helix and quintuple helix should be taken into consideration. The knowledge and innovation perspectives of quadruple and quintuple helix are broader; thus, they add crucially to the prospects and opportunities of a sustainable problem solving. The more advanced knowledge societies and knowledge economies are progressing, the more there is a need to shift the attention to broader innovation models (see Fig. 6).[20]

Figure 7 displays visually from which conceptual perspectives the co-evolution and cross-integration of different knowledge modes could be approached. Mode 3 emphasizes the additionality and surplus effect of a *co-evolution of a pluralism of knowledge and innovation modes*. Quadruple helix refers to the structures and processes of the gloCal (global and local) knowledge economy and society; quintuple helix also brings in the perspective of the natural environments (social ecology). Furthermore, the "innovation ecosystem," combining and integrating social and natural systems and environments, stresses the importance of a pluralism of a diversity of agents, actors, and organizations: universities (universities of the sciences and arts), small- and medium-sized enterprises, and major corporations, arranged along the matrix of fluid and heterogeneous innovation networks and knowledge clusters. This all may result in a *democracy of knowledge*, driven by a pluralism of knowledge and innovation and by a pluralism of paradigms of knowledge modes. The democracy of knowledge, as a concept and metaphor, is being carried by the understanding that there operates (at least potentially) a co-evolution between processes of advancing democracy and processes of advancing knowledge and innovation. Between processes and structures of advanced knowledge democracy, knowledge society, and knowledge economy, there is a certain congruence [44] (pp. 54–58, 60–61). Concepts of democracy (moving from electoral to liberal and high-quality democracies), and of knowledge and innovation (for example, refocusing from triple helix to quadruple and quintuple helices), are becoming broader and increase their complexity considerably. *Political pluralism in democracy cross-refers to creativity-encouraging heterogeneity and diversity of different forms, modes and paradigms of knowledge and innovation*.[21] In "The Republic of Science," Michael Polanyi [100] expressed already some similar ideas:

[20] Loet Leydesdorff [74] launched the interesting intellectual experiment of engaging in theorizing on "N-tuple helices" of innovation systems, introducing here multidimensional view perspectives.

[21] This, of course, also challenges our external and internal governance models of higher education. For an overview on governance approaches in higher education, see Ferlie et al. [55]; see also [3]. On structures and changes of universities, see also [71–73].

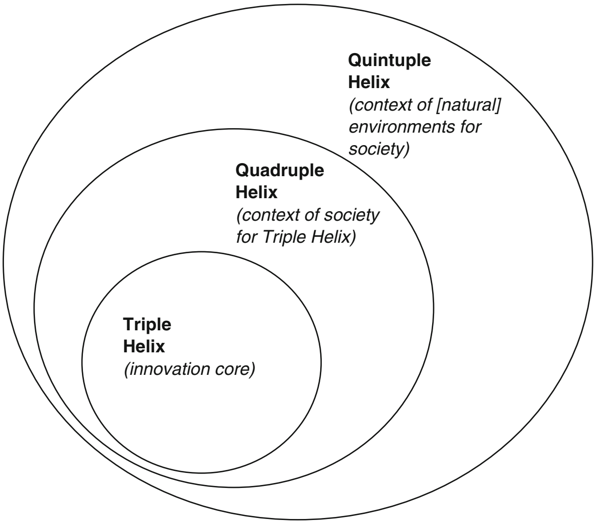


Fig. 5 Society as context for triple helix innovation systems; natural environments as context for quadruple helix innovation systems. Source: Authors' own conceptualization based on [53] (p. 122), [43] (p. 207; 2010, p. 62) and [49]

"My title is intended to suggest that the community of scientists is organized in a way which resembles certain features of a body politic and works according to economic principles similar to those by which the production of material goods is

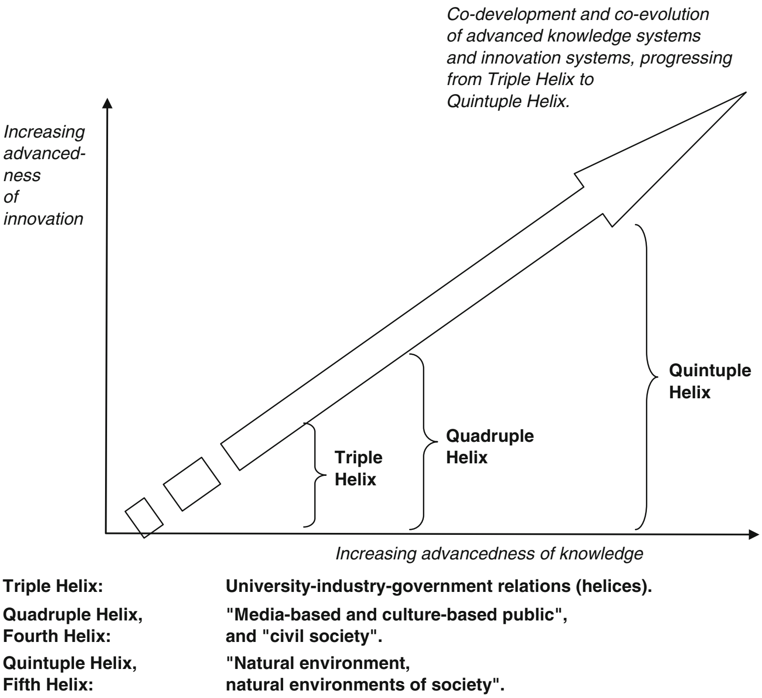


Fig. 6 Co-development and co-evolution of advanced knowledge production and vanced innovation systems. Source: Authors' own conceptualization based on [53] (p. 112), [49] (p. 207; 2010, p. 62) and [49]

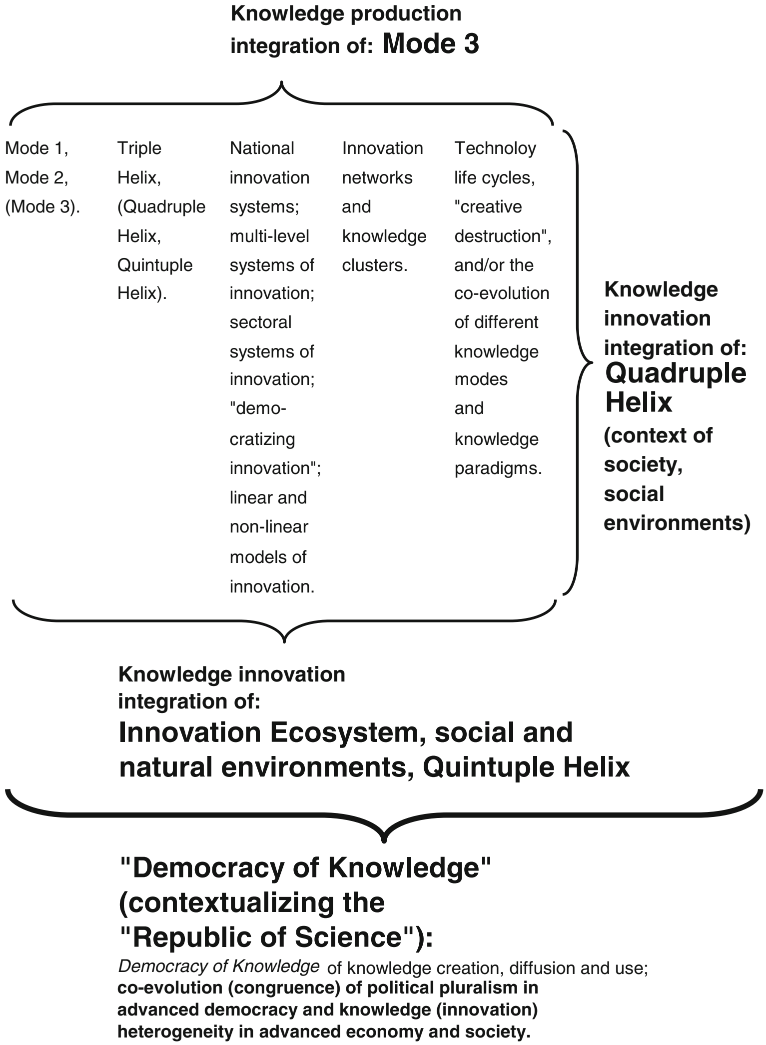


Fig. 7 Knowledge creation, diffusion, and use in a democracy of knowledge. Source: Authors' own conceptualization based on [43] (p. 208); see also [115] and [100]

regulated.” We suggest here that the *democracy of knowledge* contextualizes the *republic of science* in an already broader perspective.

