change. The book has also been designed for people not yet familiar with the systems of innovation approach: in the introduction I have summarized and analyzed some important achievements that contributors to the systems of innovation approach have made in earlier literature. The circle of readers is also likely to include policy-makers dealing with R&D, innovation, and technical change. Because of the comprehensive and crucial macroeconomic consequences of innovation, policy-makers dealing with economic growth and employment issues should also be interested.

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The most cordial thanks go to the authors who have contributed chapters to this book and also to those who added to the quality of the chapters by participating in the conference discussions.[1] In particular I want to thank the three co-editors for providing creative comments to the other authors at various stages of the Network's activities and for their imagination in helping to make the book coherent. I think we all agree that the Network activities were extremely rewarding 'interactive learning' experiences. I hope that those who read this book will gain as many new insights into the innovation process as we did!

Charles Edquist
Linköping
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[1] They include Olle Edqvist, Lennart Elg, Jean Guinet, Patrik Hidefjäll, David Mowery, Richard Nelson, Ulf Sandström, Rikard Stankiewicz, and Pekka Ylä-Anttila.

CHAPTER ONE

Systems of Innovation Approaches – Their Emergence and Characteristics

Charles Edquist

1. Introduction[1]

It is almost universally accepted that technological change and other kinds of innovations are the most important sources of productivity growth and increased material welfare – and that this has been so for centuries. They are also a major cause of the destruction of old jobs as well as the creation of new employment.[2] 'Systems of innovation' is a new approach for the study of innovations in the economy that has emerged during the last decade. In this introduction I will discuss reasons why this approach is fruitful for studying innovation and technical change, and highlight some insights the approach provides into economic development. I will also review the historical development of the approach, outline its characteristics, and address the major arguments presented in this volume.

Innovations are new creations of economic significance. They may be brand new but are more often new combinations of existing elements. Innovations may be of various kinds (e.g., technological and organizational). The processes through which technological innovations emerge are extremely complex; they have to do with the emergence and diffusion of knowledge elements (i.e., with scientific and technological possibilities), as well as the 'translation' of these into new products and production processes. This translation by no means follows a 'linear' path from basic research to applied research and further to the development and implementation of new processes and new products. Instead, it is characterized by complicated feedback mechanisms and interactive relations involving science, technology, learning, production, policy, and demand.

Innovation processes occur over time and are influenced by many factors. Because of this complexity, firms almost never innovate in isolation. In the pursuit of innovation they interact with other organizations to gain, develop, and exchange

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[2] For supporting arguments see, for example, Abramovitz (1989), Denison (1985), Edquist and McKelvey (1992), Edquist (1993b), Edquist (1996), Nelson (1981), and Romer (1990).

various kinds of knowledge, information, and other resources. These organizations might be other firms (suppliers, customers, competitors) but also universities, research institutes, investment banks, schools, government ministries, etc. Through their innovative activities firms often establish relations with each other and other kinds of organizations; therefore it does not make sense to regard innovating firms as isolated, individual decision-making units.

The behavior of firms is also shaped by institutions that constitute constraints and/or incentives for innovation, such as laws, health regulations, cultural norms, social rules, and technical standards. Interaction between various organizations operating in different institutional contexts is important for processes of innovation. The actors as well as these contextual factors are all elements of systems for the creation and use of knowledge for economic purposes. Innovations emerge in such systems.

If we want to describe, understand, explain – and perhaps influence – processes of innovation, we must take all important factors shaping and influencing innovations into account. The systems of innovation approach – in its various forms – is designed to do this. Attempts to understand the structure and dynamics of such systems are at the core of modern thinking about innovation processes.

However, the proof of the pudding is in the eating. Only general arguments for the fruitfulness of the systems of innovation approach can be presented here. It is the use of the approach, in research and in policy, that proves its usefulness, as compared to other approaches.

This book as a whole concentrates upon resolving issues of three kinds:

- sorting out some conceptual problems associated with the systems of innovation approach;
- relating the systems of innovation approach to innovation theories;[3]
- increasing our understanding of the dynamics of systems of innovation.

Each of these themes are dealt with in one of the three parts of the book.

In section 2 of the introduction I will address the genesis and theoretical origins of the different systems of innovation approaches, relate the variants to each other, and deal with some of the basic concepts and their meaning. Section 3 points out nine common characteristics of the various systems of innovation approaches. In doing so, it also identifies the main strengths and weaknesses of the approach, as it has been developed so far. A review of issues addressed in the three parts of the book will be presented in section 4 of this introduction.[4]

[3] As will be argued in section 3.9, we do not consider the systems of innovation approach as such to be a formal and established 'theory', but rather a 'conceptual framework'. In particular, we will relate the systems of innovation approach to innovation theories of an evolutionary kind. The nature of such theories is outlined in section 2.2.

[4] To talk of variants of the systems of innovation approach requires that we speak of the approach in both singular and plural terms. To reduce confusion it may be helpful to know that when dealing with differences between variants, I will speak of systems of innovation approaches, but when treating the variants as part of the same general approach, I will refer to the systems of innovation approach.

2. Various systems of innovation approaches: their genesis and anatomy

Since the objective of this book is to contribute to the development of the systems of innovation approach, it is important to review the historical basis of our arguments. In this section, the genesis of different coexisting approaches to the study of systems of innovation are briefly outlined and their main conceptual components are discussed. This means that I will relate the arguments addressed in this book to previous literature, requiring that the scope of the introduction be wider than that of the remaining chapters. However, as space does not allow a complete account of the previous literature, I have left out many predecessors to the systems of innovation approach. While this review will selectively concentrate upon some of the most important contributions to the field, it has not been easy to decide which to include and which to leave aside.

2.1. *The emergence of the systems of innovation approaches*

According to Christopher Freeman (1995:5), the first person to use the expression 'national system of innovation' was Bengt-Åke Lundvall (Freeman, 1995: 5). He suggested the term be adopted as a title for part 5 in Dosi *et al.* (1988). In addition to constituting the title the term was used in several chapters in that book.[5] However, in published form, the expression was first used by Chris Freeman himself in his book on technology policy and economic performance in Japan (Freeman, 1987).

In the early 1990s two major books on national systems of innovation were published. These were edited by Bengt-Åke Lundvall (Lundvall, 1992) and Richard Nelson (Nelson, 1993).[6] A perspective that is similar in important respects has been developed within a research program led by Bo Carlsson (Carlsson, 1995). Carlsson and his colleagues talk about 'technological systems'. They argue that these are specific for various technology fields, and hence their approach is sectoral rather than national. It may sometimes also be useful to talk about regional (or local) systems of innovation. Despite their different emphases, the various perspectives also hold important similarities which allow them to be clustered together as variants of a more general and broadly encompassing systems of innovation approach.

The various publications mentioned above are by no means the only ones using the systems of innovation approach. Its diffusion has been surprisingly fast. In academic circles it is now widely used, and has already been the subject dominating a special issue of the *Cambridge Journal of Economics*.[7] The approach is also very much used in a policy context – by national governments as well as by international organizations like the OECD and the European Union. The approach seems to be very attractive to policy-makers who look for alternative frameworks for understanding differences between economies and various ways to support technological change and innovation.

[5] See chapters by Nelson (1988), Freeman (1988), and Lundvall (1988).

[6] Various national systems of innovation approaches have been compared and critically evaluated in McKelvey (1991).

[7] *Cambridge Journal of Economics*, 19 (1), February 1995. A national systems of innovation approach was early on used in an empirical and comparative study of Denmark, Sweden, Finland, Switzerland, Austria, and Ireland (Mjöset, 1992).

Let me very briefly describe and contrast the national approaches of Nelson and Lundvall and present the 'technological systems' and the regional approaches.[8]

The book by Nelson entitled *National Systems of Innovation: A Comparative Study* (1993), includes case studies of the national systems of innovation in fifteen countries, written mostly by authors who are residents of those countries. In the various chapters of this book, different authors interpret the concept of 'national system of innovation' in different ways – explicitly or implicitly. Two general chapters are also included: an introductory chapter (Nelson and Rosenberg, 1993) which outlines the process of technical advance and the key institutions involved, and a concluding chapter (by Richard Nelson), which draws some conclusions from the whole exercise. This book essentially emphasizes empirical evidence: 'the orientation of this project has been to carefully describe and compare, and try to understand, rather than to theorize first and then attempt to prove or calibrate the theory' (Nelson and Rosenberg, 1993: 4).

The Lundvall book is quite different in orientation from the Nelson one, but it is complementary. As indicated by the title, *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, this book is theoretically oriented, with some chapters being exclusively concerned with theoretical issues. To the extent that the arguments are empirically based or illustrated, one country (Denmark) is usually referred to. In some chapters there is also a 'thematic' rather than 'country' approach, in that one aspect (such as export specialization) is studied for all OECD countries. One of the aims of the book is to demonstrate the need for developing an alternative to the neoclassical economics tradition by placing interactive learning and innovation at the center of analysis (Lundvall, 1992: 1). Most of the chapters are written by scholars belonging to the IKE Research Group at Aalborg University, Denmark.[9]

The 'technological systems' approach was developed within the framework of a five-year research program of Sweden's Technological Systems and Future Development Potential led by Bo Carlsson.[10] The program deals with theoretical aspects of the study of technological systems as well as empirical studies of specific systems

[8] A more detailed characterization is made in section 3.

[9] Lundvall and his colleagues in Aalborg refer to Friedrich List's concept of *The National System of Political Economy* (List, 1841), which shows many similarities to the current concept of 'national system of innovation' (Lundvall, 1992: 16).

