1. Introduction

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In modern research and innovation policies there is a recurrent issue that clearly is purely understood and difficult to grasp, namely the issue of how to address the variety and heterogeneity of knowledge systems. Our understanding of causes and effects of this variety is still very poor. This is true at all levels of analysis, the micro (firm level), meso (regional, sectoral, institutional) level as well as the macro (national and global) level. This book attempts to bring the analysis a step further conceptually and analytically.

CONCEPT OUTLINE

System theories address complex phenomena often characterized by heterogeneity. Heterogeneity is *the quality of being diverse and not comparable in kind* (Webster's Dictionary). It is useful to remember the Greek etymological roots of the word to mean literally 'possessing different genes'. Darwin and his followers have extensively analysed how micro-level genetic heterogeneity, mediated by processes of selection, has created varieties of species co-existing, co-evolving and co-specializing in natural ecosystems, thus feeding back into new combinations and recombinations of genes. However, as forcefully argued by Helge Godø in Chapter 2 the evolution of the knowledge economy and society cannot be understood simply through loose ad hoc metaphors to ecologies in nature.

Instead, this book develops basic building blocks of a new understanding of how heterogeneity, selection and diversity as properties of knowledge systems explain how entrepreneurship and innovation work.

The key message of the book is that heterogeneity and diversity should be seen as intrinsic and indispensable properties of knowledge systems. We address the concept of *heterogeneity* in a multi-disciplinary fashion, including perspectives from evolutionary economics and innovation system

studies. We relate this attempt to existing theories in a broad range of fields. In doing so, we explore some of the ways in which rationalities, identities, preferences and intentions are related to national, sector and regional economic structures, firm demography, technological paradigms, institutions and policies.

In Chapter 5 (see Figures 1.1–1.3) Carayannis discusses how globalization serves as both a catalyst of accelerated development as well as an agent of chaotic disruption resulting in socioeconomic and political dislocations. The emerging *gloCalizing* (i.e. simultaneously globalizing *and* localizing) (Carayannis and von Zedwitz, 2005; Carayannis and Alexander, 2006) frontier of converging systems, networks and sectors of innovation confronts us. As a result, we need to re-conceptualize the dynamics of specialization (firm, sectoral, regional, national) in this new and emerging context of the *gloCal* knowledge economy and society.

As opposed to mainstream economics, evolutionary economics and innovation studies place the issue of firm heterogeneity at the centre of economic development. This is because *entrepreneurship* and *innovation* activities are understood as *heterogeneity-inducing micro-processes*, continuously reshaped due to market selection mechanisms.

Carayannis postulates that one approach to such a re-conceptualization is the ‘Mode 3’ system consisting of ‘Innovation Networks’ and ‘Knowledge Clusters’ for knowledge creation, diffusion and use (Carayannis and Campbell, 2005). 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. In terms of enriching theory, this book attempts to promote the understanding of the role of heterogeneity and diversity in the inter-linkages of rationalities identities, preferences and intentions to macro-level phenomena such as institutions, national systems, regional city economies, the evolution of technological paradigms and the ways in which multi-level innovation systems work. Systems are systems because they reproduce themselves. At the same time, through heterogeneities of input and dynamic processes of co-opetition, co-evolution and co-specialization, systems generate outputs that differ from inputs. This has repercussions for the next round of inputs. These dynamic sequences of input – process – output – input – process, and so on, are called evolution.

A core issue in discussing evolution is the tension between structure and agency. Structures reproduce systems, whereas agents exploit and sometimes even transform them by looking for and exploiting heterogeneities. In that way, actors seek and find new combinations of input factors, and generate new processes. On the other hand, structural forces may send the

Source: Adapted from Carayannis and Campbell (2007, Figure 7.2).

Figure 1.1 Strategic knowledge, serendipity and arbitrage: a cross-sectoral view

Figure 1.2 Strategic knowledge, serendipity and arbitrage: multi-modal, multi-nodal, multi-lateral, multi-level co-opetition, co-specialization and co-evolution processes

Figure 1.3 Strategic knowledge, serendipity and arbitrage: a cross-sectoral and cross-technological view across the stages of technology innovation

system into cycles where heterogeneities are gradually reduced, and evolution narrows down into a slim trajectory.

