'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem

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Abstract: 'Mode 3' allows and emphasises the co-existence and co-evolution of different knowledge and innovation paradigms: *the competitiveness and superiority of a knowledge system is highly determined by its adaptive capacity to combine and integrate different knowledge and innovation modes via co-evolution, co-specialisation and co-opetition knowledge stock and flow dynamics*. The 'Quadruple Helix' emphasises the importance of also integrating the perspective of the media-based and culture-based public. What results is an emerging fractal knowledge and innovation ecosystem, well-configured for the knowledge economy and society.

Keywords: mode 3 innovation ecosystem; quadruple helix; innovation networks; knowledge clusters; knowledge fractals; glocal; academic firm; knowledge swings; conceptual branding; knowledge weavers.

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1 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.

1.1 The up-and-coming architecture of a Mode 3 Innovation Ecosystem

The emerging gloCalising, globalising and localising (Carayannis and von Zedwitz, 2005; Carayannis and Alexander, 2006), frontier of converging systems, networks and sectors of innovation that is driven by increasingly complex, non-linear and dynamic processes of knowledge creation, diffusion and use, confronts us with the need to re-conceptualise, if not to re-invent, the ways and means that knowledge production, utilisation and renewal takes 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, socio-economic, technological and cultural contexts are inter-woven to produce an emerging new worldview on how specialised knowledge, that 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.

We postulate that one approach to such a re-conceptualisation is what we call the 'Mode 3' system consisting of 'Innovation Networks' and 'Knowledge Clusters' (see definitions below) for knowledge creation, diffusion and use (Carayannis and Campbell, 2006a). This is *a multi-layered, multi-modal, multi-nodal and multi-lateral 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 Innovation Ecosystem" is in short the nexus or hub of the emerging 21st century Innovation Ecosystem (Milbergs, 2005),[1] where *people,*[2] *culture* (Killman, 1985)[3] *and technology* (von Braun, 1997)[4,5] (Carayannis and Gonzalez, 2003; – forming the essential "Mode 3 Innovation Ecosystem" building block or 'knowledge nugget' (Carayannis, 2004)) meet and interact to catalyse creativity, trigger invention and accelerate innovation across scientific and technological disciplines, public and private sectors (government, university, industry and non-governmental knowledge production, utilisation and renewal entities) and in a top-down, policy-driven as well as bottom-up, entrepreneurship-empowered fashion. One of the basic ideas of the paper is: *co-existence*, *co-evolution* and *co-specialisation* of different knowledge paradigms and different knowledge modes of knowledge production and knowledge use as well as their co-specialisation as a result. We can postulate a dominance of knowledge heterogeneity at the systems (national, trans-national) level. Only at the sub-system (sub-national) level we should expect homogeneity. This understanding we can paraphrase with the term Mode 3.

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:

- reveal for systems theory a new and important field of application
- 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 optimising public sector policies and private sector practices.

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

- Adding to the theories and concepts of knowledge further discursive inputs, such as suggesting a linkage of systems theory and the understanding of knowledge, emphasising multi-level systems of knowledge and innovation, summarised also under the term of '*Mode 3*' *Systems Approach to knowledge creation, diffusion and use* that we discuss below.
- This diversified and conceptually pluralised understanding should support practical and application-oriented decision-making with regard to knowledge, knowledge optimisation 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).

1.2 Definition of terms

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:

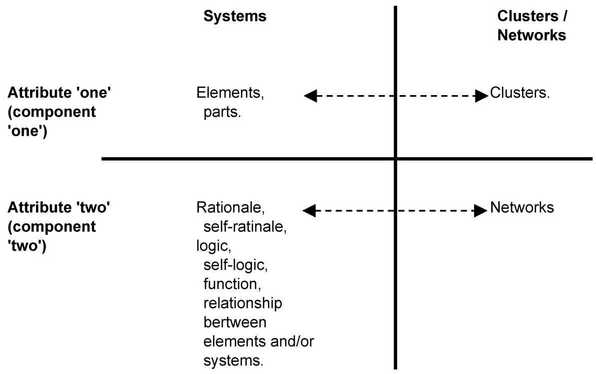
- *Geographic (spatial) clusters*. In that understanding, a cluster represents a certain geographic, spatial configuration, either tied to a location or a larger region. Geographic, spatial proximity, for example for the exchange of tacit knowledge, is considered as crucial. While 'local' clearly represents a sub-national entity, a 'region' could be either sub-national or trans-national.

- *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 (Kuhlmann, 2001, p.958).
- *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 cross-cut different geographic locations and sectors, thus operating globally and locally (across a whole multi-level spectrum). Crucial for a knowledge is when it expresses an innovative capability, for example producing knowledge that excels (knowledge-based) economic performance. A knowledge cluster, furthermore, may even include more than one geographic and/or sectoral cluster.

Networks emphasise *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'; Campbell, 2001, p.426) with clusters and networks (Carayannis and Campbell, 2006a, pp.9, 10). What results is a formation of two pairs of theoretical equivalents (see Figure 1):

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

Figure 1 Theoretical equivalents between conceptual attributes of systems and clusters/networks



Source: Authors' own conceptualisation

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 in ('moves through') 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 to understand (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 (2006a).

In the following, we list some of the key definitions, which refer to 'Mode 3' and associated concepts (see also Carayannis and Campbell, 2006c).

- *The 'Mode 3' Systems Approach for knowledge creation, diffusion and use*:

  'Mode 3' is a multi-lateral, multi-nodal, multi-modal, and multi-level systems approach to the conceptualisation, design, and management of real and virtual, 'knowledge-*stock' and 'knowledge-flow', modalities that catalyse, accelerate, and support the creation, diffusion, sharing, absorption, and use of co-specialised knowledge assets. 'Mode 3' is based on a system-theoretic perspective of socio-economic, 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"*.[6]

- *Innovation networks*:

  Innovation Networks[7] *are real and virtual infra-structures and infra-technologies that serve to nurture creativity, trigger invention and catalyse innovation in a public and/or private domain context (for instance, Government-University-Industry Public-Private Research and Technology Development Co-opetitive Partnerships (Carayannis and Alexander, 2004; Carayannis and Alexander, 1999a))*.[8,9]

- *Knowledge clusters*:

  Knowledge Clusters are agglomerations of co-specialised, mutually complementary and reinforcing knowledge assets in the form of 'knowledge stocks' and 'knowledge flows' that exhibit self-organising, learning-driven, dynamically adaptive competences and trends in the context of an open systems perspective.

