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A Survey of their Evolution in Growth Theory and Economic Geography

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VARIETIES OF SYSTEMS OF INNOVATION:
A SURVEY OF THEIR EVOLUTION IN GROWTH THEORY AND ECONOMIC GEOGRAPHY

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ABSTRACT

The systems of innovation (SI) approach has been established and extended during the last two decades. Although elementary goals and progress have been reached through seminal contributions by Freeman (1987), Lundvall (1992) or Nelson (1993), in designing a generic approach, displaying the dynamics of collaboration, networking and interactive learning, criticism has been raised that systems of innovation are still "undertheorized". The objective of this paper is to describe briefly the historical evolution of the SI concept within the academic literature and the policy sphere. This review primarily attempts to highlight some of the most important contributions that strongly assisted to the framework, by providing more consistency and a more theory-oriented perspective. Consequently, the system concept itself seems to be a kind of "boundary object". Within both, the academic and the policy field, different levels of conceptualization have been challenged and advanced in the course of time. These conceptualizations basically differ in their scale of analysis, taking geographical perspectives, technologies or sectoral classifications as foci for theorizing and empirical research. Despite these substantial levels of research, the SI framework is increasingly challenged, analyzed and extended in the context of globalization. As a result, regarding the openness and flexibility of the SI approach, this paper particularly tries to focus on the difficulties of contemporary research in defining functional and spatial boundaries in theory and empirical research. Agglomeration tendencies, knowledge externalities and localized learning are primarily based upon the concepts of knowledge diffusion, tacit knowledge and proximity. In spite of that, ICT and global business linkages foster inter-regional and trans-border knowledge flows. Thus, knowledge diffusion is also related to international and global "pipelines" that could support, strengthen and reinforce localized learning.

JEL Classification: O1, O3, R0, R1, D8, B5
KEY WORDS: National, Sectoral, Technological and Regional Systems of Innovation, Geography of Innovation, Knowledge Externalities, Localized Knowledge Spillovers, Knowledge Diffusion, Tacit Knowledge

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1 INTRODUCTION

Regional agglomerations of economic activity are assigned to be today's major sources and driving forces of economic growth at every stage of development, as implied by worldwide expansion and spread of clusters and geographical density.[1] Simultaneously, as pointed out in many publications on innovation and particularly with special regard to the contributions to the systems of innovation approach, the true nature of innovative activities and innovative processes is not rooted in firms and entrepreneurial activities that are characterized by isolation.[2] Far from linear approaches, organizations, such as entrepreneurial firms and public and private research institutes innovate through collaborative and interdependent activities.[3] In a nutshell, innovation is more likely a process that evolves uniquely over time and space, influenced by firms and non-firm entities at different hierarchical levels that either support or block innovative results.[4] This complex view of the very nature of innovation emerged and succeeded under the term "systems of innovation" (SI) – in order to explain the "black-box" of innovation and challenging linear model type thinking.[5]

The different approaches and conceptualizations that evolved in the literature during the last two decades differ in some special features. Anyway, they assume several general ideas and represent complementary systems on different levels of disaggregation.[6] These concepts also promote empirical analysis and theory on the structure of creation, commercialization and diffusion of information and (new) knowledge. Furthermore, the system concepts also contain and study small and medium enterprises (SMEs), large scale firms and multinational enterprises (MNEs) that collaborate, network and compete in complex but different and unique ways.[7] The complexity of these systems is moreover tightened by formal and informal institutions.[8] In this context, systemic innovation is enormously determined in the course of time. This view corresponds to evolutionary theory as well as to the heritage of Schumpeter.[9] The overall success of SI within the economic theory and empirical research, and its increasing usage as a concept for S&T policy is highly visible.[10]

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[1] Scott and Storper, 2003: 581
[2] Fagerberg, 2005: 7; Edquist, 2005: 182
[3] Edquist, 1997: 14, 20-22; Gregersen and Johnson, 1997: 482; See for further details Edquist, 2005: 188, Lundvall, 2007: 100, Iammarino, 2005: 498, Fagerberg, 2005: 12, OECD, 1997: 7, or Greunz, 2005: 449.
[4] Edquist, 2005: 188; OECD, 1997: 7-13
[5] Sharif, 2006: 762; Fagerberg, 2005: 7-12; Andersen et al., 2002: 186
[6] These different scales are discussed e.g. by Edquist, 2005: 198, Freeman, 2002: 192, Steg, 2005: 8, OECD, 1997: 8, Evangelista et al., 2002: 173, and Gregersen and Johnson, 1997: 482.
[7] Feldman, 1996: 72; Audretsch and Vivarelli, 1996: 250; Cooke and Memedovic, 2003: 11; Audretsch and Fritsch, 2002: 114
[8] Nelson, 1993: 507; Edquist, 1997: 18-19; Dosi, 1988: 128; Moulaert and Sekia, 2002: 291; Edquist, 2005: 182
[9] Holbrook and Salazar, 2003: 2; Lundvall, 2007: 106; Further statements on Schumpeter can be found, for instance, in Edquist, 2005: 185, Cooke, 2001: 949, Cooke and Memedovic, 2003: 6, and Sharif, 2006: 753-754.
[10] To get an overview on SI and its success in academic literature and S&T policy see Sharif, 2006: 750, Evangelista, et al., 2002: 173-174, Lundvall, 2007: 100, or Carlsson, 2006: 57.

However, there seems to be some dissent within the academic community. Whereas the general idea of SI is mainly nation-state oriented, in order to challenge the Solow residual and the "black-box"[11], some SI conceptualizations are contrariwise fostering economic geography, agglomeration theory, sectoral perspectives and industrial specialization.[12]

Furthermore, some groups stress the necessity of combining the different SI frameworks to get a better understanding of regional performance and spatial agglomeration within global production chains, innovation networks and knowledge economies.[13] Besides the combined academic efforts in order to build, analyze and promote operational and theoretical relationships between the micro-, meso- and macro-level, the SI concepts and frameworks are accused to become increasingly complex and fuzzy. However, economic complexity has not to obey obsessed system goals or a prescribed order. Contrary, system thinking centers pre-selected and relevant parts and entities. These parts then represent the system. The systems theirselves inevitably have their own boundaries which make them distinguishable from other systems. This partial view implies that system thinkers disaggregate economic phenomena in parts (systems, sub-systems, components, entities, interactions). Besides that, system thinking is used for economic analyses and for predictions of future developments.