[10] A similar term '(large) technical systems' has earlier been used by Thomas Hughes (1983). However, he means something substantially different from Carlsson and Stankiewicz, at least in his original version. Hughes concentrates much more on technological complementarities and interdependencies, although he also deals with socio-economic aspects. The individual technologies are integrated with each other into large technical systems, such as electricity systems, telecommunications systems, or water supply systems; it is primarily the technical elements that are considered to be 'systemic', not the context around them. Only some technologies qualify, mainly infrastructural ones. Manufacturing technologies or office technologies do not form 'large technical systems', as their scale or size are usually not large enough. This kind of 'technical' integration is not used as an argument for the fruitfulness of the systems approach in the form in which it is discussed in this book. This is also the reason why Hughes's perspective is not considered to be a variant of the systems of innovation approach in this review.

like factory automation, electronics and computers, pharmaceuticals, and powder technology. Although Carlsson and his colleagues do not use the same 'language' ('system of innovation'), their 'technological systems' approach is – as will be shown in later sections – quite similar in several respects.[11]

A regional perspective on innovation and industrial development has also been widely used, although the term 'regional system of innovation' as such might be less common. One example is AnnaLee Saxenian's analysis of 'regional industrial systems' which focus on Silicon Valley, California and Route 128, Massachusetts (Saxenian 1994). Other examples are analyzes in terms of 'industrial districts' from Alfred Marshall on. The phrase 'regional innovation system' is also being increasingly used. This is indicated in Cooke (1996), which includes an analysis of the origins of the concept. The regional approach is addressed by Ellinor Ehrnberg and Staffan Jacobsson in chapter 14 of this volume.

2.2. *Theoretical origins of the systems of innovation approaches*

Although the systems of innovation approach is not considered a formal and established theory here,[12] its development has been influenced by different theories of innovation such as interactive learning theories and evolutionary theories. What follows is a very brief discussion of some theoretical roots of the systems of innovation approaches.

Lundvall's (1992) book is an attempt explicitly to relate the national systems of innovation approach to innovation theory. In it, contributing authors from Aalborg University, Denmark, have placed their own previously developed innovation theories into a national systems of innovation conceptual framework. This theory stresses processes of learning and user-producer interaction.[13] In Lundvall's words:

> One of our starting-points is that innovation is a ubiquitous phenomenon in the modern economy. In practically all parts of the economy, and at all times, we expect to find ongoing processes of learning, searching and exploring, which result in new products, new techniques, new forms of organization and new markets. In some parts of the economy, these activities might be slow, gradual and incremental, but they will still be there if we take a closer look. (Lundvall, 1992: 8)

The systems of innovation approach is compatible with the notion that processes of innovation are, to a large extent, characterized by interactive learning. It could be argued that some kind of systems of innovation approach is inherent to any perspective that sees the process of innovation as interactive; interactivity paves the way for a systemic approach.

[11] This discussion of the 'technological systems' approach is mainly based upon Carlsson and Stankiewicz's (1995) theoretical chapter in a case study of factory automation in Sweden (Carlsson, 1995). An earlier version of that chapter has been published in *Journal of Evolutionary Economics*, 1, 1991: 93–118. The concept of 'technological system' is also discussed by Bo Carlsson and Staffan Jacobsson in Chapter 12 of this volume.

[12] See section 3.9. for arguments.

[13] The theory seems to fit incremental technological innovations better than discontinuous ones, the latter often being science-based. Similarly, it might fit product innovation better than process innovation, as implicitly indicated by Lundvall (1992: 10).

Several innovation theorists have convincingly argued that the model of the isolated profit-maximizing firm is an inappropriate tool for interpreting certain important aspects of the processes involved in generating and diffusing innovations. For example, many of the actors and organizations involved in R&D and processes of innovation are not primarily governed by profit-seeking motivations. These actors may be governmental or private non-profit organizations such as universities and public research laboratories. Legal conditions, rules, and norms will also significantly affect an organization's inclination and possibility to innovate. Non-profit organizations and profit-oriented ones, like firms, also interact with each other in complex ways when pursuing learning and innovation (Nelson and Winter, 1977: 50–2).

As an alternative to understanding technical change to be a result of seeking to maximize profits, Nelson and Winter propose that it can be understood as an evolutionary process (Nelson and Winter, 1977, 1982; Nelson, 1987, 1995b). An evolutionary theory of technical change often contains the following components:

1. The point of departure is the existence and 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). These include 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 operating may be the 'natural selection' of biology or the 'market selection' of competition as regards technical change.[14] 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.

Nelson writes, 'Technical change clearly is an evolutionary process; the innovation generator keeps on producing entities superior to those earlier in existence, and adjustment forces work slowly' (Nelson, 1987: 16). The technologies that are developed are only superior in a relative sense, not optimal in an absolute sense, and the system never reaches a state of equilibrium. Technological change is an open-ended and path-dependent process where no optimal solution to a technical problem can be identified.

Although the resource bases of various national systems of innovation highly influence their patterns of innovation, technical change will likely also involve considerable randomness. In addition, the processes through which new technologies are screened, selected, and implemented take considerable time. Randomness, combined with the time-consuming nature of innovation processes, may indicate

[14] In the latter case, selection mechanisms may also be of a non-market character (e.g., institutions like rules and strategies within firms, government regulations, and public technology policies).

that evolutionary models of technological change are a more realistic way of grasping and understanding innovations than the models provided in neoclassical economics (Nelson, 1981: 1036, 1059–61).[15]

It must be recognized, however, that there is no mention of evolutionary theory in Nelson and Rosenberg (1993), and that their version of the national systems of innovation approach is therefore not explicitly based in evolutionary theory. However, in his 1988 article on the US innovation system, Nelson explicitly argues that 'in capitalist countries, technical change is set-up as an evolutionary process' (Nelson, 1988: 313). In Nelson's (1995b), detailed survey of evolutionary theorizing there are no indications that he has abandoned the evolutionary perspective that he helped to establish (Nelson and Winter, 1977, 1982). Therefore, it seems perfectly safe to assume that the Nelson (and Rosenberg) version of the systems of innovation approach is implicitly based on an evolutionary theory of innovation.

The Carlsson approach is, however, explicitly based on an evolutionary perspective: 'We have chosen an evolutionary approach because of its ability to bring within a single conceptual framework the institutional/organizational as well as the cognitive/cultural aspects of social and economic change' (Carlsson and Stankiewicz, 1995: 23). Hence they have a fairly long discussion of the role of creation of diversity and of selection mechanisms.

In contrast, Lundvall does not refer to evolutionary theory in his introduction (Lundvall, 1992). However, in Chapter 4 of that text, Esben Sloth Andersen explicitly discusses an evolutionary framework as well as the evolutionary foundations of learning by doing (Andersen, 1992). I have already shown that theories of interactive learning lie behind the Aalborg version of the national systems of innovation approach. Furthermore, there might be an intimate relation between learning theories and evolutionary theories in the sense that learning is one mechanism through which diversity is created. Learning might even be an element in processes of selection.

Carlsson and Stankiewicz, Nelson and Rosenberg, as well as Lundvall and his colleagues are all committed to the idea that technological change is an evolutionary process. Not only is the systems of innovation approach compatible with evolutionary theories of innovation but there is a close affinity between the two.[16] Thus theories of interactive learning together with evolutionary theories of technical change constitute origins of the systems of innovation approach.[17]

[15] This article primarily discusses productivity growth, but the argument seems to be as relevant for technological change.

[16] For further arguments in this direction, see Chapter 8 of this book by Paolo Saviotti and Chapter 11 by Esben S. Andersen and Bengt-Åke Lundvall. In Chapter 10 Patrick Cohendet and Patrick Llerena deal with economically positive consequences of diversity and the possibilities of exploiting them. That the concept of a national system of innovation is consistent with evolutionary theory has also been argued in Niosi *et al.* (1993).

[17] In Part II we will discuss the relations between evolutionary theories and the systems of innovation approach in a more profound way.

2.3. The concept of systems of innovation

As a basis for understanding this book's discussions about various kinds of systems of innovation, it is useful to go into more depth in describing what such a system actually is. It is necessary to start by indicating what some contributing authors mean by a system of innovation.

In an early study, Christopher Freeman (1987) defines a national system of innovation as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman, 1987: 1). When describing the Japanese national system of innovation he concentrates upon four elements:

1. The role of the Ministry of International Trade and Industry (MITI).
2. The role of company R&D, especially in relation to imported technology.
3. The role of education and training and related social innovations.
4. The conglomerate structure of industry (Freeman, 1987: 4).

Lundvall explicitly defines the concept of a national system of innovation in a 'broad' sense, including

> all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place. (Lundvall, 1992: 12)

He adds that:

> Determining in detail which subsystems and social institutions should be included, or excluded, in the analysis of the system is a task involving historical analysis as well as theoretical considerations . . . a definition of the system of innovation must be kept open and flexible regarding which subsystems should be included and which processes should be studied. (Lundvall, 1992: 12, 13)

Lundvall suggests that the boundaries of a national system of innovation cannot be sharply determined, and indeed it might be an impossible task to do so in detail. However, the issue of providing a more precise definition of system of innovation will be discussed further in this book – and we hope to clarify the concept at least to some extent. Accordingly, this topic will be addressed in Chapter 9 by Maureen McKelvey and in Chapter 15 by Riccardo Galli and Morris Teubal.

Leaving the national approach, Carlsson and Stankiewicz define a technological system as: 'a network of agents interacting in a specific *economic/industrial area* under a particular *institutional infrastructure* or set of infrastructures and involved in the generation, diffusion and utilization of technology' (1995: 49; italics in original).[18]

In Nelson and Rosenberg's (1993) introductory chapter to the Nelson book no explicit definition of a national system of innovation is provided but rather three terms – *'innovation'*, *'national'*, and *'system'* – are discussed in some detail. I will

[18] In the same book, Carlsson uses a somewhat different formulation: *'technological systems* consist of *network(s)* of agents interacting in a specific technology area under a particular *institutional infrastructure* for the purpose of *generating, diffusing and utilizing technology'* (Carlsson, 1995: 7; italics in original). Technological systems are closely related to the kind of 'networks' analyzed by Håkansson (1989).

follow a similar procedure below, but go further by relating the discussion to the approaches mentioned above – as well as to the works of a few other scholars.