- *21st century innovation ecosystem*:

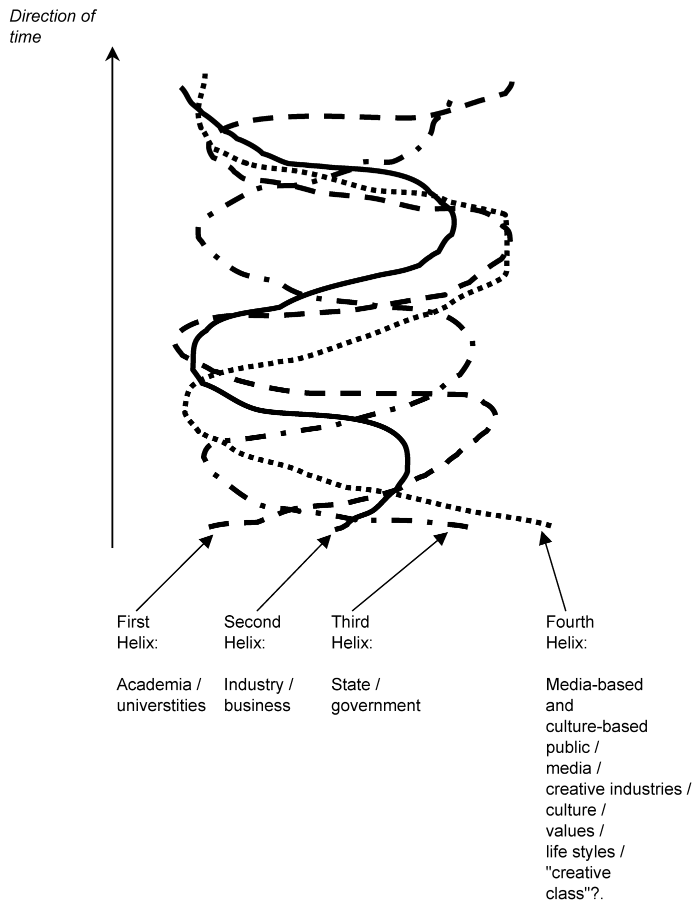
  A 21st Century Innovation Ecosystem is a multi-level, multi-modal, multi-nodal and multi-agent system of systems. The constituent systems consist of innovation meta-networks (networks of innovation networks and knowledge clusters) and knowledge meta-clusters (clusters of innovation networks and knowledge clusters) as building blocks and organised in a self-referential or chaotic [10] fractal[11] (Gleick, 1987) knowledge and innovation architecture (Carayannis, 2001), 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-specialising, and co-opeting. These innovation networks and knowledge clusters also form, re-form and dissolve within diverse institutional, political, technological and socio-economic domains including Government, University, Industry, Non-governmental Organisations and involving Information and Communication Technologies, Biotechnologies, Advanced Materials, Nanotechnologies and Next Generation Energy Technologies.

1.3 Mode 3, Quadruple Helix, 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 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-specialisation of different knowledge modes emerge. 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 Etzkowitz and Leydesdorff (2000, 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 of speaking of "university-industry-government relations" and networks, also placing a particular emphasis on "tri-lateral networks and hybrid organisations", where those helices overlap. In extension of the Triple Helix model we suggest a 'Quadruple Helix' model (see Figure 2). Quadruple Helix, in this context, means to add to the above stated helices a 'fourth helix' that we identify as the "media-based and culture-based public". This fourth helix associates with 'media', 'creative industries', 'culture', 'values', 'life styles', 'art', and perhaps also the notion of the 'creative class' (a term, coined by Florida, 2004). Plausibility for the explanatory potential of such a fourth helix are that culture and values, on the one hand, and the way how 'public reality' is being constructed and communicated by the media, on the other hand, influence every national innovation system. The proper 'innovation culture' is key for promoting an advanced knowledge-based economy. Public discourses, transported through and interpreted by the media, are crucial for a society to assign top-priorities to innovation and knowledge (research, technology, education).

Figure 2 The conceptualisation of the 'Quadruple Helix'