HETEROGENEITY AND INNOVATION SYSTEMS

Schumpeter is a natural starting point for discussing heterogeneity. His perception is that innovation is a process of combining various resources in specific ways. The combination of various resources, or combining ‘materials and forces’ as he phrased it, is a key to understanding his concept of development. According to Schumpeter, development is something that basically comes ‘from within’ the economic system, and is related to changes in the way production is organized; that is, resources are combined in new ways. Based on this, Schumpeter introduced the concept of *new combination* (1934/1996, pp. 65–66) and defined development by the introduction of a new combination.

A number of authors have discussed the principles and summarized the mechanisms of evolution. The seminal work of Nelson and Winter (1982) may represent the starting point of the evolutionary approach (Saviotti, 1996), and their approach was based on the three building blocks of organizational routines, search behaviour and the selection environment (Van den Bergh, 2004). A number of authors have followed up on this and summarized the principles in different ways (see for instance Aldrich, 1999; Carlsson and Stankiewicz, 1991; McKelvey, 1997; Peneder, 2001; Saviotti, 1996). Among them Edquist (1997) has stated that evolutionary theories often include the following elements:

1. The point of departure is the existence of reproduction of entities like genotypes in biology or a certain set-up of technologies and organizational forms in innovation studies.
2. There are mechanisms that introduce novelties in the system (i.e. mechanisms that create diversity). This includes significant random elements, but may also produce predictable novelties (e.g. purpose-oriented development work). In biology the novelties are mutations and in our context they are innovations.
3. There are mechanisms that select among the entities present in the system. This increases the relative importance of some and diminishes that of others. The selection process reduces diversity and the mechanisms operation may be the ‘natural selection’ of biology or the ‘market selection’ of competition as regards technical change. Together the selection mechanisms constitute a filtering system that functions in

several stages and leads to a new set-up of, for example, technologies and organizational forms. There might also be feedback from the selection to the generation of new innovations.

The simple version of this is that a population, system or technology develops through mechanisms of variation and selection. Diversity is a necessary condition for change; that is, evolutionary change depends on the existence of diversity in economic actions (Peneder, 2001). Not only does this mean that an initial variety is required. The continuing creation of variety, for instance through new information, is also required, as the initial diversity will be ‘consumed’ during the process of selection (Peneder, 2001). This means that the variation and selection processes are working continuously and in some kind of interaction, it is no stage model or sequential model, but rather ‘a sort of harmonica movement’ (Van den Bergh, 2004).

Diversity is thus a necessary condition for evolution. The formation of new firms may be regarded as the manifestation of diversity, and it is the variety in the system that governs the pace and direction of change (Metcalf, 2004). However, this does not mean that it will make sense to focus on diversity in isolation. Diversity per se will not create evolution, it is how the ‘system’ reacts to diversity that is important, and these reactions may be described through the type of selection processes that are at play. This means that evolution is determined by efforts to exploit diversity, and these efforts will depend on available competences and the system’s learning processes (Cohendet and Llerena, 1997). *The continuous interplay between variety creating and selection mechanisms governs evolution.*

The discussion of the relation between *randomly generated diversity and structures* in innovation system theory was opened again by Nelson and Winter (1982). They were concerned with *differences in productivity between national economies*. In their attempt to explain contemporary *differences*, they emphasized the dualism between two phenomena to be located at two different points in time: ‘variation’, followed by ‘selection’. The corollary was the ‘*co-evolution of technology and institutions*’ (Nelson, 1991):

Technology and the structure of industry co-evolve, and this process leads to growth in productivity, which is a statistical property of the system as a whole. (Nelson, 1991, p. 21)

His basic model of evolution took as a point of departure ‘*systematic selection where somewhat random variation plays a central role*’ (Dosi et al.,

2000, p. 22). These were more or less fixed structures, which Nelson and Winter – based on Abernathy and Utterback – referred to as dominant *technological paradigms*. A dominant technological paradigm may be considered as a special case, a sectoral innovation system, which selects only what fits into the paradigm from the beginning. Hence, the technological paradigm starts to close. Abernathy and Utterback were criticized by Blauwhof, who, based on Hughes and Latour, pointed out that in the invention process, prior to the phase of closing in on mature products described by Abernathy and Utterback, the networks of the entrepreneurs and innovators were wide open.