In the “Frascati Manual,” the Organization for Economic Co-operation and Development [93] (p. 29) distinguishes between the following activity categories of research (R&D, research and experimental development): basic research; applied research; and experimental development. Basic research represents a primary competence of university research, whereas business R&D focuses heavily on experimental development. Assessed empirically for the USA, one of the globally leading national innovation systems, with regard to the financial volume of R&D resources, the experimental development ranks first, applied research second, and basic research third [96, 87] (Chapter 4, pp. 8–16). Interesting, however, is the dynamic momentum when observed for a longer period of time. Basic research in the USA grew faster than applied research. In 1981, 13.4% of the US R&D was devoted to basic research. By 2008, basic research increased its percentage share to 17.47%. During the same time period, the percentage shares of applied research stagnated and experimental development even declined (see also [43], pp. 209–210). This links up to the question whether we should expect an R&D "U-curving" for US innovation system, implying that basic research further will increase its percentage shares of the overall R&D expenditure while experimental development may slide back. This would go hand-in-hand with an importance gain of basic research. Furthermore, would such a potential future scenario for the USA also spill over to other national innovation systems?

Assessed in a long-term perspective (1953–2008), there has been a substantial shift in the financing and funding of the national R&D in the USA. Until the early 1970s, the federal government was the most important funding source for R&D. After that, business moved up to become the primary funding source and gradually increased its dominance since then. During the 1970s, the funding base of national R&D in the USA converted from primarily public to primarily private [87] (Chapter 4, pp. 11, 14). This feeds general expectations that mature and advanced national R&D systems are being funded and performed, first of all, by the economy (the business enterprise sector). In less advanced R&D systems, the role of business is less important, in relative terms. However, and this appears to be a crucial argument here, this importance gain of the economy does not imply that basic or applied research is becoming less important. What seems to count then is the basic and applied research conducted by business. Business basic research creates key opportunities to interact, cross-link, and network with the university basic research in the higher education sector, thus fostering hybrid knowledge and innovation interactions, in a linear and nonlinear fashion.

The OECD [95] provides the following definition for 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." We should raise the question whether this is still an appropriate or sufficient definition for basic research? The problem is that this definition creates a contradiction between basic research and application, but why? In the old world of a dominance of "mode 1" for the universities, this may have been a legitimate position or proposition, but in the new worlds of mode 2 and mode 3 of knowledge production, this general exclusion of application, for basic research, does not make sense. In the old world of knowledge production, perhaps there was a reasonable interest in a sharp line of division (boundary) between basic and applied research. Nowadays, *basic research in the context of application* has risen to new prominence and importance, and may be one of the keys for remodeling our knowledge and innovation systems. So there also appears to be a need or even a demand for a more "application-friendly" redefinition of basic research. The here suggested phrasing for a redefinition of basic research could be as follows: "*Basic research* is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, *without or with* a particular application or use in view (in the long run)." Such a redefinition nicely balances the qualities of basic research with the opportunities of more simultaneously coupling basic research with application, linearly and nonlinearly.

There is even a chance that the established definition of basic research, quoted above and still being used by the OECD, really underestimates the extent of basic research that already is being conducted by the economy. Is the economy (in the advanced knowledge economy) performing more *basic business research* than the conventional definitions capture and reflect? Our proposed conceptual redefinition of basic research may radically and substantially shift and transform our assessment of the patterns and behavior of advanced knowledge and innovation.

In a simple understanding, the "linear model of innovation" claims: first, there is basic university research. Later this basic research converts into applied research of intermediary organizations (university-related institutions).[22] Finally, firms pick up and transform applied research to experimental development, which is then being introduced as commercial market applications. This linear understanding often is referred to Vannevar Bush [5], even though Bush himself, in his famous report, neither mentions the terms "linear model of innovation" nor even the word "innovation." "Non-linear models of innovation", on the contrary, underscore a more parallel coupling of basic research, applied research, and experimental development. Thus, universities or higher education institutions in general, university-related institutions, and firms join together in variable networks and platforms for creating innovation networks and knowledge clusters. Even though there continues to be a division of labor and a functional specialization of organizations with regard to the type of R&D activity, universities, university-related institutions, and firms can perform, at the same time, basic and applied research and experimental development. Surveys about sectoral innovation in the pharmaceutical sector [81] and the chemical sector [48] reveal how each of these industries may be characterized by complex network configurations and arrangement of a diversity of academic and firm actors. The mode 3 innovations ecosystem thus represents a model for an interactive coupling of "nonlinear innovation modes": partially, this also could mean linking together "linear innovation modes" of different degrees of maturity in the knowledge value chain or closeness to market application, fostering the setup of "creative knowledge environments" in organizations and institutions (see Fig. 8). *Cross-employment* (multi-employment) may be regarded as one strategy for realizing creative knowledge environments. Cross-employment (multi-employment) refers to a knowledge worker, employee, who is being simultaneously employed by more than one organization, possibly being located in different sectors (for example, a higher education and a non-higher education institution, e.g., a university and a firm). This supports the direct network-style coupling of very different organizations in knowledge production and innovation application, expressing, therefore, what nonlinear innovation could mean in practical terms [19].

The concept of the "entrepreneurial university" captures the need of linking more closely together university research with the R&D market activities of firms (see, for example, [54]). Mode 1 refers to a university knowledge production that focuses on basic university research that is interested in delivering comprehensive explanations of the world, structured in a "disciplinary logic," and not (per se) interested in knowledge application and innovation. Mode 2 refers to a university knowledge production that is based on the following principles: (1) "knowledge produced in the context of

[22] In the German language, "university-related" would qualify as "außeruniversitär" [13] (p. 99).

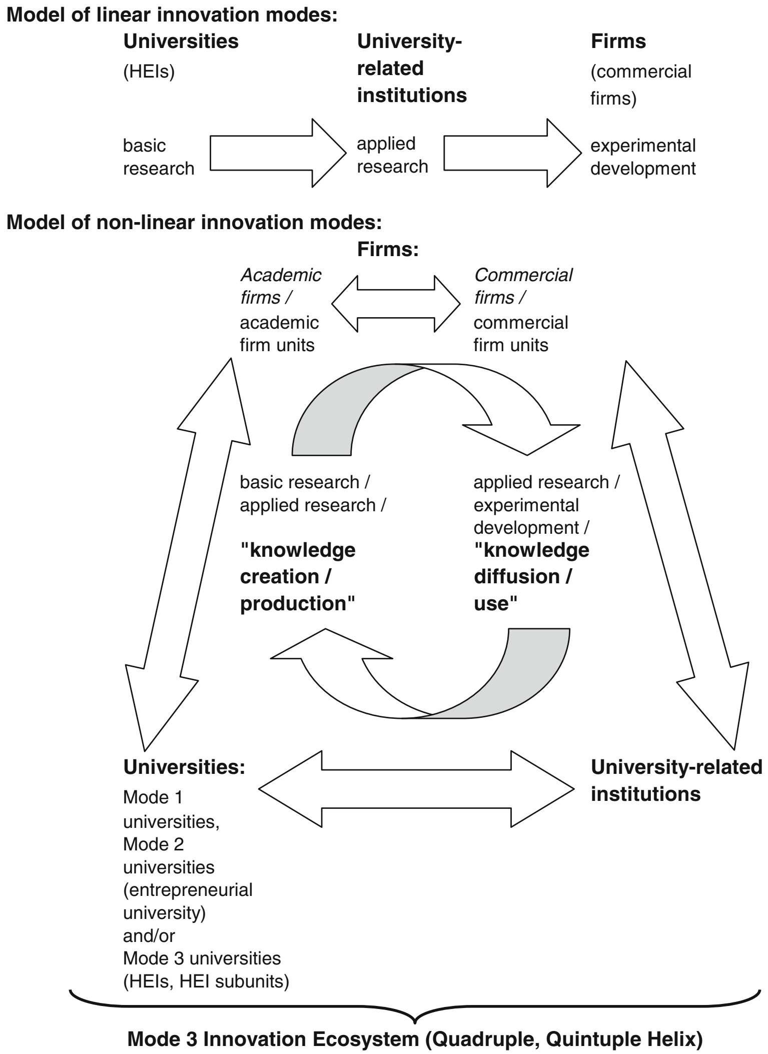


Fig. 8 Linear and nonlinear innovation modes linking together universities (mode 1, mode 2, and/or mode 3 universities) with commercial and academic firms (firm units). Source: Authors' own conceptualization based on [43] (p. 211)

application," (2) "transdisciplinarity," (3) "heterogeneity and organizational diversity," (4) "social accountability and reflexivity," and (5) "quality control" (see [60], pp. 3–8, 167). "Mode 2" universities and "entrepreneurial universities" overlap, at least conceptually. A "mode 3" university (higher education institution) or higher education sector would be an organization or a system that operates simultaneously according to the two knowledge principles of modes 1 and 2. Mode 3 universities seek organizational designs in trying to combine, in co-evolving, and co-learning patterns; modes 1 and 2, by believing that this creates a surplus in high-quality, creative, and sustainable knowledge (knowledge production). Are mode 3 universities ideal–typical concepts or are they empirical concepts? Do mode 3 universities indicate examples for ambidextrous organizations?