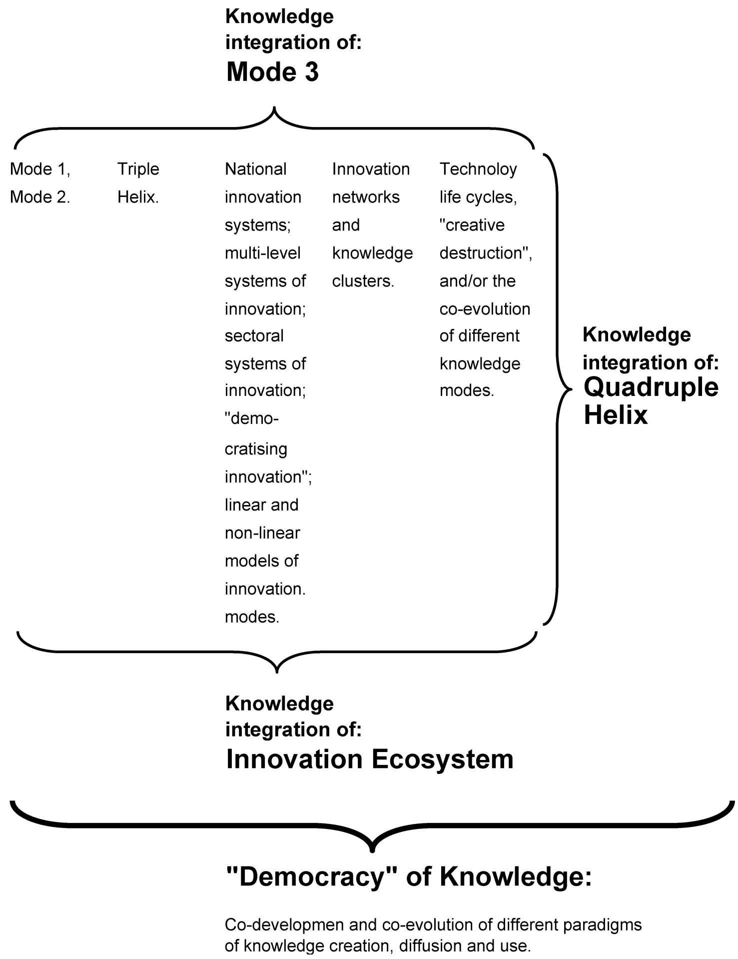


Triple Helix: University-industry-government relations (helices).
Quadruple Helix: University-industry-government-"media and culture-based public" relations (helices).

Source: Authors' own conceptualisation based on Etzkowitz and Leydesdorff (2000, p.112)

Figure 3 displays visually from which conceptual perspectives the co-evolution and cross-integration of different knowledge modes could be approached. 'Mode 3' emphasises the additionality and surplus effect of a co-evolution of a pluralism of knowledge and innovation modes. 'Quadruple Helix' refers to structures and processes of the glo*C*al knowledge economy and society. Furthermore, the 'Innovation Ecosystem' stresses the importance of a pluralism of a diversity of agents, actors and organisations: universities, 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 for knowledge modes.

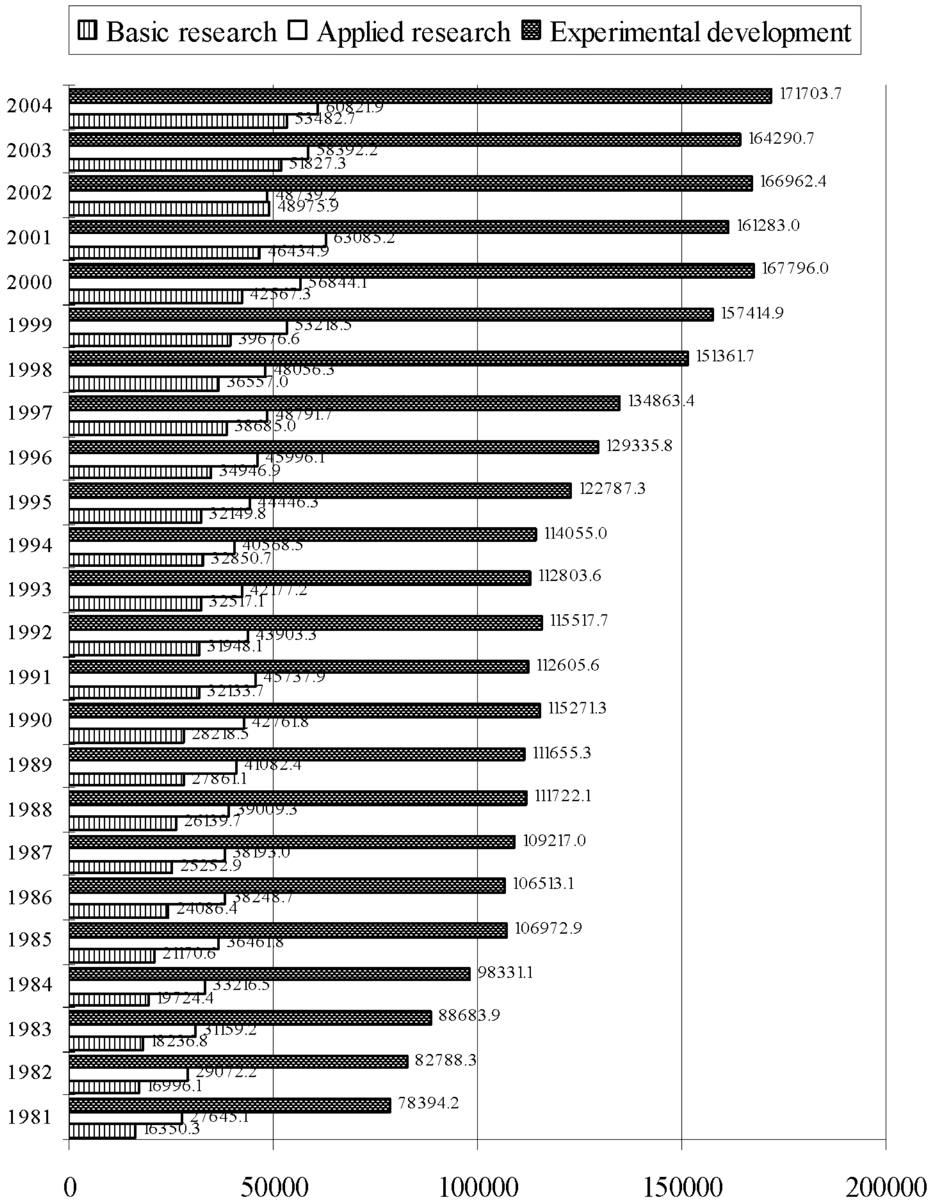
Figure 3 Knowledge creation, diffusion and use in a glocal knowledge economy and society