The emergence of different system conceptualizations (*Figure 1, Appendix*) is predominantly based upon different concepts and taxonomies that differentiate for instance between tacit and codified knowledge[14]. Moreover, federal and local governance structures, agglomerative tendencies, and Jacobian and MAR externalities[15] are conceptualized as some of the most essential influencers of innovative performance.[16] Thus, geographical proximity could represent one of the major determinants for geography of innovation, knowledge diffusion and spatially concentrated economic activities. In addition to these considerations, the openness and flexibility of the assumed theoretical system to external (codified) knowledge flows seems to be of increasing interest in academic research.[17] However, this perspective needs a renunciation from optimizing systems to adaptive systems.[18] Additionally, territorial innovation models and spatial concentrated economic phenomena like districts, innovative milieus, clusters and regional systems of innovation and their access to certain networks and sources of information and knowledge – either on a local, regional,

[11] Sharif, 2006: 753
[12] Iammarino, 2005: 497; Moulaert and Sekia, 2003: 293; Gregersen and Johnson, 1997: 482
[13] Cooke and Memedovic, 2003: 4-10; Evangelista et al., 2002: 173-174; Lundvall, 2007: 100
[14] The difference and importance of tacit and explicit knowledge will be discussed in chapter 6.
[15] There are increasingly contributions to different types of knowledge externalities and local knowledge spillovers (LKS). This issue is discussed in chapter 6.
[16] Feldman, 1996: 71; Holbrook and Salazar, 2003: 2; Cooke and Memedovic, 2003: 1; Scott and Storper, 2003: 581; Greunz, 2005: 468; Simmie, 2002: 611; Andersen et al., 2002: 185
[17] Lundvall, 2007: 103; Carlsson, 2006: 62
[18] In contrast to optimizing system modelling, adaptive system perspectives are evolutionary in the sense that they do not cope with optimization issues. Contrarily, policy interests are primarily based upon optimization of predefined goals.

national or even international level – attract special interest of several sub-groups within economic literature.[19]

Despite seminal contributions within the literature to SI during the last two decades in designing a generic approach, displaying the dynamics of interaction, networking, institutional matters and interactive learning, it is still criticized that systems of innovation are fuzzy, diffuse and 'undertheorized'.[20] This conclusion seems to be predominantly justifiable for optimality perspectives. In contrast, other sub-groups advance the view that systems of innovation rather serve as a "focusing device" and that they might serve as equivalents to formally defined economic theories.[21]

The objective of this paper is to survey the historical evolution of the SI approach in economic theory and to present its diffusion, modifications, advancements and some theoretical and empirical problems in the course of time. Although the paper tempts to give a literature review, its scope cannot saturate detailed and deep going discussions of all potential problems within the existing systems of innovation literature. Consequently, the paper will not provide a formal model or simulation studies. Anyhow, the paper tries to highlight several conceptual and analytical peculiarities and problems within SI literature. Finally, the reader will notice that the systems of innovation approach goes beyond industry policy. This idea is especially supported by the circumstance that some narrow conceptualizations center pure market systems.[22] In conclusion, the paper discloses that systems of innovation represent particular ways of approaching the geography of innovative activity.

Besides geographical perspectives, the SI concept is also used for technological and sectoral analyses and theorizing (*Figure 1 and Table 2, Appendix*).[23] For this purpose, *chapter 2* serves as a general literature review, analyzing the inspirational roots and some dissents and conflicts within the academic community. Later on, *chapter 3* surveys seminal contributions to the national systems of innovation approach (NSI) with special consideration of some conceptual and logical problems that are approached in the course of time. Subsequently, *chapter 4* shortly provides a summary of modifications and peculiarities of the sectoral and technological conceptualizations. *Chapter 5* then discusses some contributions to the spatial

[19] Interesting literature reviews can be found, for instance, in the following publications: Iammarino, 2005: 498; Asheim and Gertler, 2005: 294; Cooke, 2001: 949; Saxenian, 1996: 71; Andersen et al., 2002: 185; Evangelista et al., 2002: 174; Powel and Grodal, 2005: 74; Cooke and Memedovic, 2003: 10; OECD, 1997: 8; Moulaert and Sekia, 2003: 291; Greunz, 2005: 450; Carlsson, 2006: 58-61.

[20] Edquist, 2005: 181; Holbrook and Salazar, 2003: 2; Sharif, 2006: 758

[21] Lundvall et al., 2002: 216; Lundvall, 2007: 99; Cooke and Memedovic, 2003: 5-8; Sharif, 2006: 758
On this account, Lundvall recently defended the utility of the SI approach in describing its sense: *"In this sense it does what theory is expected to do: it helps to organize and focus the analysis, it helps to foresee what is going to happen, it helps to explain what has happened and it helps to give basis for rational action."* (Lundvall, 2007: 99). Ultimately, Lundvall et al. (2002) point out that "*...we need to find ways to capture the formation and evolution of innovation systems from their birth to their death."* (Lundvall et al., 2002: 216)

[22] These concepts exclude policy activities and exclusively focus on firms and pecuniary transactions.

[23] For a detailed overview on geographical perspectives in SI see Freeman (1987), Lundvall (1992), Nelson (1993), Cooke et al. (1997), Cooke (2001), or Braczyk et al. (1998). The SI concept is also used for technological and sectoral analyses and theorizing. These concepts are, for instance, presented by Carlsson (1995), Breschi and Malerba (1997), or Malerba (2005).

and regional case. In matters of the openness and flexibility of the SI approach, *chapter 6* particularly emphasizes the issues and difficulties of defining boundaries. For this purpose, the paper approaches the concepts of proximity, tacitness and codification of knowledge and information in the age of footloose economic activities. Moreover, global knowledge pipelines and different types of knowledge externalities[24] and localized knowledge spillovers are adjudged to reinforce agglomerative tendencies. Finally, *chapter 7* provides a brief summary and some conclusions.

2 SYSTEMS OF INNOVATION: INTELLECTUAL ROOTS AND CHALLENGES

2.1 SCHUMPETER'S HERITAGE AND THE NEO-SCHUMPETERIAN COMMUNITY

On exploring the inspirational roots of SI, today's economists center the great legacy of Josef Alois Schumpeter.[25] As pointed out in most contemporary articles on innovation, Schumpeter contributed with major works to the field of innovation research and theory.[26]

According to the majority of innovation theorists, innovation from Schumpeter's perspective implies a new product with potential profits to entrepreneurs, a process, or a new Schumpeterian combination.[27] These new combinations build upon existing pieces of knowledge.[28] Besides the *Theory of Economic Development* (1934), Schumpeter also published substantial ideas on the process of innovation in *Capitalism, Socialism and Democracy* (1942). In addition to his former assumptions on entrepreneurs, creative destruction and monopolistic competition between small and medium enterprises (SMEs), the so-called "Wild Spirits", Schumpeter also placed emphasis on in-house corporate research and development activities and innovative efforts of large firms and multinational enterprises (MNEs).[29] Consequently, based upon Schumpeter's heritage, contemporary authors now distinguish between the "Mark I" model of innovation and the "Mark II" case.[30] Both arguments might be rather complements today, differing in geographical perspectives and in the course of time.[31]

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[24] Furthermore, these technological externalities are differentiated into Marshall-Arrow-Romer- (MAR-) externalities and Jacobian externalities. Their difference will be discussed in a subsequent chapter.