2.3.1. The concept of 'innovation'

Innovation as conceived by Nelson and Rosenberg (1993) is narrow in the sense that it is restricted to technical innovations.[19] They write: 'This book is about national systems of technical innovation . . . the studies have been carefully designed, developed, and written to illuminate the institutions and mechanisms supporting technical innovation in the various countries' (Nelson and Rosenberg, 1993: 1). This is certainly an accurate description of the content of the Nelson book, for none of the contributing authors discuss organizational, institutional, or social innovations in any detail, although a few address such innovations in an ad hoc manner.

The innovation concept is, however, not always restricted to technical innovations. Schumpeter, for example, conceived of innovation in a much broader way. In his own words, he preferred to

> define innovation more rigorously by means of the production function . . . this function describes the way in which quantity of product varies if quantities of factors vary. If, instead of quantities of factors, we vary the *form* of the function, we have an innovation. (Schumpeter, 1939: 87; emphasis added)

Or in somewhat different words:

> we will simply define innovation as the setting up of a *new* production function. This covers the case of a new commodity as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on. (Schumpeter, 1939: 87; emphasis added)[20]

Directly following the quote above, Schumpeter defined innovation in extremely broad terms:

> Recalling that production in the economic sense is nothing but combining productive services, we may express the same thing by saying that innovation combines factors in a new way, or that it consists in carrying out New Combinations. (Schumpeter, 1939: 87–8)

'New combinations' is also used as a definition of innovation by, for example, Lundvall (1992: 8) and Elam (1992: 3). However, neither of these authors refer to innovations as the setting up of a new production function.

In its various forms, Schumpeter's definition is extremely wide – when compared to the innovation concept used by Nelson and Rosenberg. In another sense,

[19] Process as well as product innovations are counted as technical innovations (Nelson and Rosenberg, 1993: 4–5).

[20] Hence Schumpeter explicitly mentions new commodities (i.e., what we could also call new product technologies or product innovations). He also specifically mentions new forms of organization – which he, somewhat surprisingly, exemplifies with a merger. However, he does not explicitly define 'form of organization'. (Organizational innovations are discussed more systematically in Edquist, 1992.) Although not mentioned in the quotes above, new process technologies are also considered to be innovations by Schumpeter. As a matter of fact, 'the setting up of a new production function' is an extremely wide conception and actually covers many important changes of economic significance, including technological and organizational process innovations as well as product innovations.

however, Nelson and Rosenberg's concept is also very wide. As they state, they interpret innovation 'rather broadly, to encompass the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, whether or not they are new to the universe, or even to the nation' (Nelson and Rosenberg, 1993: 4–5). Hence their innovation concept includes not only the first introduction of a technology but also its diffusion. They point, in passing, to one difference between their concept of innovation and Schumpeter's by observing that 'the strictly Schumpeterian innovator, the first firm to bring a new product to market, is frequently not the firm that ultimately captures most of the economic rents associated with the innovation' (Nelson and Rosenberg, 1993: 4).

As with the Nelson and Rosenberg concept of innovation, the 'technological systems' approach of Carlsson and Stankiewicz focuses mainly upon technologies, their generation, diffusion, and utilization (Carlsson and Stankiewicz, 1995: 49) In technological innovation Carlsson, however, includes both know-how ('software') and artefacts ('hardware') (Carlsson, 1995: 3). Product as well as process technologies are also included in the Carlsson/Stankiewicz notion of technology. Hence their innovation concept is similar to that of Nelson and Rosenberg.[21]

Lundvall deviates here in mentioning 'new forms of organization' and 'institutional innovations' (Lundvall, 1992: 8, 9, 14, 17), in addition to technological process and product innovations. However, he does not specify his concept of innovation explicitly and systematically. It could be argued that he is more faithful to Schumpeter in understanding the concept of innovation in a very broad sense. But there are difficulties with Lundvall's approach: he does not systematically deal with non-technological kinds of innovations (i.e., he focuses mainly on technological innovations), and there is some confusion about the distinctions he makes between different kinds of innovation.

To conclude, different authors who adopt the systems of innovation approach mean different things by the term innovation. This is not necessarily problematic, since definitions and analytical distinctions are not right or wrong. However, for certain purposes specific definitions may be good or bad; useful or not.[22] This pragmatic view of conceptual matters simply implies that the object of study should influence the conceptual specification. The conceptual tools used should, for example, be influenced by whether we want to study only technological process innovations or include product innovations and/or organizational innovations as well. In summary, all authors working within the systems of innovation approach are centrally focused on technological innovation and, in addition, all are interested in organizational and institutional change.

[21] It should be added that the Carlsson approach also focuses upon 'institutional infrastructures' as constituent elements of technological systems.

[22] And analytical distinctions do not imply views about relations (causal or temporal) between the categories distinguished. For example, a distinction between development and diffusion of technology does not imply a linear view of technological change. However, such relations can, of course, be conjectured on the basis of theories and/or established in empirical work.

2.3.2. The concepts of 'national', 'regional', and 'sectoral'

Another component in the national systems of innovation concept is the notion of *'national'*. It will here be discussed in conjunction with *'regional'* and *'sectoral'*. The delimitation of systems of innovation in geographical and sectoral dimensions will be in focus.[23] On what it means to be 'national' Nelson and Rosenberg write:

> On the one hand, the concept may be too broad. The system of institutions supporting technical innovation in one field, say pharmaceuticals, may have very little overlap with the system of institutions supporting innovations in another field, say aircraft. On the other hand, in many fields of technology, including both pharmaceuticals and aircraft, a number of the institutions are or act transnational. Indeed, for many of the participants of this study, one of the key interests was in exploring whether, and if so in what ways, the concept of a 'national' system made any sense nowadays. National governments act as if it did. However, the presumption, and the reality, may not be aligned. (Nelson and Rosenberg, 1993: 5)

Thus, Nelson and Rosenberg implicitly argue for a sectoral approach, then question the usefulness of examining national systems of innovation. Because of increasing internationalization, Lundvall (1992: 3–4) also expresses arguments against studying systems of innovation from a national perspective.

Systems of innovation other than national ones can be, should be, and are being identified and studied. An innovation system can be 'supranational' in several senses; it can be truly global, or it can include only part of the world (e.g., an integrated Europe).[24] It can also be 'regional' within a country, an example being the Silicon Valley area in California or Route 128 in Massachusetts (Saxenian, 1994). An innovation system can also be supranational and regional within a country at the same time, as are parts of Germany, France, and the UK. Continuing along the spatial path one may – in Europe – distinguish between a supranational system at the European Union level, the national level, and the regional/local level.

Leaving the geographical dimension, we could also talk about 'sectoral' systems of innovation (i.e., systems that include only a part of a regional, a national, or an international system). The 'technological systems' approach, as defined in section 2.3., is a sectoral one in this sense. In contrast to the national approach represented by Nelson and Lundvall, Carlsson *et al.* (1992) talk about technological systems in specific technology fields. In other words, their approach is 'sectoral' in the sense that it is determined by generic technologies ('technology fields'). They can be, but are not necessarily restricted to one industrial branch.[25] Carlsson and Stankiewicz state that the

> nation-state constitutes a natural boundary of many technological systems. Sometimes, however, it may make sense to talk about a regional or local technological system . . . In yet other cases the technological systems are international, even global. Where the boundaries are drawn depends on the circumstances, e.g., the technological and market requirements, the capabilities of various agents, the degree of interdependence among agents, etc. (Carlsson and Stankiewicz, 1995: 49)

[23] Delimitation in a functional sense will be discussed in the next section.

[24] The development of the European Union's system of innovation will be discussed by Paraskevas Caracostas and Luc Soete in Chapter 17.

[25] In Chapter 6, Stefano Breschi and Franco Malerba also talk about 'sectoral systems of innovation'. However, they clearly do not mean the same thing as Carlsson *et al.*

Hence, technological systems may be national, regional, as well as international.

From the point of view of a transnational corporation, the relevant system of innovation may be similar to a sectoral one, but international or global at the same time.[26] Since it is active in many countries, it may also be important for the firm, in its strategy, to take differences between national systems into account – in order to exploit them. At the same time 'technological systems' constitute elements of national as well as regional systems of innovation.

The specification national systems of innovation is obviously only one among several possibilities. However, there are strong reasons to talk about innovation in terms of national systems. One reason is the fact that the various case studies in Nelson (1993) show that there are sharp differences between various national systems in such attributes as institutional set-up, investment in R&D, and performance. For example, the differences in these respects between Denmark and Sweden are remarkable – in spite of the fact that these two small countries in Northern Europe are very similar in other respects such as language, culture, standard of living, lifestyle, consumption patterns, size of the public sector, and strength of trade unions (Edquist and Lundvall, 1993: 5–6). Another very important reason is that most public policies influencing the innovation system or the economy as a whole are still designed and implemented at the national level. In other words, the importance of national systems of innovation has to do with the fact that they capture the importance of political and policy aspects of processes of innovation.[27] It is not only a matter of geographical delimitation; the state, and the power attached to it, is also important.[28]

The discussion pursued here leads to the following conclusion. Systems of innovation may be supranational[29] national, or subnational (regional, local) – and at the same time they may be sectoral within any of these geographical demarcations. There are many potential permutations. Whether a system of innovation should be spatially or sectorally delimited depends on the object of study. All the approaches mentioned above may be fruitful – but for various purposes or objects of study. Sometimes a national approach to systems of innovation is most appropriate and sometimes a sectoral or regional one is more useful.[30] The approaches complement rather than exclude each other. Sometimes one angle is useful, sometimes another. For example, Paolo Guerrieri and Andrew Tylecote combine a national and a sectoral approach in Chapter 5 of this volume.