Source: Authors' own conceptualisation

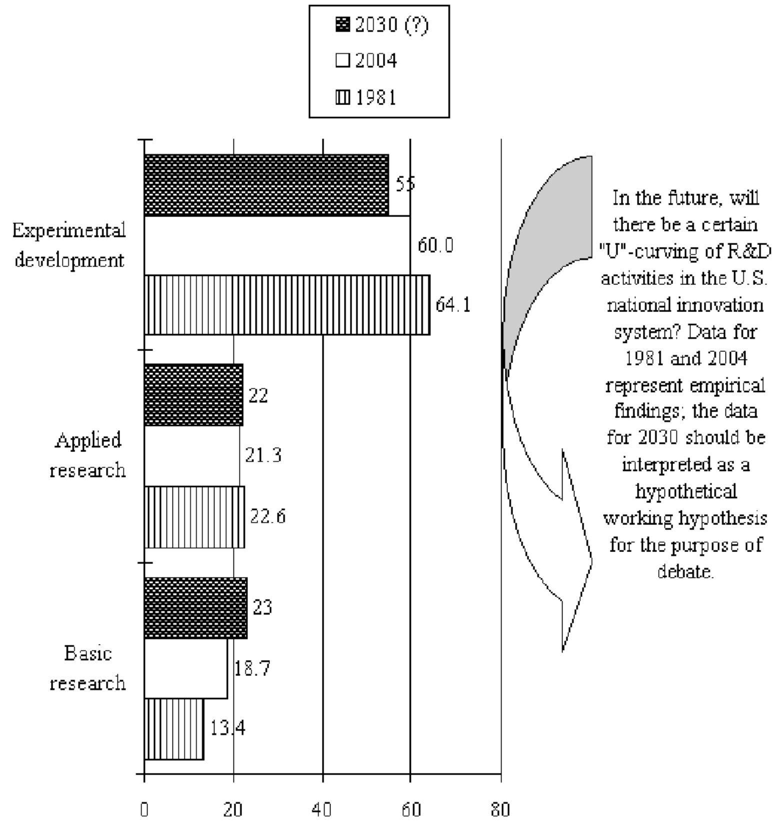
In the 'Frascati Manual', the OECD (1994, p.29) distinguishes between the following activity categories of research (R&D, research and experimental development): basic research; applied research; and experimental development. Basic research represents a primary competence of university research, whereas 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 (see Figure 4; OECD, 2006).[12] 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 2004, basic research increased its percentage share to 18.7%. During the same time period the percentage shares of applied research and experimental development declined (Figure 5). This links up to the question, whether we should expect an R&D 'U-curving' for the US innovation system, implying that basic research further will increase its percentage shares of the overall R&D expenditure. 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?

Figure 4 National R&D performance of the USA according to the 'R&D activities' of basic research, applied research activities' of basic research, applied research $ 2000 prices and PPPs, 1981–2004)



Source: 'Research and Development Statistics' (OECD, 2006; online data base)

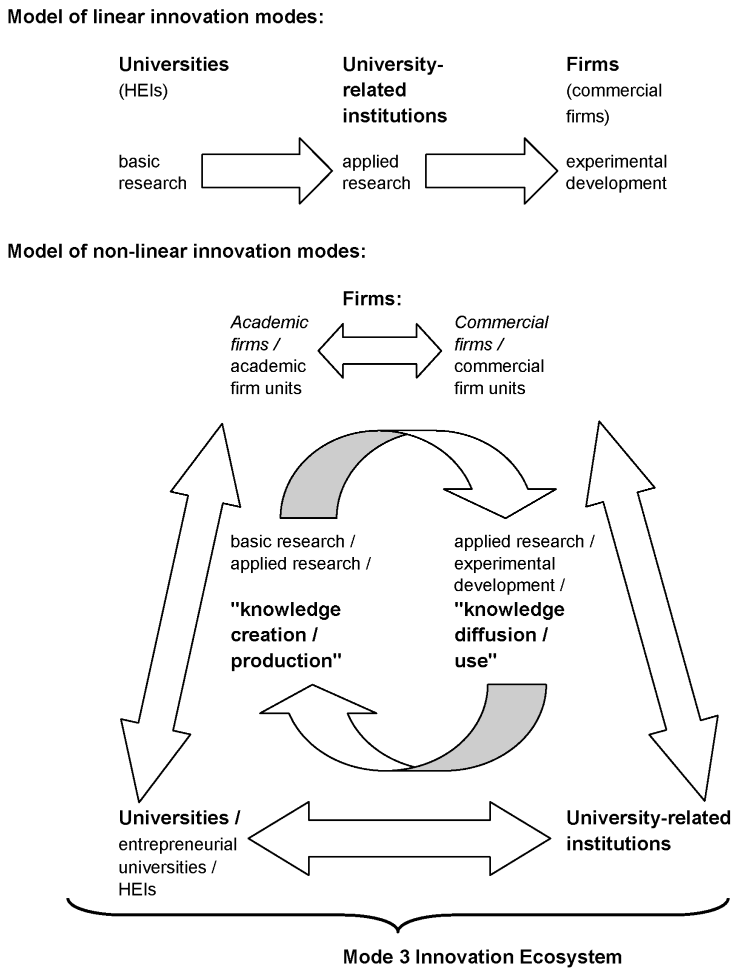
Figure 5 National R&D performance of the USA according to the 'R&D activities' of basic research, applied research and experimental development (Percentage of annual R&D activities; 1981, 2004, and a possible projection for 2030)



Source: Authors' own conceptualisation; hypothetic projection, based on "Research and Development Statistics" (OECD, 2006; online data base)

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 organisations (university-related institutions).[13] 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 Bush (1945), even though Bush himself, in his famous report, neither mentions the term "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 (HEIs) 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 labour and a functional specialisation of organisations 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 (McKelvey et al., 2004) and the chemical sector (Cesaroni et al., 2004) reveal how each of these industries may be characterised by complex network configurations and arrangements of a diversity of academic and firm actors. The Mode 3 Innovations Ecosystem thus represents a model for a simultaneous coupling of "non-linear innovation modes" (see Figure 6).

Figure 6 Linear and non-linear innovation modes linking together universities with commercial and academic firms (firm units)



Source: Authors' own conceptualisation

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, Etzkowitz, 2003). As important, as the entrepreneurial university, is for us the concept of the 'academic firm',[14] which represents the complementary business organisation and strategy *vis-à-vis* the entrepreneurial university. The interplay of academic firms and entrepreneurial universities should be regarded as crucial for advanced knowledge-based economies and societies. The following characteristics represent the academic firm

(Campbell and Güttel, 2005, 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 networking of universities and firms. 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 commercial units, interested in creating commercial revenues and profits. Alternatively, the academic firm could be seen in two ways:

- as a concept for the whole firm
- or as a concept only for a subdivision, subunit or branch of the firm.