[25] Obviously, the entire scope of Schumpeterian theory cannot be presented in this paper. Consequently, the paper only discusses these stylized facts that are also cited by the majority of scholars within economic literature.

[26] For an overview see Fagerberg, 2005: 5; Similar statements can be found, e.g., in Cooke et al., 1997: 476, Greunz, 2005: 467, Carlsson, 2006: 753, or Lundvall et al., 2002: 216, 221.

[27] Cantwell, 2001: 2; Fagerberg, 2005: 5; Lundvall, 2007: 101; Lundvall et al., 2002: 216; Greunz, 2005: 467; Freeman, 2002: 194; Edquist, 2005: 185

[28] Fagerberg, 2002: 6

[29] Fagerberg, 2002: 13; Schumpeter, 1942, ch. XII: 131-134

[30] Audretsch and Vivarelli, 1996: 251; Audretsch and Fritsch, 2002: 114

[31] Audretsch and Fritsch, 2002: 114; The Mark II case is primarily defined by innovation as a more experienced process within large firms that exercise market power. According to Cantwell (2001), the Mark I model is associated with Schumpeter's work of the year 1934, which was originally published in 1912. In contrast, the Mark II model refers to his later work (Cantwell, 2001: 3; Malerba, 2005: 382). Schumpeter's belief in the power of an entrepreneurial spirit is related to the German term "Unternehmergeist*"*. He was convinced that small aggressive entrepreneurs are major influencers of spatial

The uniqueness of the combination of major organizations and actors within the system, particularly in the sense of Schumpeterian strategies, represents additional interest. Besides pioneers who represent the early inventors and entrepreneurial spirits of an economy, there are also the early adopters and imitators.[32] It is evident that the fraction and degree of these three groups and their behavior widely differ in cross-country analyses and explicitly in cross-sector, cross-region and cross-industry comparisons.[33] A further important legacy of Schumpeter's work is the idea that innovations tend to concentrate on certain sectors and their surroundings. Furthermore, there can be a "swarming" that influences growth temporarily.[34] Following Fagerberg (2002), Schumpeter's idea of a clustering of innovations in time and space may have a very large impact and is similar to technological systems, what Freeman himself calls "technological revolutions".[35]

Moreover, the Schumpeterian heritage plays an essential part in *An Evolutionary Theory of Economic Change*, published by Richard Nelson and Sidney Winter (1982). Their seminal work on industrial dynamics, knowledge-based firms, organizational memory, entrepreneurial and routinized technological regimes in historical time and "appreciative theorizing" inspired contemporary innovation scholars severely.[36] Thus, evolutionary theory can be regarded as the second intellectual source of neo-Schumpeterian economics.[37]

Neo-Schumpeterian studies of innovation and learning at the micro level, their assumptions of industry dynamics at the meso-level and the comparisons of competitiveness and growth at the macro-level are increasingly used and advanced.[38] According to neo Schumpeterian thinking, knowledge, learning, technology, innovation and interaction are the major features and influencers of competitiveness and growth performance in globalizing and knowledge-based economies. Additionally, neo-Schumpeterian economics focuses on the question of overcoming limiting conditions. Besides the assumption of agents with bounded-rationality,

innovativeness and economic success. Related to the Mark II framework, developed later in the United States, Schumpeter linked innovation results and economic success to big companies (Malerba, 2005: 382; Fagerberg, 2002: 13; Fagerberg, 2005: 6-11; Hanusch and Pyka, 2007: 277).

[32] Lundvall et al., 2002: 223

[33] Lundvall, 2002: 223; Lundvall, 2007: 100; Furthermore, there is an extension of Schumpeter's original classification into five possible strategies. Lundvall additionally discusses "complementors" and "mixed strategies" (Lundvall et al., 2002: 223).

[34] Schumpeter, 1939: 100; Fagerberg, 2002: 7; Fagerberg, 2005: 14-15

[35] Fagerberg, 2002: 10; Complementary to this perspective, a lot of contributions focus on general purpose technologies (GPTs) as "prime movers" with generic purpose and pervasiveness (Jovanovic and Rousseau, 2005: 3; Bresnahan and Trajtenberg, 1992: 2). Indeed, scholars must call to mind that authors who survey systems of innovation often complementary discuss technological systems and GPT theory (Fagerberg, 2002: 7).

[36] Fagerberg, 2005: 17; See especially Nelson and Winter, 1982: 258-9, Winter, 1984: 297, Nelson and Nelson, 2002: 266, and Winter, 2005: 27-38 for more details on evolutionary theory. Additionally, Audretsch and Fritsch, 2002: 114, DeBruijn and Lagendijk, 2005: 1154, Sharif, 2005: 3, and Lipsey, Carlaw and Bekar, 2005: 31 give interesting reviews and overviews.

[37] See Hanusch and Pyka, 2007: 277; Evolutionary Economics thus represents an alternative approach to endogenous growth, one compatible with a more dynamic interpretation of Schumpeter's legacy.

[38] Lundvall et al., 2002: 217; Hanusch and Pyka, 2007: 276

representative consumers and firms are mostly neglected.[39] Furthermore, innovation is regarded to be a collective process.[40]

Following Lundvall et al. (2002), Schumpeter contributed to a detailed (dynamic) understanding of innovation as a process, and eminently, Schumpeter's works on innovation as a new combination created a fundamental background and major groundwork for today's research.[41]

2.2 FROM LIST TO SYSTEMS OF INNOVATION

Some authors stress several similarities of SI with earlier works of Friedrich List (1841). In *The National System of Innovation in Historical Perspective* (1995), and in *Technological Infrastructure and International Competitiveness* (1982), Freeman himself mentions the past contributions of Friedrich List (1841) in *The National System of Political Economy*. Following economists within the academic group, List contributed a great deal to a better understanding of innovation and innovation policy.[42] Regrettably, List's work is mostly adjudicated to colonial and protectionist theory, especially to the disagreeable infant industry argument.[43] Despite protectionist ideas, List contributed in certain areas to systemic innovation thinking by anticipating and discussing some contemporary ideas and issues.[44] Following Freeman (1995), List rather focused on the development of productive forces instead of putting allocation issues of scarce inputs and resources into the center of discussion.[45] List's concept of national systems of production is considered to center a wider set of supporting national institutions, which includes education, training, infrastructures and networks of transportation of commodities and people.[46] List emphasized the accumulation of "mental capital" and the influence of national institutions and supportive infrastructure to be superior to the cosmopolitan idea of Adam Smith.[47] In addition, List's nation state-oriented approach was entirely concentrated on perspectives and strategies to enable a "catching-up" process of the German economy with the UK in the mid 19th century.[48] Despite the