[26] However, a firm may, of course, produce in several sectors and be present in several technological systems simultaneously.

[27] In Chapter 7 of this volume, Mark Elam deals with the role of territoriality and why nations matter in economic development. The national dimension is also central in Chapter 16 by Slavo Radosevic on the transformation from socialist to post-socialist systems of innovation.

[28] In some countries political power is decentralized (e.g., to the German *Länder*). This increases the relevance and importance of regional systems of innovation.

[29] Freeman talks about 'continental' systems of innovation (Freeman, 1995).

[30] This is – again – an example of the conceptual pragmatism referred to in the discussion of 'innovation' at the end of section 2.3.1.

2.3.3. *The concept of 'system'*

Given the pragmatic position taken above with regard to the specification of 'innovation' and the delimitation of systems of innovation in spatial and/or sectoral terms, the concept of 'system' becomes very central. This term is problematic in all the three approaches discussed here.

It may be illuminating briefly to relate the systems of innovation concept to a general systems concept, where the term 'systems' refers to 'complexes of elements or components, which mutually condition and constrain one another, so that the whole complex works together, with some reasonably clearly defined overall function' (Fleck, 1992: 5).[31]

The systemic character of the systems of innovation approach[32] means that it has the potential of transcending the linear view of technological change, which places R&D (technology development) at the beginning of a causal chain that ends in productivity growth, mediated by innovation and diffusion.[33] As stressed in the Lundvall book, it is natural to regard innovation as an interactive process leading to a systems of innovation approach.

According to Carlsson *et al.*, the objective of government technology policy is to improve the function of existing technological systems and to enhance the creation of new ones (Carlsson *et al.*, 1992: 14). In other words technological systems are – at least partly and sometimes – consciously built by the state. In Nelson and Rosenberg (1993) the contrary is the case: national systems are not consciously designed. The elements in the systems may even be in conflict with each other (i.e., influence innovations in opposing directions). This is shown in their definition of the term 'system':

> the concept here is of a set of institutions whose interactions determine the innovative performance, in the sense above, of national firms. There is no presumption that the system was, in some sense, consciously designed, or even that the set of institutions involved work together smoothly and coherently. Rather, the 'systems' concept is that of a set of institutional actors that, together, play the major role in influencing innovative performance. The broad concept of innovation that we have adopted has forced us to consider much more than simply the actors doing research and development. Indeed, a problem with the broader definition of innovation is that it provides *no sharp guide* to just what should be included in the innovation system, and what can be left out. (Nelson and Rosenberg, 1993: 5–6; emphasis added)

Nelson and Rosenberg do not conceive 'systems' of innovation to be 'created' or 'developed' by, for example, policy-makers. In my view the truth is somewhere

[31] Fleck also quotes the Shorter Oxford English Dictionary according to which a system is a 'set or assemblage of things connected, associated or interdependent, so as to form a complex unity; a whole composed of parts in orderly arrangement according to some scheme or plan, rarely applied to a simple or small assemblage of things' (Fleck, 1992: 5).

[32] Note that it is the approach that is systemic, not technologies.

[33] This is not to imply that there is nothing at all in the linear view. It has some relevance, particularly in areas where technologies are heavily science based and technical change thereby often discontinuous. But the linear view does not in general capture the determinants of innovation in a satisfactory manner. This has been argued by, for example, Kline and Rosenberg (1986) and von Hippel (1988). These contributions could therefore be regarded as predecessors to the systems of innovation approach.

between Carlson *et al.* and Nelson and Rosenberg. Some elements of systems of innovation – they might be national or sectoral – are consciously designed by actors – sometimes by government policy-makers. Other important elements seem to be evolving spontaneously over extended time periods. It might be added that it is probably easier to influence a technological system than a national system of innovation from the policy level. A national system as a whole can certainly not be designed.

The emphasized part of the quote above indicates that a problem with broadening the definition of innovation is to define the limits of the systems studied. On this issue Lundvall writes, as we saw: 'a definition of the system of innovation must be kept *open and flexible* regarding which subsystems should be included and which processes should be studied' (Lundvall, 1992: 13; emphasis added). Lundvall specifies two key universal components of national systems of innovation – institutions and industrial structure – but he does not give clear criteria for identifying the most important ones (McKelvey, 1991: 130).

Neither are Carlsson and his colleagues clear on this issue. Carlsson and Stankiewicz (1995) do not address the issue of the non-geographic, or functional, boundaries of technological systems. It is unclear exactly which agents and institutional infrastructures are 'involved' in the generation, diffusion, and utilization of technology.[34]

Hence all three approaches are vague in specifying the boundaries of the systems.[35]

One way of specifying 'system' is to include in it all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations. Potentially important determinants cannot be excluded *a priori* if we are to be able to understand and explain innovation.[36] Provided that the innovation concept has been specified, the crucial issue then becomes one of identifying all those important factors.[37] This could – in principle – be done by identifying the determinants of (a certain group of) innovations. If, in this way, innovations could be causally explained, the explanatory factors would define

[34] See the definition of 'technological system' towards the end of section 2.3.

[35] However, this seems to be a common problem also in other spheres where a 'systems' concept is used, for example, in 'systems development' in software production.

[36] For example, there are no reasons to limit the determinants to only 'a set of institutional actors', as done by Nelson and Rosenberg (1993); see the earlier quote in this subsection. The proposal here can also be compared to the definition proposed by Lundvall as quoted in the beginning of section 2.3. Lundvall's definition is broad in the sense that it includes all kinds of learning, searching, and exploring (instead of focusing only upon innovation). However, it is limited in pointing out certain kinds of determinants (i.e., the economic structure and the institutional set-up).

[37] Clearly the system of innovation is larger than the R&D system. It must, for example, also include the system of technology diffusion and how institutions and similar factors influence both.

the limits of the system. The problem of specifying the extent of the system studied would be solved – in principle.[38]

Admittedly, this is not as easy in practice as in principle. We simply do not know in detail what all the determinants of innovation are, particularly not for all types of innovations. This procedure would require a lot of explanatory work – which remains to be done – and which is a very complex thing in the social sciences. In other words, at the present state of the art, defining the limits of a system of innovation in this way (as all determinants) is a 'catch 22' problem.[39] In spite of this and the fact that we might never be able completely to identify the determinants of innovation, we will, for the time being, specify system as including all important determinants of innovation.

An advantage of this definition is that it is open in the sense that it does not *a priori* exclude any determinants. An obvious disadvantage is that it is unspecific at the present state of the art. We are, for example, unable to specify the relative importance of determinants in various cases and there may, of course, still exist unidentified determinants which are important.[40] A primary objective of further research in the field is to decrease our ignorance in these respects. This would simultaneously increase the degree to which we can specify a 'system'.

Having defined systems of innovation functionally in this very comprehensive sense, it must also be pointed out that some factors (determinants) are viewed as being more important than others in specific versions of the systems of innovation approach. As we have seen, Lundvall argues that 'the structure of production' and 'the institutional set-up' are the two most important dimensions, which 'jointly define a system of innovation' (Lundvall, 1992: 10). They 'form the framework for, and strongly affect, processes of interactive learning, sometimes resulting in innovations' (Lundvall, 1992: 9). In a similar way Nelson singles out organizations supporting R&D. These instances serve to focus our attention on some aspects of systems of innovation. In this way the approaches serve as 'focusing devices'. Neither are, however, examples of proven theories, but rather they are interesting conjectures that need to be specified and then verified or disproved through further research.

3. Common characteristics of the systems of innovation approaches: advantages and problems

This section identifies nine characteristics that the systems of innovation approaches have in common. In doing so it also points out the advantages associated with the

[38] An attempt in this direction – but only with regard to diffusion of process technologies in the engineering industry – was made in Edquist (1989: 10–11). In that context the explanatory factors included: structure of production, relative factor prices, organizational conditions, degree of unemployment, union attitudes, technology policy, and availability of know-how.

[39] In addition, we would be forced to make some sort of distinction between important determinants and less important ones; excluding determinants of minor importance is necessary to facilitate the task (and reduce the extension of the systems).

[40] Even if a definition of 'system of innovation' is clear and unambiguous, the national system of innovation in each country might be specified in different ways. For example, the role of different institutions, organizations, and activities tend to change over time and space. We will return to this issue in section 3.4.

systems of innovation approaches as a means for studying innovation, as a conceptual framework for government policy-making, and as a basis for formulating the innovation strategies of firms.[41] The identification of common characteristics will also point out a number of problems, weaknesses, and puzzles associated with the systems of innovation approaches. Some of these weaknesses were considered challenges in the work within the Network and are hence addressed in this book.

3.1. Innovations and learning at the center

Despite their different interpretations of innovation, all versions of the systems of innovation approach place innovations at the very center of focus. Somewhat less evident is that this also applies to learning processes of various kinds. This contrasts with conventional neoclassical analysis, where technological change is treated as an exogenous factor (i.e., emerging outside the economic system). 'As a result, the causal connections between technological change and economic growth are poorly understood' (Carlsson, 1995: 1).