As important as the entrepreneurial university or the mode 3 university is for us the concept of the "academic firm,"[23] which represents the complementary business organization and strategy vis-à-vis the entrepreneurial and mode 3 universities. The interplay of academic firms and entrepreneurial (mode 3) universities should be regarded as crucial for advanced knowledge-based economies and societies. The following characteristics represent the academic firm [21] (p. 171): "support of the interfaces between the economy and the universities"; "support of the paralleling of basic research, applied research and experimental development"; "incentives for employees to codify knowledge"; "support of collaborative research and of research networks"; and "a limited 'scientification' of business R&D." Despite continuing important functional differences between universities and firms, also some limited hybrid overlapping may occur between entrepreneurial universities and academic firms, expressed in the circumstance that entrepreneurial universities and academic firms can engage more easily in university/business research networks. In an innovation-driven economy, the business R&D is being supported and excelled when it can refer to inputs from a networking of universities and firms clearly supporting business R&D. The academic firm also engages in "basic business research." Of course, we always must keep in mind that academic firms and universities are not identical because academic firms represent business units, still interested in creating commercial revenues and profits.

The *commercial firm* concentrates on maximizing or optimizing profit, whereas the *academic firm* focuses on maximizing or optimizing knowledge and innovation. While the entrepreneurial (mode 2) university represents a partial extension of business elements to the world of academia, the academic firm could serve as an example for an extension of the world of academia to the world of business. Academic firms are knowledge-oriented, interested in engaging in networks with universities (the higher education sector), encourage "academic culture and values" to motivate their employees, allow forms of academic work (such as academic-style publishing), and support continuing education and life-long learning of and for their employees (flexible time schemes, honoring life-long learning and continued, continuing education with internal career promotion).

The concept of the "academic firm" may refer to:

1. A whole firm,
2. A subunit, subdivision, or branch of a "commercial" firm,[24] and
3. Certain characteristics or elements of a whole (commercial) firm.

Are academic firms ideal–typical or empirical concepts? Are firms, interested in integrating principles of the commercial and academic firm, examples for ambidextrous organizations? For the future, this may have the following challenging implication: How can or should firms balance, within their "organizational boundaries," principles of the academic and of the more traditional "commercial" firm?

[23] The "academic firm," as a notion and concept, was first developed by Campbell and Güttel [21].

[24] In many contexts, this second option appears to be more realistic, particularly when we analyze multinational companies or corporations that operate in global context.

The “technology life cycles” explain why there is always a dynamic momentum in the gloCal knowledge economy and society [109]. The “saturation tendency” within every technology life cycle demands the creation and launch of new technology life cycles, leading to the market introduction of next-generation technology-based products and services. In reality, always different technology life cycles with varying degrees of market maturity will operate in parallel. To a certain extent, technology life cycles are also responsible for the cyclicality (growth phases) of a modern market economy. The perhaps shortest possible way of describing the economic thinking of Joseph A. Schumpeter is to put up the following equation: entrepreneurship, leveraging the opportunities of new technology life cycles, creates economic growth. Addressing the cyclicality of capitalist economic life, Schumpeter [105] used the notion of the “creative destruction”. “Mode 3” may open up a route for overcoming or transforming the destructiveness of the “creative destruction” [42].

The Conceptual Understanding of Knowledge and Innovation

Knowledge does matter: but the question is when, how, and why? Moreover, with the advancement of economies and societies, *knowledge matters even more* and in ways that are not always predictable or even controllable (for example, see the concepts of *strategic knowledge serendipity* and *strategic knowledge arbitrage* in [32]). The successful performance of the developed *and* the developing economies, societies, and democracies increasingly depends on knowledge. One branch of knowledge develops along R&D (research and experimental development), science and technology (S&T) and innovation.[25]

Innovation Placed in Context

> Discovery consists of looking at the same thing as everyone else and thinking something different.
> Albert Szent-Gyorgyi—Nobel Prize Winner

Innovation is a word derived from the Latin meaning to introduce something new to the existing realm and order of things or to change the yield of resources, as stated by J.B. Say, quoted in Drucker [51].

In addition, innovation is often linked with creating a sustainable market around the introduction of new and superior product or process. Specifically, in the literature on the management of technology, technological innovation is characterized as the introduction of a new technology-based product into the market:

> *Technological innovation* is defined here as a situationally new development through which people extend their control over the environment. Essentially, technology is a tool of some kind that allows an individual to do something new. A technological innovation is basically information organized in a new

[25] Another branch of knowledge can be based on education and its diversified manifestations.

> way. So technology transfer amounts to the communication of information, usually from one organization to another.
> The broader interpretation of the term "innovation" refers to an innovation as an "idea, practice or material artifact" adopted by a person or organization, where that artifact is "perceived to be new by the relevant unit of adoption". Therefore, innovation tends to change perceptions and relationships at the organizational level, but its impact is not limited there. Innovation in its broader socio-technical, economic, and political context, can also substantially impact, shape, and evolve ways and means people live their lives, businesses form, compete, succeed and fail, and nations prosper or decline.

From a business perspective, an innovation is perceived as the happy ending of the commercialization journey of an invention, when that journey is indeed successful and leads to the creation of a sustainable and flourishing market niche or new market. Therefore, a technical discovery or invention (the creation of something new) is not significant to a company unless that new technology can be utilized to add value to the company through increased revenues, reduced cost, and similar improvements in financial results. This has two important consequences for the analysis of any innovation in the context of a business organization.

First, an innovation must be integrated into the operations and strategy of the organization so that it has a distinct impact on how the organization creates value or on the type of value the organization provides in the market. Second, an innovation is a social process since it is only through the intervention and management of people that an organization can realize the benefits of an innovation.

The discussion of innovation clearly leads to the development of a model to understand the evolving nature of innovation. Innovation management is concerned with the activities of the firm undertaken to yield solutions to problems of product, process, and administration. Innovation involves uncertainty and disequilibrium. Nelson and Winter [89] propose that almost any change, even trivial, represents innovation. They also suggest, given the uncertainty, that innovation results in the generation of new technologies and changes in relative weighting of existing technologies [89]. This results in the *disruptive process* of disequilibrium. As an innovation is adopted and diffused, existing technologies may become less useful (reduction in weight factors) or even useless (weighing equivalent to "0") and abandoned altogether. The adoption phase is where uncertainty is introduced. New technologies are not adopted automatically, but rather markets influence the adoption rate. Innovative technologies must propose to solve a market need such as reduced costs or increased utility or increased productivity. The markets, however, are social constructs and subject to non-innovation-related criteria. For example, an invention may be promising, offering a substantial reduction on the cost of a product which normally would influence the market to accept the given innovation, but due to issues like information asymmetry (the lack of knowledge in the market concerning the invention's properties), the invention may not be readily accepted by the markets. Thus, the innovation may remain an invention. If, however, the innovation is accepted in the market, the results will bring about change to the existing technologies being replaced, leading to a change in the relative weighting of the existing technology. This is in effect *disequilibrium*.

Given the uncertainty and change inherent in the innovation process, the management must develop skills and understanding of the process a method for managing the disruption. The problems of managing the resulting disruption are strategic in nature. The problems may be classified into three groups: *engineering*, *entrepreneurial*, and *administrative*. This grouping correlates to the related types of innovation, namely, *product*, *process*, and *administrative innovation*:

- The engineering problem is one of selecting the appropriate technologies for proper operational performance.
- The entrepreneurial problem refers to defining the product/service domain and target markets.
- Administrative problems are concerned with reducing the uncertainty and risk during the previous phases.

In much of the foregoing discussion, a recurring theme about innovation is that of *uncertainty*, leading to the conclusion that an effective model of innovation must include a multidimensional approach (uncertainty is defined as unknown unknowns, whereas risk is defined as known knowns). One model posited as an aide to understanding is the multidimensional model of innovation. This model attempts to define the understanding of innovation by establishing three-dimensional boundaries. The planes are defined as product–process, incremental–radical, and administrative–technical. The product–process boundary concerns itself with the end product and its relationship to the methods employed by firms to produce and distribute the product. Incremental–radical defines the degree of relative strategic change that accompanies the diffusion of an innovation. This is a measure of the disturbance or disequilibrium in the market. Technological–administrative boundaries refer to the relationship of innovation change to the firm's operational core. The use of technological refers to the influences on basic firm output, while the administrative boundary would include innovations affecting associated factors of policy, resources, and social aspects of the firm.