By including the process of invention or innovation, Blauwhof argues, Hughes and Latour identified a communicative process (*interactive learning*) where different forms of knowledge were integrated through processes of ‘translation’, which enabled new knowledge combinations. In this early phase of inventions, the market product (the innovation) was an abstract idea, which was redefined and transformed by actors trying to find some way into the market. The ‘invention system’ was *open*, as different options were tested. Unlike the phase of invention, the mature product within an existing technological paradigm emerges with a fixed set of different forms of knowledge, linked within a specific structure. In this case the internal complexity of the innovation system may be larger than in the phase of invention, but the ‘strengths of loose ties’ are not as prominent as before. This is the parallel in the learning economy of forming a new species. In nature, part of a population that is specializing in a new direction may sooner or later discover that it has lost the capacity to mate with the population from which it once came. This loss of mating capacity is the birth of a new species.

In looking for species of specialized human knowledge, then, we must regard strategies of specialization in the context of the external threats of the market, and the capacity for agility, adaptation and turnaround. Given this rapid speed of destruction, even highly integrated clusters may – at least if they are forced to by the market – open up for new forms of knowledge. What enables this strategy is the *multi-dimensionality* of human knowledge systems. Humans may embed their various forms of specialized knowledge *in layers*. These layers may be interrelated through points of dense interactivity, where interactive learning is possible, such as organizations, regional clusters, or single humans. Here, complex processes of interactive translation and communication across different specializations are possible. For instance, two widely diverse knowledge systems may be mating inside a single human body, resulting in an entrepreneurial achievement.

Indeed, the drive towards increased specialization has resulted in the evolution of specialists who reap the benefits of crossing borders and

initiating unusual or unheard of acts of mating – the *Schumpeterian entrepreneur*. This peculiar form of socializing of humans – and their entrepreneurialism – enhances the adaptability of human knowledge to changes. In nature, this option is lost – once the new species is formed, and the barriers against mating are established, there is no return. For systems that are contextualized by the global market, staying specialized should always – as pointed out by Blauwhof – be balanced by diversity – creating buffers, enabling rapid mating with new forms of knowledge if times are changing.

In Chapter 2 of this book, Helge Godø discusses innovations as *man-made* activities in opposition to ideas regarding innovations as ‘random mutations’. Godø is concerned with the role of human will and purposeful behaviour. Purposeful behaviour, according to Godø, refers to design, which, he argues, is a core element in technological evolution and innovation. Design, in this way, moves the issue of evolution of paradigms into something different from both the evolution of the species, and the neo-classical logic of markets. It moves the issue into the realm of politics. The political implications of recognizing that innovations are made on purpose, for a purpose, according to Godø, may be beneficial for creating actions, and providing leadership and organization for innovation efforts, as suggested in the conceptual framework of innovation regimes. In the current political climate, the holders of power claim that the dynamics of market-oriented innovation will ensure that heterogeneity will flourish; that is, the market is a selection environment that ‘by nature’ will encourage people to be creative because the market represents a pressure towards innovation. However, the markets are aversive, even hostile, to radical innovations. More often than not, radical innovations need some type of strong political will or advocacy. Markets are incapable of initiating innovations in these areas – and do not possess the type of imagination or creativity that would foster heterogeneity. If society wants to be creative and imaginative, it has to muster the political will for this – innovations and heterogeneity are a matter for policy and associated agency.

More generally, innovation system theory emerged out of micro-level studies of technological systems, as well as middle- (meso-) and macro-level studies of innovation systems and innovation through interactive learning (Freeman, 1988; Lundvall, 1992; Nelson, 1993; Edquist, 1997), and through several EU and OECD publications (OECD, 1999), where the NIS perspective was promoted. A critical and comprehensive review of this literature is presented in a recent publication by Miettinen (Miettinen, 2002). Despite the fact that ‘innovation system’ has been on anyone’s lips for the last ten years, ‘system’ is more often than not used as

a heuristic device in the literature. To Lundvall, 'system' simply explained interactivity, seen in contrast to linear knowledge transfer. Schienstock and Hämäläinen (2001) define 'innovation system' with reference to the function of knowledge conversion (Schienstock and Hämäläinen, 2001), understood as new knowledge creation, diffusion, and commercial utilization, in short, the knowledge process (see also Carayannis and Campbell, 2005).