In many contexts, this second option appears to be more realistic, particularly when we analyse multinational companies or corporations (MNCs) that operate in global context. *For the future, this may have the following implication: How can or should firms balance, within their 'organisational boundary', the principle of the academic and of the traditional 'commercial' firm?*

The 'technology life cycles' explain why there is always a dynamic momentum in the gloCal knowledge economy and society (Tassey, 2001). 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 a varying degree 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 (1942) used the notion of the 'Creative Destruction'. 'Mode 3' may open up a route for overcoming or transforming the destructiveness of the 'creative destruction' (Carayannis et al., 2007).

2 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 Carayannis et al. (2003)). The successful performance of the developed *and* the developing economies, societies and democracies increasingly depends on knowledge. One branch of knowledge develops along Research and experimental Development (R&D), Science and Technology (S&T) and innovation.[15]

2.1 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 Figure 7):

- There are aspects, areas of knowledge, which can be analysed, without considering innovation (for example: 'pure basic research' in a linear understanding of innovation).
- Consequently, also there are areas or aspects of innovation, which are not (necessarily) tied to knowledge. For example, see different contributions to Shavinina (2003).
- However, there are also areas, where knowledge and innovation co-exist. These we would like to call *knowledge-based innovation*, where knowledge and innovation express a mutual interaction.

Figure 7 A four-fold typology about possible cross-references and interactions between 'knowledge' and 'innovation'

		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. 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.)*

Source: Authors' own conceptualisation

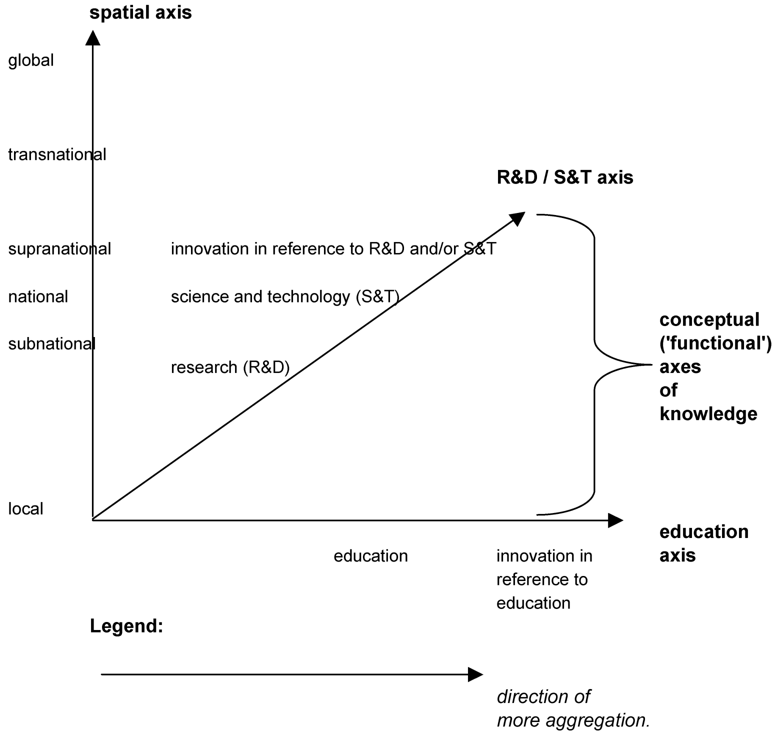
In the case of knowledge-referring innovation, we then can speak of innovation that deals with knowledge. Our impression is that in many contexts, when the focus falls on innovation, almost automatically this type of 'knowledge-referring' or 'knowledge-based' innovation is implied. Even though we will focus on this knowledge-based innovation, it still is important to acknowledge also possibilities of a knowledge without innovation, *and* of innovation, independently of knowledge. To further illustrate our point, the notion of the 'national innovation system' or 'national system of innovation' (NSI) conventionally expresses linkages to knowledge (see Lundvall, 1992; Nelson, 1993).

2.2 The 'Mode 3' systemic multi-level approach to knowledge and innovation

In research about the European Union (EU), references to a 'multi-level architecture' are quite common (see, for example, Hooghe and Marks, 2001). Originating from this research about the EU, this 'multi-level' approach is being applied in a diversity of fields, since it supports the understanding of complex processes in a globalising world. Inspired by this, we suggest using the concept of *multi-level systems of knowledge* (see Figure 8; see, furthermore, Carayannis and Campbell, 2006a). One obvious axis, therefore, is the spatial (geographic, spatial-political) axis that expresses different levels of spatial aggregations. The national level, coinciding with the nation state (the currently dominant manifestation of arranging and organising political and societal affairs), represents one type of spatial aggregation. Sub-national aggregations fall below the nation state level, and point toward local political entities. Trans-national 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 21st century we will witness a proliferation of supranational (trans-national) 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 (trans-national) clusters (Campbell, 1994). The highest level of trans-national aggregation, we currently know, is globalisation. Interestingly, the aggregation level of the term 'region(s)' has never been convincingly standardised. In the context and political language of the EU, regions are understood sub-nationally. American scholars, on the other hand, often refer to regions in a state-transcending understanding (i.e., a region consists of more than one nation state). The new term glo*C*al (global/local; Carayannis and von Zedtwitz, 2005) 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 multi-level 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;[16] 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 favoured, 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 Figure 8 we present a three-dimensional visualisation of a multi-level system of knowledge, combining one spatial with two non-spatial (conceptual) axes of knowledge (R&D and education).