The Relationship Between Knowledge and Innovation

What is the relationship between knowledge and innovation? From our viewpoint, it makes sense not to treat knowledge and innovation as interchangeable concepts. Ramifications of this are (see Fig. 9):

1. There are aspects, areas of knowledge, which can be analyzed without considering innovation (for example, "pure basic research" in a linear understanding of innovation).
2. Consequently, there are also areas or aspects of innovation which are not (necessarily) tied to knowledge or a research-based knowledge. For example, see the different contributions to Shavinina [107].
3. However, there are also areas where knowledge and innovation coexist. These we would like to call *knowledge-based innovation*, indicating areas where knowledge and innovation express a mutual interaction.

		Knowledge	
		yes	*no*
Innovation	*yes*	Knowledge-based innovation or knowledge, which through innovation, is linked with society, economy and politics. Examples: Mode 1 and technology cycles in the long run, Mode 2, Triple Helix.	Innovation, taking place with no (almost no) references to knowledge. (at least with no references to research, R&D, or a research-based knowledge). Examples: management innovations in businesses, which are not R&D or technology-based.
	no	Knowledge, without major references to innovation (and use). Examples: "pure research", perhaps some components of Mode 1 and of early phases of technology life cycles.	*? (Not of primary concern for our conceptual mapping here, perhaps in epistemological and philosophical terms of interest.)*

Fig. 9 A fourfold typology about possible cross-references and interactions between "knowledge" and "innovation". Source: Authors' own conceptualization based on [43] (p. 213)

In the case of knowledge-referring innovation, we then can speak of innovation that deals with knowledge. Our impression is that in many contexts, when the focus falls on innovation, almost automatically this type of "knowledge-referring" or "knowledge-based" innovation is implied. Even though we will focus on this knowledge-based innovation, it still is important to acknowledge the possibilities of a knowledge without innovation *and* of an innovation independently of knowledge, or a research-based knowledge. To further illustrate our point, the notion of the "national innovation system" or "national system of innovation" conventionally expresses linkages to knowledge (see [79, 88]).

The "Mode 3" Knowledge Production System Multilevel Approach to Knowledge and Innovation

In research about the European Union (EU), references to a "multilevel architecture" are quite common (see, for example, [65]). Originating from this research about the EU, this "multilevel" approach is being applied in a diversity of fields since it supports the understanding of complex processes in a globalizing world. Inspired by this, we suggest using the concept of *multilevel systems of knowledge* (see Fig. 10; furthermore, see [37]). One obvious axis, therefore, is the spatial (geographic, spatial–political) axis that expresses different levels of spatial

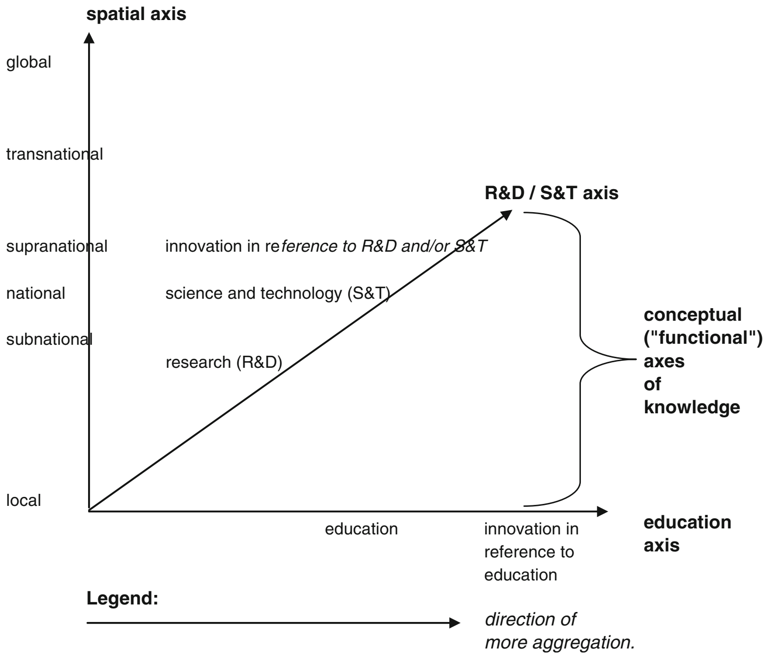


Fig. 10 "Three-dimensional" modeling of knowledge in a multilevel system understanding: axis of spatial aggregation, axis of R&D aggregation, axis of education aggregation. Source: Authors' own conceptualization, adapted from [43] (p. 215)

aggregations. The national level, coinciding with the nation state (the currently dominant manifestation of arranging and organizing political and societal affairs), represents one type of spatial aggregation. Subnational aggregations fall below the nation state level and point toward local political entities. Transnational aggregations, for example, can refer to the supranational integration process of the EU. This raises the interesting question whether we should be prepared to expect that in the twenty-first century we will witness a proliferation of supranational (transnational) integration processes also in other world regions, possibly implying a new stage in the evolution of politics where (small- and medium-sized) nation state structures become absorbed by supranational (transnational) clusters [9]. The highest level of transnational aggregation we currently know is globalization. Interestingly, the aggregation level of the term "region(s)" has never been convincingly standardized. In the context and political language of the EU, regions are understood subnationally. American scholars, on the other hand, often refer to regions in a state-transcending understanding (i.e., a region consisting more than one nation states). The new term glo*C*al (global/local) [35] underscores the potentials and benefits of a mutual and parallel interconnectedness between different levels.

Despite the importance of this spatial axis, we wish not to exhaust the concept of multilevel systems of knowledge with spatial–geographic metaphors. We suggest adding on non-spatial axes of aggregation. These we may call conceptual (functional) axes of knowledge. In that context, two axes certainly are pivotal: education and research (R&D, research and experimental development). For research, the level of aggregation can develop accordingly: R&D, S&T,[26] and R&D-referring innovation, involving a whole broad spectrum of considerations and aspects. Obviously, every "axis direction" of further aggregation—as demonstrated here for R&D—depends on a specific conceptual understanding. Should, for example, a different conceptual approach for defining S&T be favored, then the sequence of aggregation might change (concerning the education axis, for the moment, we want to leave it to the judgment of other scholars what here meaningful terms at different levels of aggregation may be). In Fig. 10, we present a three-dimensional visualization of a multilevel system of knowledge, combining one spatial with two non-spatial (conceptual) axes of knowledge (R&D and education).

How many non-spatial (conceptual) axes of knowledge can there be? We focused on the R&D and education axes. By this, however, we do not want to imply that there may not be more than two conceptual axes. Here, at least in principle, a multitude or diversity of conceptual model-building approaches is possible and also appropriate. Perhaps, we even could integrate "innovation" as an additional conceptual axis, following the aggregation line from local to national and transnational innovation systems. We then would have to contemplate what the relationship is between such an "extra innovation axis" with the "innovation" of the research and education axes. "Regional" innovation could cross-reference local and transnational innovation systems, implying even glo*C*al innovation systems and processes that simultaneously link through different aggregation levels.

We already discussed the conceptual boundary problems between knowledge and innovation. One approach, how to balance ambiguities in this context, is to acknowledge that a partial conceptual overlap exists between a *knowledge-centered* and *innovation-centered* understanding. Depending on the focus of the preferred analytical view, the same "element(s)" can be conceptualized as being part of a knowledge or of an innovation system. Concerning knowledge, we pointed to some of the characteristics of multilevel systems of knowledge, underscoring the understanding of aggregation of spatial and non-spatial (conceptual) axes. Introducing multilevel systems of knowledge also justifies speaking of multilevel systems of innovation, developing the original concept of the national innovation system [79, 88] further. For example, the spatial axis of aggregation of knowledge (Fig. 10) also applies to innovation. Of course, also Lundvall [79] explicitly stresses that national innovation systems are permanently challenged (and extended) by regional as well as global innovation systems. But, paraphrasing Kuhlmann [69], as long as nation state-based political systems exist, it makes sense to acknowledge national innovation systems. In a spatial (or geographic) understanding, the term multilevel systems of innovation already is being used [66] (pp. 395, 405–406) [69] (pp. 970–971, 973). However, only more recently has it been suggested to extend this multilevel aggregation approach of innovation also to the non-spatial axes of innovation [15, 37]. Therefore, multilevel systems of knowledge as well as multilevel systems of innovation are based on spatial and non-spatial axes. A further advantage of this multilevel system architecture is that it results in a more accurate and closer-to-reality description of processes of globalization and

[26] In that context, also the mutual overlapping between R&D, S&T, and information and communication technology should be stressed.

gloCalization. For example, internationalization of R&D crosscuts these different multilevel layers and links together organizational units of business, academic, and political actors at the national, transnational, and subnational levels [117]. One interpretation of R&D internationalization emphasizes how different subnational regions and clusters cooperate on a global scale, creating even larger transnational knowledge clusters.