Technological innovation is a matter of producing new knowledge or combining existing knowledge in new ways – and of transforming this into economically significant products and processes. Learning in the form of formal education and searching through research and development (R&D) is behind much of innovation. However, not all innovation has this source; in many cases innovation is a consequence of various kinds of learning processes embedded in various ordinary economic activities. Many different kinds of actors and agents in the system of innovation are involved in these learning processes; the everyday experiences and activities of engineers, sales representatives, and other employees matter a lot. In the words of Lundvall:

> Such activities involve learning-by-doing, increasing the efficiency of production operations (Arrow 1962), learning-by-using, increasing the efficiency of the use of complex systems (Rosenberg 1982), and learning-by-interacting, involving users and producers in an interaction resulting in product innovations (Lundvall 1988). (Lundvall, 1992: 9).

As indicated in section 2.2., Lundvall also argues that learning, searching, and exploring take place in practically all parts of the economy (Lundvall, 1992: 8).

The economic role of learning currently seems to be increasing rapidly, and there is much talk about 'the knowledge based economy' and 'the learning economy'.[42] Lundvall argues that knowledge is the most fundamental resource in the modern economy and, accordingly, that the most important process is learning (Lundvall, 1992: 1). This means that it is vital, from the viewpoint of encouraging economic growth and employment, to analyze the knowledge and learning aspects of systems of innovation, including the formal R&D system, the education and training system, as well as processes of learning embedded in routine economic activities. Not only is the creation of new knowledge crucial but so is its accessibility (i.e., its distribution

[41] This means an implicit comparison between the systems of innovation approach(es) and other approaches. Making this comparison explicit and systematic is a larger task than can be done in an introduction to an edited book.

[42] See, for example, Lundvall and Johnson (1994).

and its utilization within systems of innovation). This latter issue is addressed by Dominique Foray in Chapter 3 of this volume and by Keith Smith in Chapter 4.

3.2. Holistic and interdisciplinary

The systems of innovation approaches can be characterized as 'holistic' in the sense that they have the ambition to encompass a wide array – or all – of the determinants of innovation that are important – whether it is in a national, regional, or sectoral context. Holistic is then contrasted to 'reductionist' (i.e., the *a priori* exclusion of potentially important determinants of innovation).

The systems of innovation approach can be contrasted with previous attempts to understand innovation. 'The traditional OECD approach' to technical change and innovation has strongly influenced the kind of data collected on R&D and technical change. This approach focuses mainly on the R&D system in a narrow sense, primarily by studying resource inputs (money and personnel) into the R&D system. One reason why the systems of innovation approach goes beyond R&D is that technologies are also developed outside the formal R&D system through, for example, learning by doing, learning by using, and learning by interacting.[43] In addition, technologies are not only developed, but also produced, diffused, and used.[44] They are also changed during these processes. All these additional factors are included in a system of innovation – but not in an R&D system. Hence a 'system of innovation' is much more than an R&D system, and the systems of innovation approach is much wider and more comprehensive than the traditional OECD approach.[45]

The systems of innovation approach also allows for the inclusion not only of economic factors influencing innovation but also of institutional, organizational, social, and political factors. In this sense it is an interdisciplinary approach. Perhaps it might best be labeled a 'political–economic' approach.

Elements of systems of innovation – such as firms and other actors at the 'micro' level – behave and perform very differently with regard to innovation activities in different contexts, including national ones. For example, old and established firms in Japan and South Korea have diversified into production of new R&D-intensive products to a much larger extent than firms in the USA or Sweden. This probably is largely due to the different structural environments of the firms. In order to understand such phenomena it is important to have a structure concept. The system of innovation approach can fruitfully serve as such, because it can be considered to

[43] These learning processes operate outside the formal R&D system, as noted earlier. However, they may also be relevant to the activities within this formal system.

[44] And technologies do not have large economic and social consequences until they are widely diffused and used. For all but the – economically speaking – largest countries, this diffusion means mainly absorption from abroad. This is so for Sweden as well as for Mexico and India.

[45] It must be mentioned that the OECD secretariat has been very quick to adopt a systems of innovation approach in its work. For example, in the OECD Technology/Economy Program (TEP) reported in 1991, the notion of national systems of innovation was already important.

combine a structural and an actor-oriented approach.[46] A systemic and holistic framework in the sense discussed here has a tremendous value as a tool to facilitate understanding of the dynamics of innovation.

Let me conclude this section with some remarks of a methodological kind. A system of innovation should be looked upon as a 'whole' because many of its elements are – more or less closely – related to each other. Otherwise, there would be no 'system'. But it is also sometimes necessary to deal only with parts of the system – one at a time or a few in relation to each other.

Hence, it may sometimes be necessary to restrict the analysis to various subsystems of a system of innovation. To divide the complex 'whole' into pieces as done in some chapters of this book is sometimes useful – and sometimes even a necessary way of understanding and creating theories about the relations between various parts or 'elements' involved in the process of technological and organizational change. In other words, a study limited to, for example, the financing of innovations is not necessarily reductionism. To study only one subsystem can also contribute to the creation of a more coherent and sharp 'scientific language' appropriate for dealing with elements like technological development, diffusion of technology, the emergence and diffusion of organizational forms, education and training, as well as institutional changes related to these spheres. The combination of a holistic approach with clearly developed analytical distinctions between elements in the system as a whole is useful in interdisciplinary research on technological and organizational change.[47]

3.3. *A historical perspective is natural*

The time lag between a technical invention, its transformation into an economically important innovation, and its widespread diffusion is often long. In many of the country case studies in the Nelson book the historical dimension is therefore stressed. To use the study of Denmark and Sweden as an example, it can be seen that the natural resource base (fertile land in Denmark and forests and minerals in Sweden) and the economic history of the two countries from the industrial revolution onwards strongly influenced the present anatomies of the two national systems of innovation (Edquist and Lundvall, 1993: 269–82).[48]

The different natural resource bases of Denmark and Sweden were highly influential in determining the direction of innovation and therefore the development

[46] Anthony Giddens combines both actor and structure in his structuration theory (Giddens, 1984). Various systems of innovation approaches are discussed in a structure/actor perspective by McKelvey (1991). A theoretical framework combining a structural and an actor-oriented approach have been used in empirical work in Edquist (1985).

[47] In such work it must be kept in mind that analytical distinctions (and definitions) do not imply statements about the relations between the categories distinguished.

[48] In this analysis we also used the concept of 'development blocks', coined by Erik Dahmén (1970, 1988), as a tool to understand the formation and development of the systems of innovation in the two countries. Development blocks are similar to what Michael Porter (1990) would later call 'clusters' and what others have labeled '(industrial) complexes'. Both Dahmén and Porter could be considered to be Schumpeterian predecessors to the systems of innovation approach, although both of them are neglected in this introduction.

of the two countries' current systems of innovation. This has also been true for countries such as Canada and Australia. In Japan and South Korea the natural resource base may have been less important, while civilian technology policy has been a more important determinant of the development of the systems of innovation. Through such policy, other resources, for example human resources such as knowledge and competence, have been created as a substitute for the lack of natural resources. In the USA, military R&D and technology policy may have been crucial factors. In other words, technology policy may act as an engine for 'liberating' a country's system of innovation from its natural resource base, i.e., using the resource base without being constrained by it (Edquist and Lundvall, 1993).

Such historical processes can be captured by an analysis anchored in a systems of innovation framework. To have a historical perspective is not only an advantage when studying processes of innovation, but also necessary if we are to understand them. This is because innovations develop over time. In their development they are influenced by many factors, and it is not clear to the actors involved – e.g., firms and other organizations – what the end result is going to be or whether their efforts will be successful or not. History matters very much in processes of innovation as they are often path dependent: small events are reinforced and become crucially important through positive feedback.[49]

It is not only innovations that develop in this way but also institutions and organizations. Even systems of innovation as a whole cumulatively develop over time, and the accumulation of knowledge and skills is crucial to them. These processes might be captured in terms of the dynamic 'co-evolution' of knowledge, innovations, organizations, and institutions.

However, systems of innovation are also subject to inertia, as indicated by the examples of Denmark and Sweden. Their anatomies seem to be quite stable over long periods, and the structural resistance to change is often considerable.

3.4. *Differences between systems and non-optimality*

The systems of innovation of various countries can be quite different. The same is true for regional (or local) systems of innovation and for sectoral ones (technological systems). Various national systems of innovation differ in their structure of production (i.e., pattern of specialization in production). In some countries raw material based production is important; in others knowledge-intensive production is more dominant. For these and other reasons systems differ in the amount of resources spent on R&D and innovation. The systems also differ in their performance in terms of technology development and diffusion.

In addition, the organizations and institutions constituting elements of the systems of innovation may be different in various countries, regions, or sectors. For example, research institutes and company-based research may be important for the R&D system in one country (Japan) while research universities may perform a similar function in another (USA).[50] Legal systems, norms, and values also differ. The

[49] They may therefore be understood in an evolutionary perspective, as discussed in section 2.2.

[50] And this significantly influences the availability of R&D results to other actors.

specifications of the elements in a national system of innovation therefore normally differ between countries.[51]

In the systems of innovation approaches the differences between the various systems are stressed and focused upon rather than abstracted from.[52] This makes it not only natural but vital to compare various systems. Without comparisons between existing systems it is impossible to argue that one national system is specialized in one or the other way. Neither can we argue that one country spends much on R&D or that its system performs well – or badly. This is because the notion of optimality is absent from the systems of innovation approaches. Hence comparisons between an existing system and an ideal system are not possible.

We cannot define an optimal system of innovation because evolutionary learning processes are important in such systems and they are thus subject to continuous change. The system never achieves an equilibrium since the evolutionary processes are open ended and path dependent. We do not even know whether the potentially best trajectory is exploited at all, since we do not know which one it is. Processes of change are at least partly random and take a long time.