[39] The rejection of representative actors is widely accepted in Evolutionary Economics. In addition, this feature represents one of the core assumptions in Evolutionary Economics. Unfortunately, this assumption complicates formal modelling.
[40] Audretsch and Vivarelli, 1996: 2; Hanusch and Pyka, 2007: 276-278; obviously, the paper cannot survey the entire highlights and particularities of evolutionary theory and neo Schumpeterian economics.
[41] Lundvall et al., 2002: 216, 221; Related to Schumpeterian innovation theory, the SI approach, according to the Aalborg-Group, can be divided into four major elements: The neo Schumpeterian (re)interpretation of national production systems, microeconomic research on innovation as an interactive process, institutions and their role in supporting innovative activities and finally, many empirical studies on national innovation performance, international trade and trade specialization (Lundvall et al., 2002: 217). However, Evolutionary Economics is today also extended to deal with economic geography issues (Boschma and Frenken, 2007: 635-649).
[42] Freeman, 1995: 6; Identical and similar opinions are emphasized by Freeman, 2002: 192; Lundvall et al, 2002: 214; Lundvall, 2007: 96, 113; Cooke, 2001: 949; Carlsson, 2006: 753; Sharif, 2006: 751.
[43] Freeman, 1995: 5; Iammarino, 2005: 498
[44] Freeman, 1995: 5-6; Steg, 2005: 1
[45] Freeman, 1995: 6; Lundvall et al., 2002: 214; Lundvall, 2007: 113
[46] Lundvall, 2007: 113; Freeman, 2002: 192
[47] Freeman, 2002: 193; Lundvall et al., 2002: 215
[48] Lundvall, 2007: 113; Freeman, 2002: 193; Sharif, 2006: 751

protectionist hidden meanings in List's work, Lundvall (2002) affirms some similarities between the home-market-argument within the Aalborg-concept and the well-known infant industry argument supported by List.[49]

2.3 CHALLENGING THE LINEAR MODEL AND THE BLACK-BOX

First of all, members of the academic community emphasize several problems within neo-classical theory, especially the issues related to the idea of trajectories, uncertainty of innovation, and the Solow residual.[50] Far from neo-classical modeling, economists highlight inter- and intra-firm relationships and interactions, innovative activities of research institutes, the influence of private and public universities, and institutions. All these factors are ascribed to affect the geographical dispersion of innovative performance.[51] Opening the "black-box" consequently means to describe innovation as a complex phenomenon, as opposed to the neo-classical conception.

Furthermore, debates on knowledge as an essential driver and its stocks and flows gained ground in the 20th and 21st centuries' history of economic thought.[52] Nevertheless, the linear model of innovation almost entirely dominated economic theory and research during the 20th century.[53] Events such as the Manhattan Project (H-bomb), the Moon Race and Star Wars were considered to be the achievement of Big Science. The beliefs in big outcomes of enormous R&D programs induced a tremendous increase in research laboratories and public expenditures in R&D. Storied inventions like radar, computers, rockets and the ARPANET (1969) were originated in mammoth defense projects, such as the Cold War. Accordingly, many inventions derived from large public R&D-projects.[54] Moreover, linear model type thinking assumes a general chain of causation and identical stages of innovation without considering varieties, feedbacks and loops. The different types, directions and levels of interaction, and additionally the linkages and the various kinds of knowledge were mostly neglected. However, the linear approach, and even the OECD reports (1963) suffered from more and more criticism.[55]

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[49] Lundvall et al., 2002: 215
[50] Sharif, 2006: 753; Fagerberg, 2005: 4-14; Greunz, 2005: 450
[51] Freeman, 2002: 194; Lundvall et al., 2002: 217; Hae Seo, 2006: 1-2
[52] Fagerberg, 2006: 20
[53] To make no mistake about that, economic literature was basically influenced by the modifications of the neo-classical growth theory which contain knowledge and skills.
[54] Freeman, 1995: 9
[55] Freeman, 1995: 6, 8-10; Sharif, 2006: 754; See also Lundvall et al., 2002: 218, Fagerberg, 2005: 8-9, Cooke and Memedovic, 2003: 4, Freeman, 1995: 11, Kline and Rosenberg, 1986: 283, Fagerberg, 2006: 6-7, OECD, 1997: 9-12, Edquist, 2005: 183-187, Cooke et al., 1997: 476, Cooke, 2001: 949, Borrás and Lundvall, 2005: 603, Lundvall, 2007: 108, or Fagerberg, 2006: 7-8. An important critique, that innovation is neither linear, nor smooth, nor well behaved was stressed by Kline and Rosenberg (1986) in their work on the "chain-linked model" (Kline and Rosenberg, 1986: 285; Sharif, 2006: 757; Senker, 1995: 431-432; Hanusch and Pyka, 2007: 277). Several scientific papers summarize in an excellent manner the shifts and changes within the OECD reports (Borrás and Lundvall, 2005: 603-604; Sharif, 2006: 749-752).

As a consequence, it became obvious that even qualitative factors and interactions play essential roles in affecting geographical economic success.[56] Indeed, it is still necessary to call in mind that differences in R&D intensities in cross-country comparisons are often based on differences in private R&D investments.[57]

Furthermore, many contributions to systemic innovation are complementary related to the theory on general purpose technologies (GPTs) and the "long waves". The emergence and diffusion of generic innovations in economic theory contributed to non-linear approaches, to evolutionary ideas, and to systemic and complexity thinking.[58] According to history-friendly GPT authors, almost every innovation in human history should be regarded as the outcome and achievement of long-lasting and space-crossing activities and interactions between actors in complex systems and finally as the result of knowledge diffusion.[59]

Besides the famous academic tribe of evolutionary economists, adherents of the New Growth Theory (NGT), as for instance Paul Romer (1990), Grossman and Helpman (1991) or Aghion and Howitt (1992) have extended and enriched the literature by integrating knowledge, intellectual property rights, learning-by-doing and knowledge externalities.[60] It is the public good idea of knowledge creation and diffusion that assumes enhancements of the public knowledge pool by entrepreneurial activities.[61] The endogenous growth theory and its concern and efforts to explain the phenomena of continuing economic growth endogenously represents a well established approach in academic theory and research.[62] However, these efforts are mostly accused of not really overcoming the linear perspective, such as R&D-inputs, human capital, aggregation, and homogeneity assumptions.[63]