Finn Orstavik, in Chapter 6, indicates how innovation systems analysis hitherto has been developed mainly by institutional and evolutionary economists, but that such analysis has its more remote origins in classical social science. Orstavik argues that advances in innovation systems theory have been obstructed by theorists making inadequate assumptions about the nature of systems. Progress must be based on a better understanding of terms such as knowledge, communication and learning. By focusing on interactive learning, for example in the form of user–producer interactions, Bengt-Åke Lundvall has moved the analytical focus from overall institutional structures towards the actual core of innovation processes. But we claim that only a first move towards coherent and robust theorizing has been taken. A crucial resource for making further advances theoretically, we believe is found in Luhman's general theory about *social systems*. Building on the notion of *reflexivity* we develop a concept of innovation as a human, sociotechnical and organizational endeavour of 'reflexive transformation'. The fundamental difference between this approach and the national innovation system thinking model is that we move out of the whole-part systems discourse, and into the new paradigm of systems theory where systems–environment is the fundamental distinction. In this way, we eliminate resource-consuming discussions about which elements should be considered part of an innovation system, and which should not.

System–environment is also related to the degree of openness/closedness of a knowledge system. However, to *open* or *close* may be seen as optional strategies. The standard argument for closing in the boundaries of the knowledge system; that is, enhancing specialization is:

1. Reducing external transaction costs. Instead of investing in the transaction costs involved in contacting external sources of knowledge, the system may focus on its own specialization, thus . . .
2. Avoiding internal complexity. Closing in and specializing may be seen as a strategy to avoid the internal complexity that is necessary to be able to relate to and integrate external knowledge. It is better and more efficient to make it simple, and stay specialized within a narrow niche.

3. Specialization may be profitable. Specialization in the function of the system may prove to be a profitable strategy that is rewarded by the market, as the specialist may avoid price competition from other, less sophisticated competitors.

Strategies of specialization have their downsides as well.

1. Exposure to random events. A closed system is a system with no knowledge of its environment. It may be exposed to random and rapid destruction triggered by the market.
2. Loss of 'adaptive capacity'. A too narrow specialization may run the risk of turning the system into a unique species, which loses the mating option that may be necessary when the niche is made obsolete.

Furthermore, in focusing on system learning dynamics, we have to pay attention to the relation between '*Creative Accumulation*', with a low level of heterogeneity, and '*Creative Destruction*', with a high level of heterogeneity. One could consider '*Creative Accumulation*' (see Schumpeter's Mark I and II comments, 1943/1996) as a manifestation of co-specialization, an interim point between '*Creative Destruction*' (Schumpeter, 1943/1996) and what we call '*Destructive Creation*'. This move is possible through opening the issue of the specific *heterogeneities of human knowledge*. Heterogeneities of *human knowledge* – as opposed to forms of biological life – are feeding into a particular form of *knowledge 'mating' or knowledge 'osmosis'* (Carayannis, 2000–2005; Carayannis and von Zedwitz, 2005), which, as described by Niklas Luhmann (1984, 1994), is the act whereby humans share knowledge with each other – through shared *understanding* of what they are doing, enabling expectations and, hence, learning and adapting.

In saying so, however, we must at the same time remember that *knowledge* in this context is not an abstract substance. We are not interested in knowledge from the perspective of *stored symbols and texts*, whether it is found carved into a stone, in a library or in a hard-drive. Our interest is in *living knowledge*, used in practice for policy making and economic useful purposes, in contexts of shared understanding. Niklas Luhmann (1984, 1994) argues that shared understanding is a basic form of autonomous human self-organization, which may be seen as a form of life. This should not be regarded as allegorical. Quite the contrary, shared understanding – or social systems – is created interactively; the systems evolve through reproduction – and they die when they go out of practice.

Living knowledge is *embedded* in bodies, brains, spaces, institutions, organizations, communities of practice, as well as communities sharing

formalized forms of knowledge. This is why, in analysing the heterogeneities of knowledge, we must relate to the deeper layers of organizational, regional and institutional arrangements within which different species of interbreeding knowledge are embedded. As argued by Lam (2000), these forms of institutional embedding of knowledge are crucial in *structuring* the relations between different forms of knowledge in the processes of interactive learning leading to innovation. We wish to better understand the tension between *heterogeneity* – which opens up the way for major changes generated by random events (radical innovations) – and *structure*, which tends to give evolution a specific direction. This question is accordingly similar to another problem, that of the relation between an open and a closed system. Whereas a closed system follows its own, internally defined path – until it eventually is struck by some unforeseen disaster – an open system may adjust to changes in the environment. This, again, is a part of an even wider debate.