The concept of the "sectoral systems of innovation" (SSI) crosscuts the logic of the multilevel systems of innovation or knowledge. A sector often is being understood in terms of the industrial sectors. Sectors can perform locally/regionally, nationally, and transnationally. Reviews of SSIs often place a particular consideration on knowledge and technologies, actors and networks, and, furthermore, institutions. Malerba [80] recommends that analyses of sectoral systems of innovation should include "the factors affecting innovation, the relationship between innovation and industry dynamics, the changing boundaries and the transformation of sectors, and the determinants of the innovation performance of firms and countries in different sectors."

Linear Versus (and/or) Nonlinear Innovation Models (Modes)

Is the *linear model of innovation* still valid? In an ideal typical understanding, the linear model states: first there is basic research, carried out in a university context. Later on, this basic research is converted into applied research, and moves from the university to the university-related sectors. Finally, applied research is translated into experimental development, carried out by business (the economy). What results is a *first–then relationship*, with the universities and/or basic research being responsible for generating the new waves of knowledge creation which are, later on, taken over by business and where business carries the final responsibility for the commercialization and marketing of R&D. National (multilevel) innovation systems, operating primarily on the premises of this linear innovation model, obviously would be disadvantaged: the time horizons for a whole R&D cycle, to reach the markets, could be quite extensive (with negative consequences for an economy, operating in the context of rapidly intensifying global competition). Furthermore, the linear innovation model exhibits serious weaknesses in communicating user preferences from the market end back to the production of basic research. In addition, how should the tacit knowledge of the users and markets be reconnected back to basic research? In the past, after 1945, the USA was regarded as a prototype for the linear innovation model system, with a strong university base, from where basic research gradually would diffuse to the sectors of a strong private economy, without the intervention of major public innovation policy programs (see [5], Chapter "The Importance of Basic Research"). As long as the USA represented the world-leading national economy, this understanding was sufficient. But with the intensification of global competition, also the demand for shortening the time horizons from basic research to the market implementation of R&D increased [94] (pp. 179–181, 185–186). In the 1980s, Japan in particularly heavily pressured the USA. In the 2000s, global competition within the triad of the USA, Japan, and the EU escalated further, with China and India emerging as new competitors in the global context. In a nutshell, further-going economic competition and intrinsic knowledge demands challenged the linear innovation model.

As a consequence, we can observe a significant proliferation of *nonlinear innovation models*. There are several approaches to nonlinear innovation models. The "chain-linked model," developed by Kline and Rosenberg [68] (cited according to [85], p. 716; see, furthermore, [36]), emphasizes the importance of feedback between the different R&D stages. Particularly, the coupling of marketing, sales, and distribution with research claims to be important. "Mode 2" [60] (pp. 3–8, 167) underscores the linkage of production and use of knowledge by referring to the following five principles: "knowledge produced in the context of application," "transdisciplinarity," "heterogeneity and organizational diversity," "social accountability and reflexivity," and "quality control" (furthermore, see [90, 91]).[27] Metaphorically speaking, the *first–then* sequence of relationships of different stages within the linear model is replaced by a *paralleling* of different R&D activities [11] (pp. 139–141). Paralleling means: (1) linking together in real time different stages of R&D, for example basic research and experimental development, and/or (2) linking different sectors, such as universities and firms. The "triple helix" model of Etzkowitz and Leydesdorff [53] stresses the interaction between academia, state, and industry, focusing consequently on "university–industry–government relations" and "tri-lateral networks and hybrid organizations." Carayannis and Laget [34] emphasize the importance of cross-national and cross-sectoral research collaboration by testing these propositions for transatlantic public–private R&D partnerships. Anbari and Umpleby [1] claim that one rationale for establishing research networks lies in the interest of bringing together knowledge producers, but also practitioners, with "complementary skills." Etzkowitz [54] speaks also of the "entrepreneurial university." An effective coupling of university research and business R&D demands, furthermore, the complementary establishment of the entrepreneurial university and the "academic firm" [21] (pp. 170–172). Extended ramifications of these discourses also refer to the challenge of designing proper governance regimes for the funding and evaluation of university research [59] (see, furthermore, [10, 13, 106]). Furthermore, this imposes consequences on the structures and performance of universities [97]. Also interesting is the concept of "democratizing innovation." With this concept, Eric von Hippel proposes a "user-centric innovation" model in which "lead users" represent "innovating users" who again contribute crucially to the performance of innovation systems. "Lead users" can be individuals or firms. Users often innovate because they cannot find on the market what they want or need [115] (also, [114]). Non-proprietor knowledge, such as the "open source" movement in the software industry [108] (p. 240), may be seen as successful examples for glo*C*ally self-organizing "user communities."

Put in summary, one could set up the following hypothesis for discussion: while mode 1 and perhaps also the concept of "technology life cycles"[28] appear to be more closely associated with the linear innovation model, the mode 2 and triple helix knowledge modes have more in common with a nonlinear understanding of knowledge and innovation. At the same time, we should add that national

[27] Should we add a further comment to the concepts of modes 1 and 2, it would be interesting to consider how modes 1 and 2 relate to the notions of "science one" and "science two," which were developed by Umpleby [111].

[28] Concerning a further-going discussion of the technology life cycles, see [46, 109].

(multilevel) innovation systems are challenged by the circumstance that several technology life cycles, at different stages of market maturity (closeness to commercial market introduction), perform in parallel. This parallel as well as sequentially time-lagged unfolding of technology life cycles also expresses the characteristics of mode 2 and of nonlinear innovation because organizations (firms and universities) often must develop strategies of simultaneously cross-linking different technology life cycles. Universities and firms (commercial and academic firms) must balance the non-triviality of a fluid pluralism of technology life cycles.

Extending the "Triple Helix" to a "Quadruple Helix" Model of Knowledge and Innovation

In their own words, Etzkowitz and Leydesdorff [53] (p. 118) state that 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." Triple helix is very powerful in describing and explaining the helix dynamics of "university–industry–government relations" that drives knowledge and innovation in the glo*C*al knowledge economy and society. We suggest that advanced knowledge-based economy and advanced democracy have increasingly similar features in the sense of combining and integrating different knowledge modes and different political modes.[29] Modern political science claims that democracy and politics develop along the premises of a "media-based democracy." Fritz Plasser [98] offers the following description for media-based democracy: media reality overlaps with political and social reality, perception of politics primarily through the media, and the laws of the media system determining political actions and strategies. Politics may convert from a "parliamentary representative" to a "media presenting" democracy where "decision" politics moves to a "presentation" politics. Ramifications of the "multimedia information society" clearly impact "political communication" (see also [99]).

The "fourth helix" of the quadruple helix refers to this "media-based and culture-based public" as well as to "civil society" (see again Fig. 2). Knowledge and innovation policies and strategies must acknowledge the important role of the "public" for a successful achieving of goals and objectives. On the one hand, public reality is being constructed and communicated by the media and media system. On the other hand, the public is also influenced by culture and values. Knowledge and innovation policy should be inclined to reflect the dynamics of "media-based democracy" to draft policy strategies. Particularly, when we assume that traditional economic policy gradually (partially) converts into innovation policy, leveraging knowledge for economic performance and thus linking the political system with the economy, then innovation policy should communicate its objectives and rationales, via the media, to the public to seek legitimation (legitimacy) and justification (see Fig. 11; furthermore, see [37], p. 18, and [38], p. 335). Also the public relation strategies of companies, engaged in R&D, must reflect on the fact of a "reality

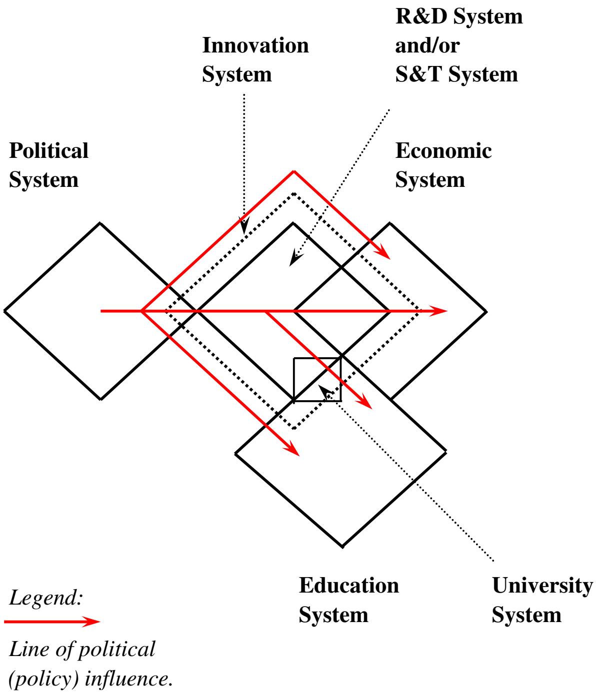
[29] A political mode could be seen as a particular political approach (clustering political parties, politicians, ideologies, values, and policies) to society, democracy, and the economy. Conservative politics, liberal politics, or social democratic politics could be captured by the notion of a "political mode."

construction" by the media. Culture and values also express a key role. Cultural artefacts, such as movies, can create an impact on the opinion of the public and their willingness to support public R&D investment. Some of the technical and engineering curricula at universities are not gender-symmetric because a majority of the students are male. Trying to make women more interested in enrolling in technical and engineering studies would imply also changing the "social images" of technology in society. The sustainable backing and reinforcing of knowledge and innovation in the glo*C*al knowledge economy and society requires a substantive support of the development and evolution of "innovation cultures" [69] (p. 954). Therefore, the successful engineering of knowledge and innovation policies and/or strategies leverages the self-logic of the media system and leverages or alters culture and values. Etzkowitz and Leydesdorff, in their stated quote, emphasize their intention that the triple helix model should help in displaying patterns of "social structure." This in fact provides a rationale why a fourth helix of "media-based and culture-based public" could serve as a useful analytical tool, providing additional insights.