Additionally, scientific research and economic theory on tacit and codified knowledge increasingly diffused innovation literature.[64] Since researchers focus on empirical and theoretical analyses of systemic processes of innovation, concepts such as those of localized learning and knowledge spillovers induced a tremendous expansion and variety of research questions on innovation.[65]

[56] Freeman, 2002: 194; Lundvall et al., 2002: 217; Jacqueline Senker (1995) also gave a nice summary of the evolution from the "Technology push model" to the "Fifth generation innovation model", based on the classification of Rothwell (1992) (Senker, 1995: 434).
[57] Fagerberg, 2006: 10
[58] Freeman, 1995: 11; Edquist, 2005: 187; During the 1990s, contributions to ICT increased tremendously and, already years before, academic research on the steam engine, railroads and electricity diffused literature (Freeman, 1995: 11; Lipsey, Carlaw and Bekar, 2005: 94).
[59] Lipsey, Carlaw and Bekar, 2005: 85; OECD, 1997: 11
[60] For a detailed review of NGT see Seiter, 1997: 67-154.
[61] Lundvall et al., 2002: 216; Fagerberg, 2003: 22; Fagerberg, 2006: 5
[62] Freeman, 1995: 6; Fagerberg, 2003: 22; Fagerberg, 2006: 6; Greunz, 2005: 449
[63] Lundvall et al., 2002: 216
[64] Gertler, 2003: 77; Leamer and Storper, 2001: 648
[65] Fagerberg, 2005: 4-14; Greunz, 2005: 450; However, recent publications especially try to model heterogeneity of actors and a fusion of New Economic Geography (NEG) and NGT (Baldwin and Martin, 2004: 2671-2711).

3 NATIONAL SYSTEMS OF INNOVATION

3.1 CONTEMPORARY CONTRIBUTIONS TO NSI

According to the majority of authors within the academic community, the expression and debate on "national systems of innovation" (NSI) has been developed, introduced, fostered, and highly influenced by elementary contributions of Bengt-Åke Lundvall (1988, 1992), Christopher Freeman (1984, 1987), Richard Nelson (1988, 1993), Giovanni Dosi, Gerald Silverberg and Luc Soete (1988).[66] In addition, and as mentioned in many articles, one of the leading roles in innovation research is adjudicated to the Science Policy Research Unit (SPRU) at the University of Sussex (UK).[67]

Besides Freeman's enriching work on Japan (1987), *Technology Policy and Economic Performance*, he presented ideas on industrial innovations in the year 1974. In *The Economics of Industrial Innovation*, Freeman (1974) developed some first ideas which were extended in *Unemployment and Technical Innovation* (1982), and finally in the year 1987.[68] Thereafter, Lundvall and Freeman (1988) published a book entitled *Small Countries Facing the Technological Revolution* on the case of small economies.[69]

As soon as scholars explore SI, they discover some dissent and ambiguity within the academic community regarding the introduction and first usage of the expression "innovation system". Following the majority of literature reviews, the term was introduced by Lundvall (1985), but without explicit national reference.[70] Consequently, the very first publication with explicit application of the expression "national systems of innovation" was in Freeman's work on Japan (1987). In this publication, Freeman defined the (national) system as a network of institutions in the public and private sectors, whose activities and interactions indicate, import and diffuse new technologies.[71] On this account, the SI approach has been developed and theorized at different locations, but with great collaboration within the academic community.[72] Following some notes of Lundvall (2007), the IKE Aalborg group primarily focused on national production systems and industrial complexes, which are supported by

[66] Lundvall et al., 2002: 215; Lundvall, 2007: 95; Carlsson, 2006: 57; Fagerberg, 2005: 12; Sharif, 2006: 750; definitely, other economists also contributed to NSI. Sharif (2006), for example, offers a broad literature review of NSI.
[67] Lundvall et al., 2002: 218; Fagerberg, 2005: 2; Fagerberg, 2006: 8; Lundvall, 2007: 107); Fagerberg (2005) gives a brief outline of the major contributions by Christopher Freeman, Keith Pavitt and others. Fagerberg also emphasizes the role of *Research Policy* as being the central academic journal in this field of research (Fagerberg, 2005: 3).
[68] Fagerberg, 2005: 3; Carlsson, 2006: 56; Sharif, 2006: 750; Freeman's paper *Technological Infrastructure and International Competitiveness* (1982) was unpublished at this time (Sharif, 2006: 751).
[69] Freeman and Lundvall, 1988; Lundvall, 2007: 96
[70] Lundvall et al, 2002: 215; Carlsson, 2006: 57; Sharif, 2006: 751
[71] Freeman, 1987: 1; More statements on the contributions by Christopher Freeman can be found in Lundvall et al. 2002: 215, Carlsson, 2006: 57, Edquist, 2005: 183, or Sharif, 2006: 750-751. According to Lundvall (2007), Christopher Freeman brought deep understanding of innovation as a process, historical insights and even wisdom to the collaboration with the IKE Aalborg-group (Lundvall 2007: 90, 96).
[72] Carlsson, 2006: 56-67; Sharif, 2006: 750

vertical interactions and linkages. This network character of interaction and production are declared to be essential for national economic performance and competitiveness.[73]

For a further diffusion and advancement of the general idea of SI, important works by Freeman (1988), Nelson (1988), Lundvall (1988) and Pelikan (1988) were published in Dosi et al. (1988), *Technical Change and Economic Theory*, which emerged out of the IFIAS project. The preface was entitled *National Systems of Innovation* by Richard Nelson (1988).[74] Only a few years later, Lundvall (1992) and Nelson (1993) published further works on systemic innovation. While Nelson (1993) contributed with several empirical results and case studies in *National Innovation Systems – A comparative Analysis* which was descriptively oriented, Bengt-Åke Lundvall's contribution (1992) concentrated on theoretical issues and sought to develop an alternative framework to the standard neo-classical economic theory. In the well-known book *National Systems of Innovation – Towards a Theory of Interactive Learning*, Lundvall (1992) primarily highlighted interactive learning, learning as a process, dynamic knowledge and user-producer-interactions.[75] Following his ideas, the structure of production and the institutional set-up represent two of the major dimensions which, together, define the systemic character of innovation.[76]