In the absence of any notion of optimality, a method for comparing existing systems is necessary for understanding what is good or bad or what is a high or low value for a variable. Large benefits could be reaped if comparisons between systems were made explicit and systematic. Comparisons are also crucial for policy purposes; for the identification of problems that should be subject to intervention. Such comparisons between systems must be genuinely empirical and would therefore be similar to what is often called 'benchmarking' at the firm level.[53]

3.5. Emphasis on interdependence and non-linearity

Following Schumpeter, innovations can be considered to be 'new combinations' of elements of existing and/or new knowledge. These knowledge elements often originate from different actors and agents such as firms and universities. It has long been recognized that firms almost never innovate in isolation. When innovating, they interact more or less closely with other organizations, and they do so in the context of existing laws, rules, regulations, and cultural habits. The other organizations may be firms as well (customers, competitors, or suppliers of inputs – including knowledge and finance), but they may also be other kinds of organizations such as universities, schools, training institutes, government agencies, etc.[54]

[51] The fact that there are differences between countries in all these respects is clearly shown for Japan in Odagiri and Goto (1993), for South Korea in Kim (1993), for the USA in Mowery and Rosenberg (1993), and for Sweden and Denmark in Edquist and Lundvall (1993).

[52] This is in sharp contrast to neoclassical economic theory which is supposed to be valid for all market economies, and treats all as the same.

[53] The usefulness of empirical–comparative analysis as a basis for policy design is argued in Edquist (1994).

[54] What has been mentioned here are simply important elements of systems of innovation. In Chapter 15 Riccardo Galli and Morris Teubal deal with the main elements of a national system of innovation and the linkages between them. Keith Smith partly uses a similar perspective in Chapter 4.

These insights are here considered to be a driving force behind the emergence of the systems of innovation approach, an approach in which interdependence and interaction between the elements in the systems is one of the most important characteristics. In the systems of innovation approach, innovations are not only determined by the elements of the system but also by the relations between these.[55] For example, the long-term innovative performance of firms in science-based industries is strongly dependent upon the interaction between these firms and universities (or other organizations that carry out relevant basic research).[56] To describe a system of innovation it is therefore not sufficient only to enumerate its elements. The relations between the elements must also be addressed.[57]

These relations are extremely complex and often characterized by reciprocity, interactivity, and feedback mechanisms in several loops. They are clearly not characterized by unilateral and linear causal relationships. This means that the systems of innovation approach has the potential to transcend the linear view of technical change, as mentioned in section 2.3.

This emphasis on the complex relations between elements constitutes a major advantage of the systems of innovation approach. However, it also constitutes a challenge; we simply do not know enough about these relations. It is important to be able to capture these interdependencies in empirical work – which includes the development of concepts and indicators that relate elements to each other. Quantification is important. This is needed for the development of a more sophisticated systemic and interactive view of innovation processes. It is, however, not an easy task. More work is needed on identification of the central elements in systems of innovation, estimating their relative importance, as well as investigating the relations between them. In particular, we need to know more about the interdependence and connectivity of the systems. We also ought to find out more about the division of labor between elements of innovation systems; who is responsible for what kind of knowledge and why?

One consequence of the interdependent and non-linear view which characterizes the systems of innovation approach is that it is natural also to bring in demand as a determinant of innovation. This has been done by Lundvall when focusing on interactive learning as a relation between using and producing firms. 'Demand conditions' have also been singled out by Porter as one of four factors that determine the creation of competitive advantage of an industry (Porter, 1990: 71).[58] Porter emphasizes the nature of home demand for the industry's product. He claims that the size of home demand is far less significant than its character, and stresses the importance of buyers that are sophisticated and demanding, since they pressure

[55] Elements and relations are both seen as determinants of innovation; see section 2.3.3., as well as Chapter 16 by Slavo Radosevic.

[56] The increasing roles of science-based technologies and interdisciplinarity are discussed by Frieder Meyer-Krahmer in Chapter 13.

[57] Various kinds of interactions within firms, between firms, and between firms and other organizations are the focus of Paolo Guerrieri and Andrew Tylecote in Chapter 5.

[58] The others are factor conditions, related and supporting industries, and firm strategy, structure, and rivalry.

companies into meeting higher standards and innovating. Under 'demand conditions' he includes not only demand from other firms, but also consumer demand for end products (Porter, 1990: 86–100). Corresponding to Porter's stress of demand is the emphasis on 'lead users' in the technological systems approach.

A corollary of treating demand as an important determinant of innovation is a widening of the traditional view on innovation policy. The traditional view strongly emphasizes innovation policy instruments at the supply side, e.g., support and subsidies to R&D or absorption of new products and processes from abroad. It is obviously influenced by the linear view. The emphasis on demand as a determinant of innovation points also to demand side innovation policy instruments such as laws, taxes, regulations, and subsidies which may influence the diffusion of technologies, including choices between alternatives and their use. Such regulations can, for example, be motivated by environmental reasons.[59]

A focus on demand also naturally leads to an emphasis on government technology procurement as an innovation policy instrument. This means that a government agency places an order for a product or a system that does not (yet) exist. Hence the agency serves as a sophisticated customer, and innovation activities become necessary for satisfying the demands of the buyer. This instrument has been used in the defense material sector of many countries. It has also proved to be an extremely potent instrument for influencing the speed and direction of innovation at the civilian side in some countries. Sometimes government technology procurement has also served to strongly enhance the competitiveness of those firms successfully meeting the demands and thereby winning the contracts.[60]

3.6. Encompasses product technologies and organizational innovations

The concept of innovation can be used in many senses – as we saw in section 2.3.1. In mainstream economic theory innovation is, more or less explicitly, often assumed to be limited to process innovations (which normally lead to productivity growth and decreased employment per unit of output, at least as an immediate or direct effect).[61]

At the same time, technological product innovations are probably more important than technological process innovations. A considerable part of industrial R&D goes to the development of new and/or better products (rather than processes), although this figure varies between countries.[62] Intuitively, we expect there to be more new goods – i.e., more product innovation – in R&D intensive sectors of manufacturing than in other sectors.[63] Examples are electronics and pharmaceuticals (Edquist, 1996).

The production of R&D intensive goods is also positively correlated to high productivity and high productivity growth.[64] We also expect the market for new goods to grow faster than for old goods. As a consequence, we expect a 'mediated' correlation between sectors with high R&D intensity (and a lot of product innovation) and sectors with rapid market growth; there is a correlation between R&D intensive products and growth products (Edquist and Texier, 1996).

A historical comparison shows that over the past hundred years there have been tremendous cultural, social, and technological transformations resulting from the development and diffusion of new products. Just assume away the automobile, the telephone, the computer, and the television! Product innovation, leading to the substitution of old goods and services or to the satisfaction of new needs, is the main mechanism effecting structural change in economies. It propels development forward to a larger extent than increasing efficiency through process innovations. Hence product innovation seems to be the more important part of technological innovation.[65] This is probably the reason why Lundvall, Nelson and Carlsson include product innovations in their concept of innovation. Hence, the systems of innovation approach has no problems in capturing and dealing with product innovation.

If the objective is to understand the growth and employment effects of innovation, there are strong reasons for also including organizational innovation in the analysis. Developments in production have led managers and researchers to give more emphasis to organizational change as a source of productivity growth and competitiveness, and we are all familiar with 'just-in-time' and 'lean production'. Arguments favoring organizational change are persuasive. Although Japanese auto assembly plants in the USA use process technologies similar to their US counterparts, the Japanese 'transplants' are more productive than domestic plants. Thus organizational forms may be 'national', i.e., rooted in and emerging from specific characteristics of societies. But they may also be 'firm based' and 'international' at the same time, as shown by the existence of transplants.

There are three specific arguments for including organizational innovations in the concept of innovation:

[59] Supply versus demand side innovation policy instruments have been discussed in Edquist (1994).

[60] Government technology procurement as an innovation policy as well as an industrial policy instrument has been discussed in some detail in Edquist (1995).

[61] However, some neoclassical models deal with product innovation and the emergence of new products.

[62] Depending on how one counts, this figure is between 75 and 90 per cent for Sweden (SCB, 1991: table 4). In 1985 68 per cent of industrial R&D was spent on developing new products and product changes in the USA. The figure for Japan was 36 per cent (Mansfield, 1988: 1771). The rest of industrial R&D was in all three countries spent on the development of new processes and process changes.

[63] An R&D intensive sector has a high ratio between R&D expenditures and production value or value added.

[64] This has been shown in Edquist and McKelvey (1992, 1996), Edquist (1993b), and Tyson (1992: 35). Learning curves are also steeper for R&D intensive goods, and their development and production are often associated with positive externalities. This means that a country with a – relatively speaking – large production of R&D intensive goods can be expected to experience a higher productivity growth (and a higher economic growth) than other countries.

[65] Product innovation is the main source of the creation of new jobs in industrial countries (Edquist and Texier, 1996; Edquist, 1996). The development and production of new products might be associated with increased productivity as well as the creation of new jobs (Edquist, 1993c).

- Organizational changes are important sources of productivity growth and competitiveness and they might also strongly influence employment (Edquist, 1992: 23–4; 1996);
- Organizational and technological changes are closely related and intertwined in the real world, and organizational change is often a requirement for technological process innovation to be successful;[66]
- All technologies are created by human beings; they are in this sense 'socially shaped', and this is achieved within the framework of specific organizational forms.

This means that organizational changes are important process innovations. They are also vital for the development and use of technological innovations. Nevertheless, the study of organizational innovations is neglected compared to the study of technological innovations. We need much more systematic knowledge about the emergence and diffusion of organizational innovations and their socio-economic consequences. Therefore the marginal return of work along this path can be expected to be high.

However, organizational innovations are not included in the innovation concepts used by Nelson and Rosenberg (1993) and Carlsson and Stankiewicz (1995). In Lundvall (1992) innovations other than technological ones are mentioned, but they are not systematically analyzed (see section 2.3.1.). An exception is Chapter 5 in Lundvall (1992), which deals with work organization and the innovation design dilemma.