Figure 8 A 'three-dimensional' modelling of knowledge in a multi-level system understanding: axis of spatial aggregation, axis of R&D aggregation, axis of education aggregation



Source: Authors' own conceptualisation

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 trans-national 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 trans-national 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 conceptualised as being part of a knowledge or of an innovation system. Concerning knowledge, we pointed to some of the characteristics of multi-level systems of knowledge, underscoring the understanding of aggregation of spatial and non-spatial (conceptual) axes. Introducing multi-level systems of knowledge also justifies speaking of multi-level systems of innovation, developing the original concept of the national innovation system (Lundvall, 1992; Nelson, 1993) further. For example, the spatial axis of aggregation of knowledge (Figure 8) also applies to innovation. Of course, also Lundvall (1992, pp.1, 3) explicitly stresses that national innovation systems are permanently challenged (and extended) by regional as well as global innovation systems. But, paraphrasing Kuhlmann (2001, pp.960–961), 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 multi-level systems of innovation already is being used (Kaiser and Prange, 2004, pp.395, 405–406; Kuhlmann, 2001, pp.970–971, 973). However, only more recently has it been suggested to extend this multi-level aggregation approach of innovation also to the non-spatial axes of innovation (Campbell, 2006a; Carayannis and Campbell, 2006a). Therefore, multi-level systems of knowledge as well as multi-level systems of innovation are based on spatial and non-spatial axes. A further advantage of this multi-level systems architecture is that it results in a more accurate and closer-to-reality description of processes of globalisation and glo*C*alisation. For example, internationalisation of R&D cross-cuts these different multi-level layers, links together organisational units of business, academic and political actors at national, trans-national and sub-national levels (von Zedtwitz and Heimann, 2006). One interpretation of R&D internationalisation emphasises how different sub-national regions and clusters cooperate on a global scale, creating even larger trans-national knowledge clusters.

The concept of the "Sectoral Systems of Innovation" (SSI) cross-cuts the logic of the multi-level systems of innovation or knowledge. A sector often is being understood in terms of the industrial sectors. Sectors can perform locally/regionally, nationally and trans-nationally. Reviews of SSIs often place a particular consideration on: knowledge and technologies; actors and networks; furthermore institutions. Malerba recommends that analyses of SSI 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." (Malerba, 2004, p.i)

2.3 Linear vs. (and/or) non-linear 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 commercialisation and marketing of R&D. National (multi-level) 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 re-connected 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 Bush, 1945, 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 (OECD, 1998, pp.179–181, 185–186). In the 1980s, Japan in particular heavily pressured the USA. In the 2000s, global competition within the triad of the USA, Japan and the EU escalated, 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 *non-linear innovation models*. There are several approaches to non-linear innovation models. The 'chain-linked model', developed by Kline and Rosenberg (1986) (cited according to Miyata (2003, p.716) see furthermore Carayannis and Alexander, 2006)), emphasises 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' (Gibbons et al., 1994, 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 organisational diversity"; "social accountability and reflexivity"; and 'quality control' (furthermore, see Nowotny et al., 2001, 2003; Umpleby, 2002).[17] 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 (Campbell, 2000, pp.139–141). Paralleling means:

- linking together in real time different stages of R&D, for example basic research and experimental development
- linking different sectors, such as universities and firms.

The 'Triple Helix' model of Etzkowitz and Leydesdorff (2000, pp.109, 111) stresses the interaction between academia, state and industry, focusing consequently on "university-industry-government relations" and "tri-lateral networks and hybrid organisations". Carayannis and Laget (2004, p.17, 19) emphasise the importance of cross-national and cross-sectoral research collaboration, by testing these propositions for transatlantic public-private R&D partnerships. Anbari and Umpleby (2006, pp.27–29) claim that one rationale, for establishing research networks, lies in the interest of bringing together knowledge producers, but also practitioners, with 'complementary skills'. Etzkowitz (2003) 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' (Campbell and Güttel, 2005, 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 (Geuna and Martin, 2003; see, furthermore, Shapira and Kuhlmann, 2003; Campbell, 1999, 2003). Furthermore, this imposes consequences on structures and performance of universities (Pfeffer, 2006). Interesting is also the concept of 'democratising 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 (von Hippel, 2005; also, von Hippel, 1995). Non-proprietor knowledge, such as the "open source" movement in the software industry (Steinmueller, 2004, p.240), may be seen as successful examples for glo*C*ally self-organising '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' (Cardullo, 1999)[18] appear to be closer associated with the linear innovation model, the Mode 2 and Triple Helix knowledge modes have more in common with a non-linear understanding of knowledge and innovation. At the same time we should add that national (multi-level) 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 characteristics of Mode 2 and of non-linear innovation, because organisations (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.

2.4 Extending the 'Triple Helix' to a 'Quadruple Helix' model of knowledge and innovation

In their own words, Etzkowitz and Leydesdorff say 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." (Etzkowitz and Leydesdorff, 2000, p.118)

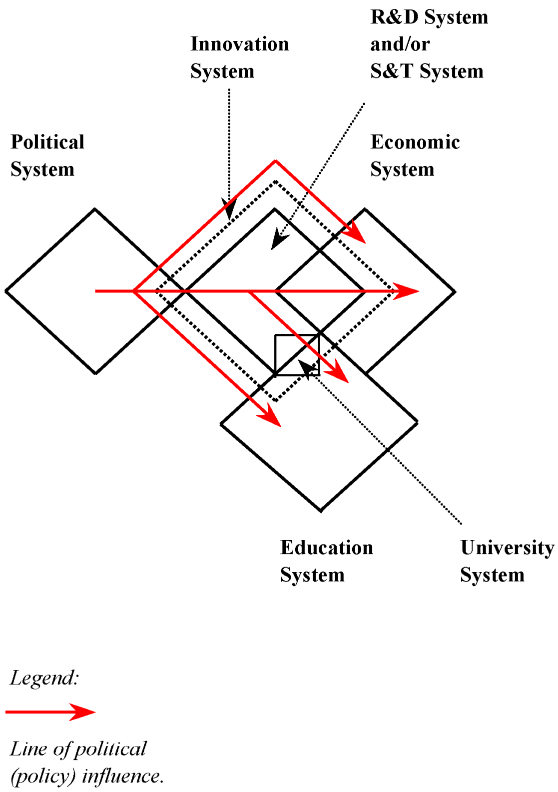
Triple Helix is very powerful in describing and explaining the helices dynamics of "university-industry-government relations" that drives knowledge and innovation in the glo*C*al knowledge economy and society. We suggest that advanced knowledge-based economy and advanced democracy have increasingly similar features, in the sense of combining and integrating different knowledge modes and different political modes.[19] Modern political science claims that democracy and politics develop along the premises of a 'media-based democracy'. Plasser (2004, pp.22, 23) 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 'multi-media information society' clearly impact 'political communication' (see also Plasser and Plasser, 2002).