Complementary to Lundvall (1992), the work of Nelson and Rosenberg (1993) *Technological Innovation and Systems* displays interactions between organizations as the main sources of influence on innovation.[77] In contrast, Lundvall's approach is classified by colleagues and by himself to be a broader and wider concept.[78] Due to this broader analysis of innovation, Lundvall's approach presents organizations as fractions of a much wider socio-economic system which influences the emergence and the relative success of innovation.[79] In spite of using similar expressions, Nelson and Lundvall define national systems of innovation not identically. Their definitions contain different determinants. As a consequence, the absence and lack of a generally accepted definition in economic literature is approached by a sub-group within the academic community.[80]

Extending on these contributions, Charles Edquist (1997) finally published his book *Systems of Innovation: Technologies, Institutions and Organizations.* He engages in combining these similar but also different views and conceptualizations.[81]

The SI approach was surprisingly successful in academic circles and policymaking. The framework has been diffused rapidly and is today widely used for different purposes. As a

[73] Lundvall, 2007: 96
[74] Edquist, 2005: 183-185); See also Fagerberg, 2002: 8, Fagerberg, 2005: 12, Steg, 2005: 5 and Sharif, 2006: 750.
[75] Lundvall, 1992: 1; See also Edquist, 2005: 183, Cooke and Memedovic, 2003: 5, and Sharif, 2006: 757.
[76] Lundvall, 1992: 10
[77] Nelson and Rosenberg, 1993: 5, 9-13; see also Edquist, 2005: 183 and Cooke and Memedovic, 2003: 5.
[78] Lundvall, 2007: 110; Edquist, 2005: 183
[79] Freeman, 2002: 195; Edquist, 2005: 183; Cooke and Memedovic, 2003: 5
[80] Edquist 2005: 183; Fagerberg, 2005: 12; Sharif, 2006: 757
[81] Edquist, 2005: 186; Reviews of the contributions by Charles Edquist can be found, e.g., in Steg, 2005: 5, Fagerberg, 2005: 20 and Sharif, 2006: 757.

consequence, the SI approach emerged side by side in economic theory and the policy sphere. However, it seems unambiguous that there have been distortions of the concept during the process of diffusion, compared to the original versions. These modifications represent an existing dissent in literature.[82]. Today's ambiguity is almost the result of the need for serving special interests in both worlds.[83] As mentioned by Sharif (2006), the SI concept experienced these numerous modifications due to its elasticity. Thus, the SI approach represents a "boundary object", captured between the academic field and the policy sphere. Due to its flexibility and ambiguity, the SI approach simply fits to both sides. As a result, the concept has finally been adopted by various public authorities and organizations, by regional and national governments, and by international organizations, such as the European Union, OECD, UNCTAD and UNIDO.[84]

In the recent paper *National Innovation Systems – Analytical Concept and Development Tool*, which mainly deals with systemic innovation and its historical evolution, Lundvall (2007) analyzes the diffusion of the expression "national systems of innovation" in the World Wide Web. As a result, he points on 50.000 hits in Google and 5.000 hits in Google Scholar. In comparison, and replicating the analysis (1 may 2007), I could find 114.000.000 hits in Google and even 9.200 entries in Google Scholar. Later on, I could find 125.000.000 hits (6 may 2007), 129.000.000 hits (17 may 2007) and 189.000.000 hits (21 november 2007) in Google.[85]

3.2 DIFFERENCES, SIMILARITIES AND COMPLEMENTARITIES OF NSI

At first sight, the boundaries of the national system seem to be simply defined by the territorial frontiers of the country at a nation-state level. This assumption is supported by many contributions of established members within the academic community, as surveyed by Sharif (2006). In challenging existing economic thinking, the system concept had to be established at the national level, coping with neo-classical economics at the macro-level.[86] From this point of view, systems of innovation at other levels of research only represent sub-fields (*Figure 1 and Table 2, Appendix*).

Nevertheless, many authors within the community point out to conceptual ambiguity, grey zones and missing links within the SI literature.[87] Relying upon this sub-group, the SI approach needs to be increasingly advanced towards a more consistent, more clearly defined,

[82] Most policymakers and authorities apply the analytical SI concept for comparative studies, serving their own specific interests. Regrettably, some of these "user-groups" don't seem to be interested in the specific origins of these SI concepts.
[83] Fagerberg, 2005: 2; Edquist, 2005: 184; Sharif, 2006: 752
[84] See especially Lundvall, 2007: 97; moreover, the Swedish Agency for Innovation Systems (VINNOVA) was extremely influenced and determined (Lundvall, 2007: 97).
[85] See Lundvall, 2007: 97; A similar experience is pronounced by Fagerberg (2005), who displays the increasing number of scientific articles with the term "innovation" in the title (Fagerberg, 2005: 2).
[86] Sharif, 2006: 754
[87] Edquist, 2005: 186; Sharif, 2006: 754

and generally accepted theory.[88] As a consequence, it seems that some scholars and authors within the academic community apologize and challenge the flexibility and the existing different meanings of the system concept. Due to this supposed holistic idea of the framework and its multidisciplinarity, some authors and mainly its critics condemn the SI approach for being conceptually diffuse and inconsistent. This critique primarily applies to theorizing and formal modeling, but also to its practical application.[89] A serious critique and severe criticism on that issue can be found in *Systems of Innovation: Perspectives and Challenges* by Charles Edquist (2005). His contributions to SI, especially his general definition of a system and its entities, can be valued as ambitions in making the concept less fuzzy and more theory oriented. However, his criticism and ambitions are not equally honored by his academic colleagues, as surveyed by Sharif (2006).[90] In my opinion, the claim for clearly defined concepts should not be interpreted as "definition fetishism".[91] Furthermore, the presented claims for elasticity and flexibility directly foster economists to define boundaries for partial analysis.