Coexistence and Co-evolution of Different Knowledge and Innovation Paradigms

Discussing the evolution of scientific theories, Thomas S. Kuhn [70] introduced the concept of *paradigms*. Paradigms can be understood as basic fundamentals upon which a theory rests. In that sense, paradigms are axiomatic premises which guide a theory, however cannot be explained by the theory itself: but paradigms add to the explanatory power of theories that are interested in explaining the (outside) world.

Fig. 11 Different societal systems: lines of political (policy) influence. Source: [43] (p. 18 Figs. 1-7)



Paradigms represent something like beliefs. According to Kuhn, there operates an evolution of scientific theories following a specific pattern: there are periods of "normal science" interrupted by intervals of "revolutionary science," again converting over into "normal science," again challenged by "revolutionary science," and so on [23, 24, 26, 27] (see also [112], pp. 287–288). According to Kuhn, every scientific theory, with its associated paradigm(s), has only a limited capacity for explaining the world. Confronted with phenomena which cannot be explained, a gradual modification of the same theory might be sufficient. However, at one point, a revolutionary transformation is necessary, demanding that a whole set of theories/paradigms be replaced by new theories/paradigms. For a while, the new theories/paradigms are adequately advanced. However, in the long run, these cycles of periods of normal science and intervals of revolutionary science represent the dominant pattern.

Kuhn emphasizes this shift of one set of theories and paradigms to a new set, meaning that new theories and paradigms represent not so much an evolutionary offspring but actually replace the earlier theories and paradigms. While this certainly often is true, particularly in the natural sciences, we want to stress that there also can be a *coexistence and co-evolution of paradigms* (and theories), implying that paradigms and theories can mutually learn from each other. Particularly in the social sciences, this notion of coexistence and co-evolution of paradigms might be sometimes more appropriate than the replacement of paradigms. For the social sciences, and politics in more general, we can point toward the pattern of a permanent mutual contest between ideas. Stuart A. Umpleby [110], for instance, emphasizes the following aspect of the social sciences very accurately: "Theories of social systems, when acted upon, change social systems." Not only (social) scientific theories refer to paradigms, also other social contexts or factors can be understood as being based on paradigms: we can speak of ideological paradigms, or of policy paradigms [63]. Another example would be the long-term competition and fluctuation between the welfare-state and the free-market paradigms (with regard to the metrics of left–right placement of political parties in Europe, see [113], p. 158).

These different modes of innovation and knowledge creation, diffusion, and use, which we discussed earlier, certainly qualify to be understood also as linking to *knowledge paradigms*. Because knowledge and innovation systems clearly relate to the context of a (multilevel) society, the (epistemic) knowledge paradigms can be regarded as belonging to the "family of social sciences." Interestingly, mode 2 addresses "social accountability and reflexivity" as one of its key characteristics [60] (pp. 7, 167–168). In addition to the possibility that a specific knowledge paradigm is replaced by a new knowledge paradigm, the relationship between different knowledge and innovation modes may often be described as an ongoing and continuous interaction of a dynamic coexistence and (over time) a co-evolution of different knowledge paradigms. This reinforces the understanding that in the advanced knowledge-based societies and economies, linear and nonlinear innovation models can operate in parallel.

The "Co-opetitive" Networking of Knowledge Creation, Diffusion, and Use

Knowledge systems are highly complex dynamic and adaptive. To begin with, there exists a conceptual (hybrid) overlapping between multilevel knowledge and multilevel innovation systems. Multilevel systems process simultaneously at the global, transnational, national, and subnational levels, creating glo*C*al (global and local) challenges. Advanced knowledge systems should demonstrate the flexibility of integrating different knowledge modes, on the one hand combining linear and nonlinear innovation modes and on the other hand conceptually integrating mode 1, mode 2, and triple helix (for an overview of mode 1, mode 2, triple helix, and technology life cycles, see [15], pp. 71–75). This displays the practical usefulness of an understanding of a coexistence and co-evolution of different knowledge paradigms and what the qualities of an "innovation ecosystem" could or even should be. The elastic integration of different modes of knowledge creation, diffusion, and use should generate synergistic surplus effects of additionality. Hence, for advanced knowledge systems, networks and networking are important [30, 38] (pp. 334–339; for a general discussion of networks and complexity, see also [102]).

How do networks relate to *cooperation and competition?* "Co-opetition," as a concept [4], underscores that there can always exist a complex balance of cooperation and/or competition. Market concepts emphasize a competitive dynamics process between (1) forces of supply and demand, and the need of integrating (2) market-based as well as resource-based views of business activity. To be exact, networks do not replace market dynamics; thus, they do not represent an alternative to the market economy principle of competition. Instead, networks apply a "co-opetitive" rationale, meaning that internally, networks are based primarily on cooperation, but may also allow a "within" competition. The relationship between different networks can be guided by a motivation for cooperation. However, in practical terms, competition in knowledge and innovation often will be carried out between different and flexibly configured networks. While a network cooperates internally, it may compete externally. In short, "co-opetition" should be regarded as a driver for networks, implying that the specific content of cooperation and competition is always decided in a case-specific context.

Conclusion

> *Until philosophers are kings, or the kings and princes of this world have the spirit and power of philosophy,*…cities will never have rest from their evils—no, nor the human race as I believe…." (emphasis added)
>
> Plato, The Republic, Vol. 5, p. 492

> The empires of the future are the empires of the mind
>
> Winston Churchill, 1945

The "mode 3" systems approach for knowledge creation, diffusion, and use emphasizes the following key elements [39]:

1. *GloCal multilevel knowledge and innovation systems*: Because of its comprehensive flexibility and explanatory power, systems theory is regarded as suitable for framing knowledge and innovation in the context of multilevel knowledge and innovation systems [35, 39, 40]. GloCal expresses the simultaneous

processing of knowledge and innovation at different levels (for example, global, national, and subnational; see, furthermore, [58, 116]) and also refers to stocks and flows of knowledge with local meaning and global reach. Knowledge and innovation systems (and concepts) express a substantial degree of hybrid overlapping, meaning that often the same empirical information or case could be discussed under the premises of knowledge or innovation.

2. *Elements/clusters and rationales/networks*: In a theoretical understanding, we pointed to the possibility of linking the "elements of a system" with clusters and the "rationale of a system" with networks. Clusters and networks are common and useful terms for the analysis of knowledge.
3. *Knowledge clusters, innovation networks, and "co-opetition"*: More specifically, we emphasize the terms of "knowledge clusters" and "innovation networks" [40]. Clusters, from an ultimate perspective, by taking demands of a knowledge-based society and economy seriously for a competitive and effective business performance, should be represented as knowledge configurations. Knowledge clusters, therefore, represent a further evolutionary development of geographical (spatial) and sectoral clusters. Innovation networks, internally driving and operating knowledge clusters or crosscutting and cross-connecting different knowledge clusters, enhance the dynamics of knowledge and innovation systems. Networks always express a pattern of "co-opetition," reflecting a specific balance of cooperation and competition. Intra-network and inter-network relations are based on a mix of cooperation and competition, i.e., co-opetition [4]. When we speak of competition, it often will be a contest between different network configurations.
4. *Knowledge fractals*: "Knowledge fractals" emphasize the continuum-like bottom-up and top-down progress of complexity. Each subcomponent (sub-element) of a knowledge cluster and innovation network can be displayed as a micro-level sub-configuration of knowledge clusters and innovation networks (see Fig. 12). At the same time, one can also move upward. Every knowledge cluster and innovation network can also be understood as a subcomponent (sub-element) of a larger macro-level knowledge cluster or innovation network, in other words, innovation meta-networks and knowledge meta-clusters (see again Fig. 12).[30]
5. *The adaptive integration and co-evolution of different knowledge and innovation modes, the "quadruple helix" and "quintuple helix"*: "mode 3" allows and emphasizes the coexistence and co-evolution of different knowledge and innovation paradigms. In fact, a key hypothesis is: The competitiveness and superiority of a knowledge system or the degree of advanced development of a knowledge system are highly determined by their 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 nonlinear innovation). The specific context (circumstances, demands, configurations, cases) determines

[30] Perhaps, only when the whole world is being defined as *one global knowledge cluster and innovation network*, then, for the moment, we cannot aggregate and escalate further to a mega-cluster or mega-network.