The emergence of new organizational forms, their diffusion, as well as the interaction between these forms and technological innovations can – in principle – be analyzed within a systems of innovation approach.[67] It may simply be achieved by including organizational innovation in the innovation concept – in the pragmatic spirits aired at the end of section 2.3.1.[68] However, organizational innovation takes place under different circumstances and is governed by different determinants as compared to technological innovation.

3.7. *Institutions are central*

One of the most striking characteristics the systems of innovation approaches have in common is their emphasis on the role of 'institutions'. In all the definitions

[66] This is, for example, shown in Nyholm (1995) and also discussed in Edquist and Jacobsson (1988).

[67] Since there are organizational forms in most areas of human activity, it is useful to talk about such forms in different 'spheres' or at various levels of aggregation. For example, the organizational form in an R&D department influences the design of product technologies – some of which are later transformed into process technologies. The organizational form where the process technology is used – i.e., in the process of production – influences the implementation of the technology. See Edquist (1992, 1996).

[68] This is, for example, done by Dosi: 'In an essential sense, innovation concerns the search for, and the discovery, experimentation, development, imitation, and adoption of new products, new production processes and new organizational set-ups' (Dosi, 1988: 222). The relations between the three innovation categories mentioned by Dosi is discussed in some detail in Edquist (1996) for manufacturing goods as well as for services.

presented in section 2.3. institutions influencing innovation are central elements, rather than being assumed away from the array of potential determinants of innovation:

- Freeman talks about 'the network of *institutions*' in his definition (Freeman, 1987: 1).
- For Lundvall, 'The *institutional* set-up . . . is the second important dimension of the system of innovation' (Lundvall, 1992: 10).
- Nelson and Rosenberg stress 'the *institutions* and mechanisms supporting technical innovation' (Nelson and Rosenberg, 1993: 1).
- Carlsson and Stankiewicz point to the 'particular *institutional* infrastructure . . . involved in the generation, diffusion, and utilization of technology' (Carlsson and Stankiewicz, 1995: 49).[69]

'Institutions' are of crucial importance for innovation processes, as has been convincingly shown in a large part of the innovation literature and as will be argued in several chapters of this book. It is therefore a great strength of the systems of innovation approach that 'institutions' are central in all versions of it. However, it is a weakness that the various contributors to the development of the approach do not mean the same thing when they use the term 'institution'. In order to show that this is the case, it is necessary to quote the various authors at some length.

Carlsson *et al.* divide the 'institutional infrastructure' which is related to each 'technological system' into four parts:

- industrial research and development;
- academic infrastructure;
- other institutions;
- state policy (Carlsson *et al.*, 1992: 14).

Later Carlsson and Stankiewicz write:

> Institutions are the normative structures which promote stable patterns of social interactions/transactions necessary for the performance of vital societal functions. . . . By the institutional infrastructure of a technological system we mean a set of institutional arrangements (both regimes and organizations) which, directly or indirectly, support, stimulate and regulate the process of innovation and diffusion of technology. The range of institutions involved is very wide. The political system, educational system (including universities), patent legislation, and institutions regulating labor relations are among many arrangements which can influence the generation, development, transfer and utilization of technologies. (Carlsson and Stankiewicz, 1995: 45)

Their concept of institutions seems to be quite heterogeneous and very complex. It includes 'normative structures', 'regimes', as well as 'organizations' of various kinds. At the end of their paper they verify this by including 'both rules or laws determining behavior and organizational structures' in the concept of institutional infrastructure (Carlsson and Stankiewicz, 1995: 51).

While Nelson and Rosenberg do not provide an explicit definition of the concept of institutions, it is clear from their discussion that they consider firms and industrial research laboratories to be the most important institutions involved in industrial

[69] The emphasis in these four quotes has been added.

innovation. They also include what they call 'supporting institutions' which incorporate research universities, government laboratories, as well as technology policies (Nelson and Rosenberg, 1993: 5, 9–13).[70]

Hence, institutions for Nelson and Rosenberg are basically different kinds of organizations, although they also seem to include 'technology policies'.

Lundvall states that: 'Institutions provide agents and collectives with guide-posts for action' and as such 'institutions may be routines, guiding everyday actions in production, distribution and consumption, but they may also be guide-posts for change. In this context, we may regard technological trajectories and paradigms, which focus the innovative activities of scientists, engineers, and technicians, as one special kind of institution' (Lundvall, 1992: 10).

'Institutions' in the sense of 'routines' and 'guide-posts for action' (including trajectories and paradigms) is obviously something very different from the meaning Nelson and Rosenberg give the term.

The conceptual ambiguity surrounding the term 'institution' should be sorted out before we go into deeper theoretical, empirical, and policy-oriented work on the specific ways in which 'institutions' influence innovation. It seems that the term 'institutions' is used in two main senses. One being 'things that pattern behavior' like norms, rules, and laws (e.g., Lundvall), and the other 'formal structures with an explicit purpose', i.e., what is normally called organizations (e.g., Nelson and Rosenberg).[71] The Nelson and Rosenberg perspective could gain from a stronger emphasis on 'things that pattern behavior' and Lundvall could perhaps give more weight to organizations in his theoretical elaboration. Carlsson and Stankiewicz take both into account in their conceptualization, but do not make a clear distinction between them.

It must be mentioned here that 'institutions' play quite different roles for innovations. Both R&D laboratories, patent systems and technical standards are often regarded to be 'institutions' intended to stimulate technical innovation. It is also important to keep in mind that institutions may also be (or become) obstacles to innovation. Institutions – once established – tend to live a life of their own and may become unsuitable to perform functions they previously performed or for which they were originally intended. Then institutional change – or institutional innovation – is called for; but there is often intense resistance to such change. Dismantling institutions and perhaps replacing them with alternative ones may be necessary. Less drastically, institutional 'shake-ups' may now and then be required.[72] All this calls for research on how institutional change is actually taking place.

3.8. *Conceptually diffuse*

The systems of innovation approach is associated with various kinds of ambiguities. Some conceptual problems have to do with the fact that different definitions of the

[70] Patel and Pavitt mean something similar with 'institutions': business firms, universities, other education and training institutions, and governments (Patel and Pavitt, 1994: 10, 12).

[71] This is argued by Björn Johnson and me in Chapter 2. The role of institutions is also very much at the center of Dominique Foray's analysis of knowledge openness in Chapter 3.

[72] To the extent that 'institutional change' is subject to influence by policy-makers and firm managers, this might be a matter of innovation policy or firm strategy.

systems of innovation concept are used by different authors (see section 2.3.). Other problems are related to the vagueness of some concepts upon which the approach is based. We have just concluded that the concept of institution, which is so central to the systems of innovation approaches, is used differently by various authors. Similar problems concern other conceptual elements in the approach.[73]

In addition none of the major authors provide a sharp guide to what exactly should be included in a '(national) system of innovation'; they do not define the limits of the systems in an operational way. As we saw in section 2.3.3., both Nelson and Lundvall explicitly state that the boundaries are unspecific. Carlsson offers no further clarification. My own proposal is subject to our ability to identify the determinants of innovation, and therefore, for the time being, is also unclear in practice if not in principle. There is simply no given demarcation between a system and its surrounding context.

The issue of delimiting systems of innovation in functional terms will be discussed further in this book (e.g., in Chapter 9 by Maureen McKelvey). However, it might be an impossible task to identify the boundaries in detail, as argued by Lundvall (1992: 13).[74] An important complement to these attempts at specification is then to try to identify the core elements in systems of innovation, and focus on the relations between these (see section 3.5.).

Conceptual ambiguity, or in more positive language, conceptual 'pluralism', is natural for a new approach under formation. At an early stage it is uncertain which concepts are essential to the conceptual core of the approach, what their exact content should be, and what the precise logical relations are between them. By comparison, the development of neoclassical economics required the efforts of a large number of extremely competent people over more than a hundred years.

At its current stage of development, the conceptual ambiguity of the systems of innovation approach is a strength in providing openness and flexibility that make room for competing perspectives and solutions. By comparison, in the early breakthrough period of a new technology area it is normal to find different solutions competing. It is important to allow such diversity so that we do not prematurely exclude solutions that may have large potential. At the same time, a hundred flowers cannot bloom forever. It is hard to optimize the timing of selection between alternatives; it may be fatal to exclude options too early and wasteful to do so too late. Doing it too early may result in closing what may potentially be the most fruitful trajectories and working instead along those that are inferior. Doing it too late may absorb excessive amounts of resources.

The process of selection between alternatives is always gradual, reducing pluralism by degrees. In the case of analytical approaches or conceptual frameworks it cannot be 'managed', but is spontaneous (if the invisible college in the field functions well). Obviously, we are currently at a stage where some scholars consider the diffuseness of the systems of innovation approach to be a weakness. The Systems of Innovation Research Network was established partly for this reason. In some cases

[73] Examples are 'organization', 'science and technology infrastructure', and 'technological regime'.

[74] As we saw in section 2.3.3. Lundvall argues that a definition must be kept open and flexible, the reason being that as the systems develop, the boundaries also move.

the time is now right for further development, clarification, and specification of some conceptual elements of the systems of innovation approach.[75] This is reflected in several contributions to this book. We are aware of the conceptual discrepancies of the approach and have opened a discussion with the objective of trying to increase the commonality of the conceptual framework. We hope to clarify some conceptual ambiguities, but are certainly aware that conceptual 'pluralism' remains in many respects.

3.9. *Conceptual frameworks rather than formal theories*

One may mean many different things with the term 'theory'. There are 'hard core' theories which are proven and not disputed, then there are formal models, conceptual frameworks useful for the generation of hypotheses, and empirical generalizations, etc.