Following Edquist (2005), theory has to explain which potential factors could or could not be excluded from analysis. This assumption raises questions about the importance of factors that promote or trig innovative activities and their results.[92] Even though literature has become more accurate and specific in defining systems of innovation and their multidimensional drivers, definitions are still fuzzy. In disaggregating on several sub-levels, contemporary publications are pointing out divergent objectives, whereas the aim of a general and common definition of SI seems to be more and more blurred.[93] Consequently, some definitions differ to a great extent, and additionally, some definitions explicitly or implicitly refer to technological innovations. However, some authors propose a broader system concept, including also organizational and institutional innovations at the macro-level, and also managerial innovations at the micro- or meso-level. This wider definition in turn, is in line with Schumpeter's broad(er) definition of innovation.[94]

The *Table 1* (*Appendix*) summarizes several definitions of SI, especially NSI, sorted by the year of publication. Comparing these definitions, we can differentiate nuances from core

[88] Edquist, 2005: 187
[89] Edquist, 2005: 186; Cooke and Memedovic, 2003: 6; Sharif, 2006: 756
[90] Sharif, 2006: 758
[91] I owe much gratitude to Prof. R. R. Nelson for the useful and interesting discussion and his comments on the necessity of different conceptualizations of SI in theory and empirical research. Especially his remarks on "definition fetishism" within SI literature represent an essential point of view.
[92] Edquist, 2005: 183; In contrast to Charles Edquist, some authors seem to neglect the utility of theorizing SI. Following their opinion, SI should be rather analyzed in case studies. Regrettably, this consideration flattens SI research to anecdotal writing.
[93] Edquist, 2005: 186; According to this estimation, one can find some interesting conclusions to the analytic concept and the necessity of boundaries and flexibility in Cooke and Memedovic (2003): "*Defining the systems concept as an analytical tool, we do not need to assume that innovation systems always consist of tight linked actors and that they have clear cut boundaries. We also do not need to expect that innovation systems consist of the same actors performing the same function. On the contrary, such an understanding of a system approach is open to flexible interpretation.*" (Cooke, and Memedovic 2003: 6)
[94] Edquist, 1997: 24; Edquist, 2001: 5; Edquist, 2005: 6-11

features. As a result of these definitions, conceptual ambiguity and fuzziness seems to be a logical consequence.[95] To be conducive to this issue within academic literature, the paper proposes a general definition of the major components and their relationships which show some "Northian" character.[96]

> *"Organizations are formal structures that are consciously created and have an explicit purpose." (Edquist and Johnson, 1997: 46-47; Edquist, 2005: 188)*
>
> *"They (organizations) are players or actors. Some important organizations in SIs are firms, universities, venture capital organizations and public agencies responsible for innovation policy, competition policy or drug regulation." (Edquist, 2005: 188)*
>
> *"Institutions are sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups, and organizations." (Edquist and Johnson, 1997: 46)*
>
> *"They (institutions) are the rules of the game." (Edquist, 2005: 188)*

Although contemporary contributions support a lot of ambitions to transform the approach towards a theory, the vast amount of different definitions does not reduce, ease or simplify the general ambiguity and confusion.[97] This issue is stressed in the next chapter.

While some economists do not really differentiate between institutions and organizations, Lundvall (1992) and Edquist (2005) define institutions as rules.[98] Organizations are strongly influenced and shaped by institutional set-ups. Thus, they seem to be embedded in a specific set of rules that includes, besides routines, common habits and standards, also laws, rules, and consequently the entire legal system. Institutions themselves are in return influenced by these actors.[99]

For this reason, systems of innovation and systemic analyses can be generally differentiated according to their diverse objectives.[100] Some sub-groups within the academic community rightly claim that economists and theorists mainly mean different things when referring to a national system of innovation.[101] The concepts and frameworks which are used by Christopher Freeman (1987) and even by the Aalborg-Group (1988) analyze systemic innovation activities in a much broader and wider sense. This view corresponds to Lundvall's assumption that the definition of SI must be kept open and flexible to some extent.[102] However, this point of view underpins the rejection of economic optimization.

Whereas Lundvall's work is mainly oriented towards aspects of learning, knowledge, and some social dimensions of innovation processes, authors like Nelson attribute innovation still

[95] Niosi, 2002: 292; Steg, 2005: 8; OECD, 1997: 10; Edquist, 2005: 186; Sharif, 2006: 758
[96] Edquist, 2005: 188; Malmberg and Maskell, 2005: 3
[97] Edquist, 2005: 187; Lundvall, 2007: 98
[98] Edquist, 2005: 186-189
[99] Edquist, 2005: 188; Edquist and Johnson, 1997: 59-60; OECD, 1997: 12; Edquist, 2005: 188
[100] Lundvall, Edquist, Johnsson, 2003: 4; Sharif, 2006: 756
[101] Lundvall, Edquist, Johnsson, 2003: 4; Steg, 2005: 5
[102] Edquist, 2005: 186; Lundvall, 2007: 99

closer to evolutionary theory and to institutional economics.[103] In a recent paper, however, Lundvall (2007) seizes contemporary criticism on NSI, challenging and defining the core of the system and the wider setting. In this conceptualization, interacting firms and their knowledge infrastructure represent the system core.[104] Moreover, this assumption underpins the fact that systems of innovation should not be equated with industry policy. Regrettably, some economists broaden and modify the SI concept to put it on a level with industry policy.

3.3 TIME-IRREVERSIBILITY, COUNTRY SPECIFICITY AND OPTIMIZATION

History-friendly modeling and conceptualizations conclude that nation-state performance in innovation and its uniqueness is to a large extent determined by institutional elements. This assumption of trajectories, non-linearity, and heterogeneity of firms and households applies for nearly all contributions within the SI literature.[105]

Complementary, this assumption can also be found in literature on general purpose technologies.[106] The choice of Schumpeterian attitudes shows path-dependant roots and certain evidence of lock-in.[107] As discussed by Lipsey, Carlaw and Bekar (2005), populations and societies differ extremely in their habits. Thus, entrepreneurial performance and technological results are the outcome of historical trajectories, knowledge accumulation and learned and accumulated capabilities and skills in the course of time.[108] This idea of path-dependent evolution, co-evolution and time-irreversibility is frequently used by the authors who contribute to the systems of innovation literature and to GPT theories.[109] Additionally, the combinations and proportions of SMEs and MNEs within regions and countries represent unique and diverse Schumpeterian strategies with high persistence.

In this regard, policymakers always feel committed to avoid irreversible lock-ins into innovational and technological weakness. This opinion applies especially to "low-road regions" and the so-called "hinterland". These beliefs intensify the demand of policymakers for optimal and extraordinary S&T-policy and it brings up the question if core-periphery structures are conducive or not. However, according to the majority of scholars within this

[103] Steg, 2005: 5, 10; Borrás and Lundvall, 2005: 612

[104] Lundvall, 2007: 102; Similar and competing conceptual tools emerged in literature, which also focus on relationships and interactions between firms and public organizations. As mentioned in literature, the narrow system concept shows some strong similarities to the well-known "Triple Helix" concept of Etzkowitz and Leydesdorff (1998). Their concept centers especially universities, governmental entities, and firms and their linkages. Additionally, scholars accentuate some similarities of SI with the "New production of knowledge approach" of Gibbons (1994), and Porter's "Diamond concept", which was published in "*The Competitive Advantage of Nations*" (1990) (Lundvall, Edquist and Johnsson, 2003: 4; Etzkowitz and Leydesdorff, 1998: 195-197; Cooke and Leydesdorff, 2006: 11; Lundvall, 2007: 100; Sharif, 2006: 754; Porter, 1990). Admittedly, this paper does not analyze and compare their features.