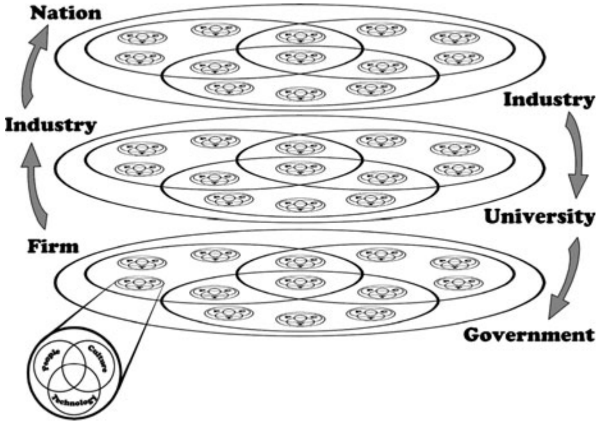


Fig. 12 The twenty-first century fractal innovation ecosystem. Source: Derived from authors' unpublished notes and lectures at GWU,authors' own conceptualization, adapted from [43] (p. 223)

which knowledge and innovation mode (*multimodal*), at which level (*multilevel*), involving what parties or agents (*multilateral*), and with what knowledge nodes or knowledge clusters (*multi-nodal*) will be appropriate. What results is an emerging fractal knowledge and innovation ecosystem ("mode 3 innovation ecosystem"), well configured for the knowledge economy and society challenges and opportunities of the twenty-first century by being endowed with mutually complementary and reinforcing as well as dynamically co-evolving, co-specializing, and co-opeting diverse and heterogeneous configurations of knowledge creation, diffusion, and use. The intrinsic litmus test of the capacity of such an ecosystem to survive and prosper in the context of continually glo*C*alizing and intensifying competition represents the ultimate competitiveness benchmark with regards to the robustness and quality of the ecosystem's knowledge and innovation architecture and topology as it manifests itself in the form of a knowledge value-adding chain. The concept of the "quadruple helix" innovation systems broadens our understanding because it adds the "media-based and culture-based public" and "civil society" to the picture. The "quintuple helix" is even broader by contextualizing the quadruple helix by referring to the "natural environments of society" [44] (p. 62). The *fractal research*, *education* and *innovation ecosystem* (FREIE) represents another conceptual view of bringing those different and complex perspectives dynamically together, what is necessary, when we want to understand, manage, and govern mode 3 as well as the quadruple and quintuple helices. Open innovation diplomacy qualifies as a novel and interesting strategy, policy making, and governance approach in the context of the quadruple and quintuple helices.

The societal embeddedness of knowledge represents a theme that already mode 2 and triple helix explicitly acknowledge. As a last thought for this article, we want to underscore *the potentially beneficial cross-references between democracy and knowledge* for a better understanding of knowledge. In an attempt to define democracy, democracy could be shortcut as an interplay of two principles [14]: (1) *Democracy* can be seen as a *method* or *procedure* based on the application of the rule of the majority.[31] This acknowledges the "relativity of truth" and "pluralism" in a society, implying that decisions are carried out not because they are "true" (or truer) but because they are backed and legitimized by a majority. Since, over time, these majority preferences normally shift, this creates political swings, driving the government/opposition cycles, which crucially add to the viability of a democratic system. (2) *Democracy* can also be understood as a *substance* ("substantially"), where substance, for example, is being understood as an evolutionary manifestation of fundamental rights [92] (pp. 26–27, 47, 54–55). Obviously, the method/procedure and the substance approach overlap. Without fundamental rights, the majority rule could neutralize or even abolish itself. On the other hand, the practical "real political" implementation of rights also demands a political method, an institutionally set-up procedure.

There are several international initiatives interested in systematically measuring democracies globally and in empirical terms. These measurements allow drawing comparisons between the theory of democracy and the actual behavior and performance of democracies. Freedom House, as an example, focuses on freedom as a key dimension of democracy, distinguishing between free, partly free, and not free countries.[32] For Guillermo O'Donnell [92], the interplay of human rights and human development defines and creates the quality of democracy. The Democracy Ranking, another democracy measurement initiative, is being theoretically influenced by O'Donnell and applies the following conceptual formula for defining the quality of democracy: "quality of democracy=(freedom+other characteristics of the political system)+(performance of the non-political dimensions)" [17] (p. 41).[33] Furthermore, the Democracy Ranking distinguishes between the following five dimensions: politics, gender, economy, knowledge, health, and the environment. To the dimension of politics, a weight of 50% is being assigned (for the overall ranking scores); all the other dimensions follow with a weight of 10% [17] (pp. 33–34). With this focus on performance across a variety of dimensions, the Democracy Ranking wants to be *left/right neutral*, as far as possible, not favoring one-sidedly "freedom" or "equality." Often, freedom is being associated more closely to conservative (right) and equality to left ideologies [17] (pp. 31–32; see also [22]). The Democracy Ranking asserts conceptually a link between the quality of democracy and "sustainable development" (at least in a mid-term or long-term perspective). Furthermore, with the specific selection of dimensions for their model of democracy and the quality of democracy, the Democracy Ranking emphasizes knowledge (and innovation) and the environment (the natural environments of society). This makes the Democracy Ranking clearly quadruple helix-friendly and also quintuple helix-friendly, supporting comparative analysis of democracy, knowledge, and innovation. Some key findings of the *Democracy Ranking 2010* are: "The Nordic countries (Norway, Sweden, Finland, Denmark) and Switzerland are the top 5 countries; also New Zeeland, the Netherlands, Ireland, Germany, and the UK have very high scores [18] (p. 2). This continuing global top position of the Nordic countries is impressive, also because this top position is being reproduced quite stably across the different (sub-)dimensions. Thus, it can be said that the Nordic countries define—in a positive

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[31] For example, Joseph A. Schumpeter [105] emphasized this method-based criterion for democracy.

[32] For more information on Freedom House, see http://www.freedomhouse.org/template.cfm?page=1.

[33] On the web, the Democracy Ranking can be visited at http://www.democracyranking.org/en/.

view—a global benchmark for the quality of democracy that is empirically already available. From the top 10 countries, seven belong to the EU. In total, the prominent representation of European democracies at the top positions is remarkable. This underscores that the European integration process should be understood, in the global context, even more clearly as a 'democracy project'." Sustainable development, progress, and performance across different dimensions provide one explanation for the success and the high quality of democracy in the Nordic countries. These are some of the lessons to be learned in context of global analysis (see also [2]).

Linking democracy even more directly to knowledge and innovation, we want to highlight the following aspects (see Fig. 13 for a suggested first-attempt graphical visualization; see also [62], p. 358, and [41]):

1. *Knowledge-based and innovation-based democracy*: The future of democracy depends on evolving, enhancing, and ideally perfecting the concepts of a knowledge-based and innovation-based democratic polity as the manifestation and operationalization of what one might consider the, paraphrased, "twenty-first century platonic ideal state." "It has been basic United States policy that government should foster the opening of new frontiers. It opened the seas to clipper ships and furnished land for pioneers. Although these frontiers have more or less disappeared, the frontier of science remains. It is in keeping with the American tradition—one which has made the United States great—that new frontiers shall be made accessible for development by all American citizens" [5] (p. 10). Knowledge, innovation, and democracy interrelate. Advances in democracy and advances in knowledge and innovation express mutual dependencies.[34] The "quality of democracy" depends on a knowledge base. We see how the gloCal knowledge economy and society and the quality of democracy intertwine. Concepts such as "democratizing innovation" [115] underscore such aspects. Also the media-based and culture-based public of the "quadruple helix" emphasizes the overlapping tendencies of democracy and knowledge.[35]
2. *Pluralism of knowledge modes*: Democracy's strength lies exactly in its capacity for allowing and balancing different parties, politicians, ideologies, values, and policies, and this ability was discussed by Lindblom [76] as *disjointed incrementalism*[36]: "…as the partisan mutual adjustment process: Just as entrepreneurs and consumers can conduct their buying and selling without anyone attempting to calculate the overall level of prices or outputs for the economy as a whole, Lindblom argued, so in politics. Under many conditions, in fact, adjustments among competing partisans will yield more sensible policies than are likely to be achieved by centralized decision makers relying on analysis [76, 77]. This is partly because interaction economizes on precisely the factors

[34] For attempts trying to analyze the quality of a democracy, see for example Campbell and Schaller [20].
[35] On "democratic innovation," see, furthermore, Saward [104].
[36] The *disjointed incrementalism approach* to decision making (also known as *partisan mutual adjustment*) was developed by Lindblom [76, 77] and Lindblom and Cohen [78] and found several fields of application and use: "The Incrementalist approach was one response to the challenge of the 1960s. This is the theory of Charles Lindblom, which he described as 'partisan mutual adjustment' or disjointed incrementalism. Developed as an alternative to RCP, this theory claims that public policy is actually accomplished through decentralized bargaining in a free market and a democratic political economy" (http://www3.sympatico.ca/david.macleod/PTHRY.HTM).