Nelson and Winter (1982) make a distinction between appreciative theorizing and formal theorizing (in economics). Appreciative theorizing tends to be close to empirical substance and empirical work. It provides both interpretation and guidance for further exploration. It is normally expressed verbally, and certain variables and relationships are treated as important while others are ignored. It is an abstract body of reasoning. There is generally explicit causal argument (Nelson, 1995a: 5).

Formal theorizing, on the other hand, almost always proceeds at some intellectual distance from what is known empirically; it is an abstract structure expressed in highly stylized form and set up to enable one to explore, find, and check proposed logical connections. Good formal theorizing is less likely than appreciative theorizing to contain logical gaps and errors. An important role of formal theorizing is to discipline and sharpen appreciative theory, thus assisting in its development (Nelson, 1995a: 5).

In these terms, the systems of innovation approach is certainly not a formal theory. It does not provide convincing propositions as regards established and stable relations between variables. The most it does in this direction is to provide a basis for the formulation of conjectures, e.g., that various factors, like institutions or learning, are important for technological innovations. However, it has yet to confront these hypotheses with empirical matter. The systems of innovation approach – like many other institutionally oriented approaches – is characterized by a rather uninhibited formulation of conjectures. And we know too little about whether the hypotheses are true or false or about causal relations between variables. Combined with the fact that it is also conceptually diffuse, I would argue that, at the present state of the art, the systems of innovation approach is not an example of appreciative theorizing.

I prefer to label the systems of innovation approach a conceptual framework – or 'approach' as I have consistently called it in this introduction – which many scholars and policy-makers consider to be useful for the analysis of innovation. It is a kind of 'wide trawl' intended to capture processes of innovation, their determinants, and some of their consequences (e.g., productivity growth and employment) in a useful way.[76] As a framework it is fairly advanced and has a great potential, as indicated by the characterization done in section 3 of this introduction.[77]

Although the systems of innovation approach is not called a theory here, it has, as we saw in section 2.2., important roots in various theories of innovation. It is also an important task to continue investigating the relations between various innovation theories and the systems of innovation approach, and this will be done in Part II of this book. In combination with conceptual work this can be expected to contribute to raising the theoretical status of the approach and to making it more formal, rigorous, and coherent.[78]

4. Issues addressed in this book

Most of the characteristics of the systems of innovation approach outlined in section 3 must be considered to be important advantages in work intended to understand the determinants of innovation processes and their consequences for variables such as growth and employment. Given the complex and comprehensive character of innovation processes, it is important that the systems of innovation approach places innovations and learning at the very center of focus, makes a historical perspective possible, ensures that comparisons between systems are natural, emphasizes interdependence, includes product technologies and organizational innovations, accounts for institutions, etc.

Hence most characteristics of the systems of innovation approach constitute a promising point of departure for studies intended to increase our understanding of innovations. Therefore the systems of innovation approach can be expected to continue to gain ground, and it is likely to develop into an even more important school or tradition in the future.

The broad characterization presented in section 3 also serves to identify a number of problems associated with the approach, such as a certain conceptual diffuseness and an immature theoretical status. These problems were considered to be challenges in the work within the Systems of Innovation Research Network and are therefore dealt with in various chapters below. In this book we will concentrate upon three kinds of issues:

- sorting out some conceptual problems associated with the systems of innovation approach;
- relating the systems of innovation approach to innovation theories, particularly of an evolutionary kind;
- increasing our understanding of the dynamics of systems of innovation.

These issues are addressed in Parts I to III respectively.

[75] In the beginning of section 4.1., four general reasons for conceptual clarity are discussed.

[76] It is useful partly because some of the questions that are natural in a systems of innovation approach could not be asked within the framework of other theories and approaches.

[77] As mentioned at the end of section 2.3.3., specific versions of the systems of innovation approach, however, point out some factors (determinants) as more important than others.

[78] However, this might be achieved at the cost of reductionism and decreased relevance since there seems often to be a trade-off between relevance and degree of formality.

4.1. Part I: overview and basic concepts

Part I seeks to clarify the concept of systems of innovation for four general reasons. First, conceptual clarity is a precondition for identifying research questions and for formulating conjectures and theories, i.e., for making propositions about the relations between variables. Second, it is necessary for communication. We do not understand each other if we cannot make clear what we mean when using key concepts. Third, it is required for carrying out theoretically based empirical studies (i.e., for operationalization). Clearly defined concepts are necessary in order to make it possible to identify empirical correspondents to theoretical constructs and to identify the data that should be collected. Therefore, conceptual specification to make possible empirical studies is of particular importance.[79] Fourth, ambiguity of key concepts reduces the credibility of the researcher and the approach.

We saw earlier that the systems of innovation approach suffers from conceptual ambiguity.[80] Although such diffuseness is natural for a new approach, further conceptual work that takes a step back and tries to sort out the arguments is important. It can contribute to the development of a more solid conceptual basis for empirical work, causal explanation, and policy-oriented research.[81] Although some conceptual and theoretical tension and competition might have a stimulating role, unnecessary conceptual heterogeneity is confusing. Therefore Part I of this book makes an attempt to address some of the conceptual problems. However, we will not be able to straighten out all of them.

The conceptual ambiguity did not emerge with the systems of innovation approach. It is associated with innovation studies and the economics of technical change in general. Hence, the efforts in Part I of this book to address conceptual issues might benefit innovation studies in a wider sense. In Björn Johnson's introduction to the chapters included in Part I further insight into the dilemmas of building conceptual coherence is provided.

4.2. Part II: evolutionary perspectives

In section 3.9. I argued that it is preferable to label the systems of innovation approach a conceptual framework for the study of innovation processes rather than a formal theory. We have also seen (section 2.2.) that the approach reflects previous theoretical understandings in the theory of innovation; it has been influenced by innovation theories such as interactive learning theories and evolutionary theories. It is important to continue investigating the relations between the systems of innovation approach and innovation theories and thereby elevate the theoretical status of the approach and increase its degree of formalization.

[79] A precise scientific language is a precondition for empirical work; analytical distinctions and conceptual specificity are essential. For example, the relation between two phenomena cannot be satisfactorily investigated if they are not conceptually distinguished from each other.

[80] This concerns, for example, the core concept of 'institution' and the definition of the functional limits of innovation systems. See sections 3.7. and 3.8.

[81] However, there are also strong reasons to integrate conceptual and theoretical work with empirical studies; it leads to cross-fertilization. This is not done in this book to any large extent, although such integration is the ultimate objective.

Strengthening the components that make up a conceptual framework or a theory can be done in several ways. An obvious method is to formulate specific hypotheses within the framework and confront them with empirical data; this may increase the body of established knowledge. Another is theoretical reflection in an intuitive and heuristic manner – as attempted in this book. Explicit theoretical development is important.

We do have considerable knowledge of various aspects of innovation processes; there are many theories and bodies of established empirical knowledge focused on parts or elements of systems of innovations and the relations between variables within them. Most of this knowledge existed before the emergence of the systems of innovation approach, and the emergence of the approach is actually partly a result of the development of this knowledge.

An efficient way of elevating the theoretical status of the systems of innovation approach is to relate it to other existing bodies of – theoretical as well as empirical – knowledge and research, and to do this explicitly and systematically. In particular, the specific relations between the systems of innovation approach and more formal theories of innovation should be investigated further. This is a major task, but one that could be expected to provide more coherence and rigour to the systems of innovation approach. This was a primary motivation for establishing the Network.

We saw in section 2.2. that the Lundvall *et al.* version of the systems of innovation approach is explicitly based on learning theories of innovation. The relation between the two could probably be developed, and the learning theory itself could also be specified. This will not, however, be attempted in this book. In Part II of the book we will, instead, concentrate on evolutionary theories of innovation. This means that all the chapters deal with various aspects of the creation of diversity and/or selection mechanisms of various kinds. The more specific content of Part II is discussed by Esben S. Andersen in his introduction.

4.3. Part III: systems transformation

Systems of innovation are by no means static. I have earlier discussed whether it is reasonable to talk about national systems, given the apparent rapid processes of internationalization. These processes have an economic as well as a political dimension. The economic dimension has been around for centuries, but has grown during the last few decades through direct foreign investment, increasing trade, global sourcing and marketing, etc. At the political level we have seen the establishment of free trade areas and the consolidation of the European Union. It can be argued that these processes have increased the importance of systems of innovation at the supranational and regional levels at the expense of those at the national level.

I have earlier pointed out that processes of innovation have evolutionary characteristics, i.e., they are path dependent, develop over time, and it is highly uncertain what the end result is going to be. The idea of optimality is absent. Systems of innovation are also subject to similar processes of change. Although the systems are often relatively stable, they also change – and in exceptional cases these changes may be rapid.

Processes like these are captured in Part III which deal with 'systems dynamics'. The chapters deal with issues like changes in the way R&D is carried out (such as the increased science-base of innovation and increased degree of interdisciplinarity) and problems associated with technological discontinuities. Such changes have implications for the ways that systems of innovation develop and for the actors, such as firms, operating within these systems.

The dynamism of the real world is characterized by transitions from relatively stable systems to more temporary and unstable 'hybrid' forms. The transformation from a socialist to a post-socialist system in the USSR/Russia is fairly unstable at present. The building of a supranational system of innovation through the European Union is more stable and has more of a sense of direction in its development. Such transitions can either be modeled or analyzed empirically. In both cases the roles of organizational and institutional change seem to be crucial. In the analyses of these changing configurations of systems of innovation in Part III, the interaction among various systems and levels are also explored. The more specific content of these chapters are addressed in Staffan Jacobsson's introduction to Part III.

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