The 'fourth helix' of the Quadruple Helix refers to this "media-based and culture-based public" (see again Figure 7). 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', for drafting 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 and justification (see Figure 9; furthermore, see Carayannis and Campbell, 2006a, p.18; 2006b, p.335). Also the PR (public relation) strategies of companies, engaged in R&D, must reflect on the fact of a 'reality 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 supporting of the development and evolution of 'innovation cultures' (Kuhlmann, 2001, 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, emphasise their intention that the Triple Helix model should help 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.

2.5 Co-existence and co-evolution of different knowledge and innovation paradigms

Discussing the evolution of scientific theories, Kuhn (1962) 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. 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 (Carayannis, 1993, 1994, 2000, 2001; see also Umpleby, 2005, 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 will 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.

Figure 9 Different societal systems: lines of political (policy) influence (see online version for colours)



Source: Carayannis and Campbell (2006a, p.18, Figures 1–7)

Kuhn emphasises 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 off-spring, 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 *co-existence 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 co-existence 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. Umpleby (1997, p.635), for instance, emphasises 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 (Hall, 1993). 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 Volkens and Klingemann, 2002, 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 them to *knowledge paradigms*. Because knowledge and innovation systems clearly relate to the context of a (multi-level) 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 (Gibbons et al., 1994, 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 co-existence 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 non-linear innovation models can operate in parallel.

2.6 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 multi-level knowledge and multi-level innovation systems. Multi-level systems process simultaneously at the global, trans-national, national, and sub-national 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 non-linear innovation modes; on the other hand, conceptually integrating the modes of Mode 1, Mode 2 and Triple Helix (for an overview of Mode 1, Mode 2, Triple Helix, and Technology Life Cycles, see Campbell, 2006a, pp.71–75). This displays the practical usefulness of an understanding of a co-existence 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 (Carayannis and Alexander, 1999b; Carayannis and Campbell, 2006b, pp.334–339; for a general discussion of networks and complexity, see also Rycroft and Kash (1999)).

How do networks relate to *cooperation and competition?* 'Co-opetition', as a concept (Brandenburger and Nalebuff, 1997), underscores that there can always exist a complex balance of cooperation and/or competition. Market concepts emphasise a competitive dynamics process between

- forces of supply and demand, and the need of integrating
- 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: 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.

3 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

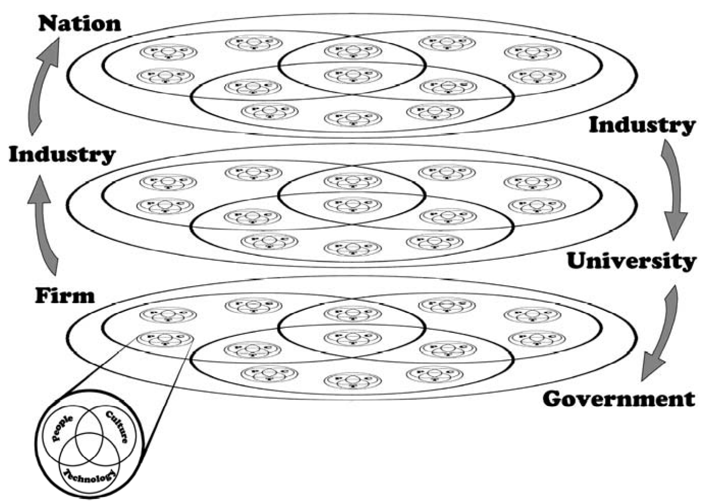
The 'Mode 3' systems approach for knowledge creation, diffusion and use emphasises the following key elements (Carayannis and Campbell, 2006c):

- *GloCal multi-level 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 multi-level knowledge and innovation systems (Carayannis and von Zedtwitz, 2005; Carayannis and Campbell, 2006c; Carayannis and Sipp, 2006). GloCal expresses the simultaneous processing of knowledge and innovation at different levels (for example, global, national and sub-national; see, furthermore, Gerybadze and Reger, 1999; von Zedtwitz and Gassmann, 2002), 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.
- *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.
- *Knowledge clusters, innovation networks and 'co-opetition'*. More specifically, we emphasise the terms of 'knowledge clusters' and 'innovation networks' (Carayannis and Sipp, 2006). 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 cross-cutting 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 (Brandenburger and Nalebuff, 1997). When we speak of competition, it often will be a contest between different network configurations.
- *Knowledge fractals*. 'Knowledge fractals' emphasise 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 Figure 10).

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 Figure 10).[20]

- *The adaptive integration and co-evolution of different knowledge and innovation modes, the 'Quadruple Helix'.* 'Mode 3' allows and emphasises the co-existence and co-evolution of different knowledge and innovation paradigms. In fact, a key hypothesis is: *The competitiveness and superiority of a knowledge system is highly determined by its adaptive capacity to combine and integrate different knowledge and innovation modes via co-evolution, co-specialisation and co-opetition knowledge stock and flow dynamics* (for example, Mode 1, Mode 2, Triple Helix, linear and non-linear innovation). The specific context (circumstances, demands, configurations, cases) determines which knowledge and innovation mode (*multi-modal*), at which level (*multi-level*), involving what parties or agents (*multi-lateral*) 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 21st century by being endowed with mutually complementary and reinforcing as well as dynamically co-evolving, co-specialising 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 gloCalising 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' even broadens our understanding, because it adds the "media-based and culture-based public" to the picture.