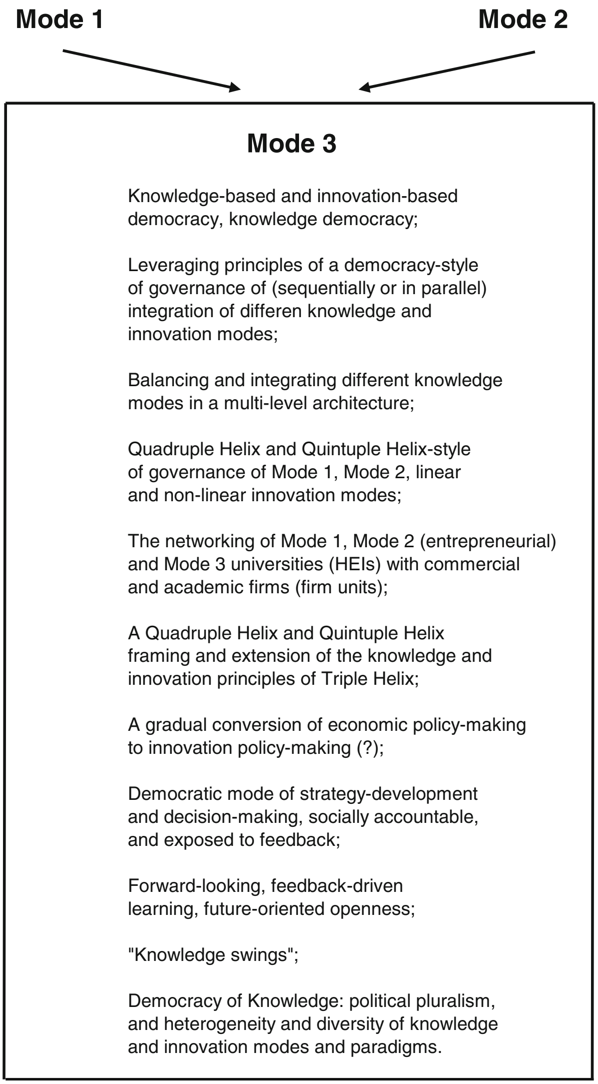

Fig. 13 Knowledge, innovation, and democracy in a democracy of knowledge: gloCal governance styles of the gloCal knowledge economy and society? Source: Authors' own conceptualization based on [62] (p. 358) and on [43] (p. 226)

on which humans are short, such as time and understanding, while analysis requires their profligate consumption. To put this differently, the lynchpin of Lindblom's thinking was that analysis could be—and should be—no more than an adjunct to interaction in political life" (http://www.rpi.edu/~woodhe/docs/redner.724.htm). Similarly, democracy enables the integrating, coexistence, and co-evolution of different knowledge and innovation modes. We can speak of a pluralism of knowledge modes and can regard this as a competitiveness feature of the whole system. Different knowledge modes can be linked to different knowledge decisions and knowledge policies, reflecting the communication skills of specific knowledge producers and knowledge users to convince other audiences of decision makers.

3. "*Knowledge swings*": Through political cycles or *political swings* [8], a democracy ties together different features: (a) decides who currently governs; (b) gives the opposition a chance to come to power in the future; (c) and acknowledges pluralism. Democracy represents a system which always creates and is being driven by an important momentum of dynamics. For example, the statistical probability for governing parties to lose an upcoming election is higher than to win an election [86] (p. 589). Similarly, one could paraphrase the momentum of political swings by referring to "knowledge swings": in certain periods and concrete contexts, a specific set of knowledge modes expresses a "dominant design"[37] position; however, also the pool of non-hegemonic knowledge modes is necessary for allowing alternative approaches in the long run, adding crucially to the variability of the whole system. "Knowledge swings" can have at least two ramifications: (a) What are the dominant and non-dominant knowledge modes in a specific context? (b) There is a pluralism of knowledge modes which exist in parallel and thus also co-develop and co-evolve. Diversity is necessary to draw a cyclically patterned dominance of knowledge modes.
4. *Forward-looking, feedback-driven learning*: Democracy should be regarded as a future-oriented governance system fostering and relying upon social, economic, and technological learning. The "mode 3 innovation ecosystem" is at its foundation an open, adaptive, learning-driven knowledge and innovation ecosystem reflecting the philosophy of *strategic or active incrementalism* [23–27] and the strategic management of technological learning [25] (furthermore, see [50]). In addition, one can postulate that the government/opposition cycle in politics represents a feedback-driven learning and mutual adaptation process. In this context, a democratic system can be perceived of as a pendulum with a shifting pivot point reflecting the evolving, adapting dominant worldviews of the polity as they are being shaped by the mutually interacting and influencing citizens and the dominant designs of the underlying cultures and technological paradigms [27] (pp. 26–27).

In conclusion, we have attempted to provide an emerging conceptual framework to serve as the "intellectual sandbox" and "creative whiteboard space" of the mind's eyes of "knowledge weavers" (*Wissensweber*)[38] across disciplines and sectors as they strive to tackle the twenty-first century challenges and opportunities for socioeconomic prosperity and cultural renaissance based on knowledge and innovation: "As a result of the gloCalized nature and dynamics of state-of-the-art, specialized knowledge…one needs to cope with and leverage two mutually-reinforcing and complementary trends: (a) the symbiosis and co-evolution of top-down national and multi-national science, technology and innovation public policies…and bottom-up technology development and knowledge acquisition private initiatives; and (b) the leveling of the competitive field across regions of the world via technology diffusion and adoption accompanied and complemented by the formation and exacerbation of multi-dimensional, multi-

[37] "Studies have shown that the early period of a new area of technology is often characterized by technological ferment but that the pace of change slows after the emergence of a dominant design" (http://www.findarticles.com/p/articles/mi_m4035/is_1_45/ai_63018122/print).

[38] The term constitutes the brainchild or *conceptual branding* of the authors as part of this journey of discovery and ideation.

lateral, multi-modal and multi-nodal divides (cultural, technological, socio-economic, …).…In closing, being able to practice these two functions—being able to be a superior manager and policy-maker in the twenty-first century—relies on a team's, firm's, or society's capacity to be superior learners…in terms of both learning new facts as well as adopting new rules for learning-how-to-learn and establishing superior strategies for learning to learn-how-to-learn. Those superior learners will, by necessity, be both courageous and humble as these virtues lie at the heart of successful learning" [36]. Already the early Lundvall [79] underscored the importance of learning for every national innovation system.

Mode 3 (mode 3 knowledge production), in combination with the widened perspective of the quadruple helix and quintuple helix (quadruple and quintuple helices innovation systems), emphasizes an innovation ecosystem (social and natural systems and environments) that encourages the co-evolution of different knowledge and innovation modes as well as balances nonlinear innovation modes in the context of multilevel innovation systems. Hybrid innovation networks and knowledge clusters tie together universities, commercial firms, and academic firms. Mode 3 may indicate an evolutionary and learning-based escape route for Schumpeter's "creative destruction" [41]. The "knowledge state" [16] has the potential to network "high-quality" democracy with the gloCal knowledge economy and society. There appears to be, at least potentially, a co-evolution and congruence between advanced knowledge, innovation, economy, society, and democracy. The *democracy of knowledge*, as a concept and metaphor, highlights and underscores parallel processes between political pluralism in advanced democracy, and knowledge and innovation heterogeneity and diversity in advanced economy and society. Here, we may observe a hybrid overlapping between the knowledge economy, knowledge society, and knowledge democracy (see again Figs. 7 and 13). High-quality democracies encourage *sustainable development* across a broad spectrum of dimensions where, for certain, knowledge and innovation are of a key importance. High-quality democracies are "broader" than earlier concepts of a liberal democracy that were restricted to electoral democracy. There is even more of a tendency that democracy as well as processes of advancing knowledge and innovation will become continuously broader, conceptually and in empirical terms [44] (pp. 54–58, 60–61). We encourage to seeing the creative spectrum of the manifold links and cross-links between *innovation*, *entrepreneurship*, and *democracy.*

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