METHODOLOGICAL CONSIDERATIONS

Knowledge systems are multi-level. At the core, we find mutually driving, complementary and reinforcing processes of *co-opetition* (a hybrid form of collaboration and competition), *co-specialization* and *co-evolution* (C3) (Carayannis et al., 2003; Carayannis and Alexander, 2004; Carayannis and Coleman, 2005; Freeman and Soete, 1997; Nowotny, 2006; Lundvall, 2006) (see Figure 1.4). In particular, we view heterogeneity as both a cause *and* an effect of the input, process and output (IPO) innovation stages (see Figure 1.4).

Dynamically, as Figure 1.4 illustrates, we depict a system for adding value via interconnected and interacting stages of socioeconomic being and becoming. Core phases are the concept of C3 as discussed above, which drives the creation, diffusion and use of knowledge. This system consists of multiple layers (macro, meso, micro) as well as modules (*input*, *process*, *output*). The presence of heterogeneity in those layers and modules acts as both cause and effect for driving the value-creating, diffusing and potentially destroying, processes of *co-opetition*, *co-specialization* and *co-evolution* (C3) as shown in Figure 1.4 (Carayannis and Campbell, 2005). *Input heterogeneity* refers to the variety and diversity of the key inputs to economic activity. Intrinsic in all these inputs is knowledge, which has been increasingly the key source of value adding of most human endeavours. *Process heterogeneity* reflects the variety and diversity intrinsic in the ways that the key inputs to economic activity are leveraged, allocated, re-

Figure 1.4 Heterogeneity dynamics – input/process/output

combined and recreated as part of the processes of technology innovation and entrepreneurship aiming at the maximization of value added. *Output heterogeneity* reflects the diverse ways and means that the value added of economic activity combining and leveraging the key inputs discussed earlier, is captured and exploited.

Table 1.1 provides an overview of the chapters and how they relate to the model presented in Figure 1.4.

Table 1.1 Conceptual topology

	Key system characteristics	Input heterogeneity diversity	Process co-evolution, co-opetition, co-specialization	Output heterogeneity diversity
Concepts and theory	Technological evolution, human intentionality, policies (Chapter 2)	Human intentionality policy decisions	Regulations co-evolving with innovation	New path creation
	Diversity and heterogeneity in economic thought (Chapter 3)	Competitive rivalry	Co-opetition through innovation regimes	
	Rationality and institutions (Chapter 4)		Market based innovation	
	Innovation systems constituted through communication (Chapter 6)	Institutional heterogeneities	Differentiation of rationalities	
	The conceptual foundation of diversity and heterogeneity in innovation studies (Chapter 5)	Diversities of innovation systems understood as development coalitions sharing understanding (co-opetition)	Interactive learning	
	Entrepreneurship and heterogeneity (Chapter 7)	Heterogeneity of opportunities and knowledge base within	Co-evolution of machines, routines and rules	Diversification of production systems (new forms of co-specialization)
			Entrepreneurial (Mark I) and formalized (Mark II) regimes, operating	New firms, combinations of resources,

Analysis	The role of institutions: Trademarks and diversity of products (Chapter 8)	entrepreneurial communities and technological regimes	through recognition, exploration and exploitation	technologies and products
	Firm populations (Chapter 8)	Heterogeneity of firm population (size, ownership, age, etc.)	Diverse patterns of development	Understanding the role of institutions in output heterogeneity
	City economies (Chapter 9)	Specialization and differentiation in big city economies	Co-evolution and co- specialization of KIBS and their customers KIBS as knowledge translators	Survival – closure Transformation (takeover, spin-off, spinout, move) Innovation and diffusion
	Small national systems (Chapter 10)	Diversities of institutional complementarities	Co-evolution of institutions and industrial sectors	National specialization, small country squeeze
	EU15, USA and Japan The knowledge specialization of the EU15 (Chapter 11)	R&D investments	Patenting Scientific profiles and sectoral technological profiles (patents) of the EU15 compared with the USA and Japan	Economic specialization measured in value added, employment and exports. The EU's sectoral economic specialization (value added, employment, exports) compared with the USA and Japan

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