Figure 10 The 21st century fractal innovation ecosystem



Source: Derived from authors' unpublished notes and lectures at GWU

The societal embeddedness of knowledge represents a theme that already Mode 2 and Triple Helix explicitly acknowledge. As a last thought for this paper 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 (Campbell, 2005):

- *Democracy can be seen as a method or procedure,* based on the application of the rule of the majority.[21] This acknowledges the 'relativity of truth' and of 'pluralism' in a society, implying that decisions are carried out, not because they are 'true' (or truer), but because they are backed and legitimised 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.
- *Democracy can also be understood as a substance* (*'substantially'*)*,* where substance, for example, is being understood as an evolutionary manifestation of fundamental rights (O'Donnell, 2004, pp.26, 27, 47, 54, 55).

Obviously, the method/procedure and the substance approach overlap. Without fundamental rights, the majority rule could neutralise 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. For the purpose of bridging democracy with knowledge and innovation, we want to highlight the following aspects (see Figure 11 for a suggested first-attempt graphical visualisation; see also Godoe (2007, p.358), Carayannis and Ziemnowicz (2007)):

- *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 operationalisation of what one might consider the, paraphrased, "21st 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." (Bush, 1945, p.10)

  Knowledge, innovation and democracy interrelate. Advances in democracy and advances in knowledge and innovation express mutual dependencies (Campbell and Schaller, 2002).[22] 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 'democratising innovation' (von Hippel, 2005), underscore such aspects. Also the media-based and culture-based public of the 'Quadruple Helix' emphasises the overlapping tendencies of democracy and knowledge (Saward, 2006).[23]

- *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 (1959) as *disjointed incrementalism* (Linblom and Cohen, 1979)[24]: " … 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 centralised decision makers relying on analysis (Lindblom, 1959, 1965). This is partly because interaction economises on precisely the factors 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, co-existence 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.

- *'Knowledge swings'*. Through political cycles or political *swings* (Campbell, 1992, 2007) a democracy ties together different features:
  - decides, who currently governs
  - gives the opposition a chance, to come to power in the future
  - 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 up-coming election is higher than to win an election (Müller and Strøm, 2000, 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*'[25] 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:
  - What are dominant and non-dominant knowledge modes in a specific context?
  - 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.

- *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* (Carayannis, 1993, 1994, 1999, 2000, 2001) and the strategic management of technological learning (Carayannis, 1999; see, furthermore, de Geus, 1988). 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 (Carayannis, 2001, pp.26, 27).

Figure 11 Knowledge, innovation and democracy. Glocal governance styles of the Glocal Knowledge Economy and Society?

Source: Authors' own conceptualisation based on Godoe (2007, p.358)

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*)[26] across disciplines and sectors as they strive to tackle the 21st century challenges and opportunities for socio-economic prosperity and cultural renaissance based on knowledge and innovation:

> "As a result of the glocalised nature and dynamics of state-of-the-art, specialised 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 levelling 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-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 21st 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." (Carayannis and Alexander, 2006)

Already the early Lundvall (1992, pp.1, 9) underscored the importance of learning for every national innovation system.

Mode 3, in combination with the broadened perspective of the Quadruple Helix, emphasises an Innovation Ecosystem that encourages the co-evolution of different knowledge and innovation modes as well as balances non-linear innovation modes in the context of multi-level 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' (Carayannis and Ziemnowicz, 2007). The 'knowledge state' (Campbell, 2006b) has the potential to network 'high-quality' democracy with the gloCal knowledge economy and society.

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Notes

[1]Furthermore, see Milbergs (2005).

[2]See discussion on democracy in the conclusion of this paper.

[3]"*Culture* is the invisible force behind the tangibles and observables in any organisation, a social energy that moves people to act. Culture is to the organisation what personality is to the individual – a hidden, yet unifying theme that provides meaning, direction, and mobilisation." (Killman, 1985).

[4]*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*" (Carayannis, 2001) or "*the science of crafts*" (von Braun, 1997).

[5]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, catalyses, and accelerates interactions and manifestations between creativity and innovation as shown in Figure 3, along with public-private partnerships, international 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" (Carayannis and Gonzalez, 2003, p.593).

[6]Carayannis and Zedwitz (2005).

[7]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 (sub-nationally, nationally, trans-nationally) 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.

[8]Carayannis and Alexander (2004).

[9]Carayannis and Alexander (1999a).

[10]Carayannis (2001, pp.169, 170) 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 (Gleick, 1987). 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 organisation in question."

[11]"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 behaviour 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).

[12]The data in Figure 4 express the R&D performance of the USA, for the period 1981–2004, in million 2000 dollars in constant prices and PPP (purchasing power parities).

[13]In the German language, 'university-related' would qualify as 'außeruniversitär' (Campbell, 2003, p.99).

[14]The 'academic firm', as a notion and concept, was first developed by Campbell and Güttel (2005).

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

[16]In that context also the mutual overlapping between R&D, S&T and Information and Communication Technology (ICT) should be stressed.

[17]Should we add a further comment to the concepts of Mode 1 and Mode 2, it would be interesting to consider, how Mode 1 and Mode 2 relate to the notions of 'Science One' and 'Science Two', which were developed by Umpleby (2002).

[18]Concerning a further-going discussion of the Technology Life Cycles, see: Cardullo (1999), and Tassey (2001).

[19]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'.

[20]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.

[21]For example, Schumpeter (1942, Chapters XX–III) emphasised this method-based criterion for democracy.

[22]For attempts, trying to analyse the quality of a democracy, see for example Campbell and Schaller (2002).

[23]On ‘democratic innovation’, see, furthermore, Saward (2006).

[24]The *disjointed incrementalism approach* to decision making (also known as *partisan mutual adjustment*) was developed by Lindblom (1959, 1965) and Linblom and Cohen (1979) 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 decentralised bargaining in a free market and a democratic political economy.” (http://www3.sympatico.ca/david.macleod/PTHRY.HTM)

[25]“Studies have shown that the early period of a new area of technology is often characterised by technological ferment but that the pace of change slows after the emergence of a dominant design” (http://www.findpapers.com/p/papers/mi_m4035/is_1_45/ai_63018122/print).

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