[105] Nelson, 1993: 507; Edquist, 1997: 18-19; For additional views, please see also Johnson, 1992: 23, 38, Sharif, 2006: 753, Cooke et al., 1997: 476, Edquist, 2001: 15, Edquist, 2005: 185, and Fagerberg, 2005: 13.

[106] Lipsey, Carlaw and Bekar, 2005: 32, 120; Freeman, 1995: 11; Jovanovic and Rousseau, 2006: 1

[107] Lundvall, 2002: 223

[108] Lipsey, Carlaw and Bekar, 2005: 221-289

[109] Lundvall, 2007: 106; Lipsey, Carlaw and Bekar, 2005: 32

academic field, there are no ideal or optimal spatial systems of innovation, e.g. NSI, RSI.[110] As a consequence, benchmark studies, cross-county comparisons and imitated S&T-policies with the intention to copy well performing geographical innovation systems seem senseless and unreasonable.[111] This view reveals again the different objective of optimizing and non-optimizing system perspectives. However, a partial systemic view is always based upon a certain intention or goal of analysis. Consequently, the partial analysis follows prescribed requirements. In this regard, optimization of the spatial case is not impossible at any rate. Thus, the whole debate on systems of innovation is eminently determined by the fact that scholars assume diverse partial views. Given the fact, that most economies that are analyzed at a national or geographical scale consist in most cases of a quite stable but unique coexistence and proportion of radical and incremental innovators and imitators, one could argue in terms of non-equal and scale-specific systems of innovation.[112] Summarizing the latter assumptions and reflections, it is obvious to define systems of innovation as a geographical feature.[113]

In conclusion, when relying on heterogeneity assumptions, uncertainty and non-representative actors and environments, there exists always a form of non-optimality of systemic interaction. This thinking regrettably forbids formal modeling and optimization.[114]

3.4 FROM NSI TO COMPLEMENTARY CONCEPTS

Besides the hitherto dominating field of research at the nation-state level, academic literature and the policy sphere show both some really interesting modifications, conceptualizations and co-evolutions in reference to more disaggregated levels of analysis (*Figure 1, Appendix*).[115] Anyhow, the former section underlined the fact that national systems of innovation are still of high importance and interest.

Complementary to this point, the literature is increasingly enriched by many publications and contributions that rather focus on the striking forms of agglomeration and territorial innovation.[116] Spatial phenomena like Silicon Valley (CA), Route 128 (MA) or Silicon Alley

[110] Edquist, 2001: 15

[111] Edquist, 2005: 185; Andersen et al., 2002: 189; Cook and Memedovic, 2003: 6; Sharif, 2006: 757; Authorities can only compare the evolution of the operational (real) system to theoretical considerations and their policy targets. However, because of measured differences in cross-country set-ups, policymakers are primarily interested in studies on SI. A good overview of such empirical studies is given, for instance, by Balzat and Hanusch (2003).

[112] Lundvall, 2002: 223; Andersen et al., 2002: 189

[113] These considerations are advanced in many empirical research studies and books on evolutionary economics that attend to the regional and sectoral level, and even to the nation-state level (Freeman, 2002: 192, 224; Lundvall, 1988, Edquist and Lundvall, 1993). Geographical uniqueness and time-specific systems are similarly discussed in Dosi (1988) and count for every level of research: "*Technological bottlenecks and opportunities, experiences and skills embodied in people and organisations, capabilities and memories…tend to organise context conditions which are country specific*." (Dosi, 1988: 128)

[114] Cooke, 2001: 952; Cooke and Memedovic, 2003: 3; Similar statements can be found in Johnson, 1992: 23, 38, Edquist, 2005: 185, 193 and Lundvall, 2007: 107. However, not all authors support heterogeneity with the same intensity.

[115] Evangelista et al., 2002: 174; Lundvall, 2007: 100; Sharif, 2006: 756

[116] Cooke et al., 1997: 476; Scott and Storper, 2003: 581; For an additional overview see also Legler, Rammer, Schmoch, 2006, Lundvall, 2007: 112, Moulaert and Sekia, 2003: 289, or Evangelista et al., 2002: 173.

(NY) represent local (production) systems and agglomerations, where sectoral specialization and causes of local agglomeration overlap. As a consequence, it seems difficult to establish explicit distinctions between sectoral and local indications and perspectives.[117] For this purpose, technological, organizational, institutional and economic changes within and between systems either on global, continental, national, or sub-national lines of argumentation come to the fore. Freeman (1995) for instance mentions the necessity of changing the perspective from nation-state analyses to other criteria of classification, accentuating that these variations could also be valid for geographical issues, especially for regional agglomeration appearances.[118]

Therefore, these complementary conceptualizations and analyses represent an essential method for elaborating the dynamics of spatial innovation performance and competitiveness, due to different criteria of classification.[119] This circumstance corresponds in an analogous manner to both the theoretical and operational (analytical) system concept. Moreover, some sub-groups within the academic community propose the utility of the SI concept even for supranational, transnational and global perspectives (*Figure 1 and Table 2, Appendix*).[120] This trans-border aspect will be discussed in *chapter 6.*

4 TECHNOLOGICAL AND SECTORAL SYSTEMS OF INNOVATION

The purpose of inquiry defines the level of analysis. Several issues related to the national systemic analysis of innovation were soon recognized and challenged within academics. Nelson and Rosenberg (1993) already offered a good reason that supports the sectoral conceptualization.

> *"On the one hand, the (national) 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." (Nelson and Rosenberg, 1993: 5)*

With similar intention, Bo Carlsson and other economists focused to a great extent on *technological systems of innovation* by centering technology fields.[121] In this regard, most authors refer to their work *Technological Systems and Economic Performance. The Case of*

[117] Malerba, 2005: 400; Scott and Storper, 2003: 582; Saxenian, 1994: 4

[118] Freeman, 1995: 21; Sharif, 2006: 756; The conceptualization at various levels and the evolution of these complementary frameworks is equally accentuated by Lundvall et al. (2002), Edquist (2005) and Cooke et al. (1997) (Lundvall, 2002: 216; Lundvall, 2007: 100; Sharif, 2006: 756; Cooke, 2001: 952; Edquist, 2005: 181).
"*These are not alternatives to the analysis of national systems. They have important contributions to make to the general understanding of innovation in their own rights.*" (Lundvall, 2007: 100; see also Lundvall et al., 2002: 216)

[119] Lundvall, 2007: 100; Edquist, 2005: 198-199

[120] Freeman, 2002: 209; Lundvall et al., 2002: 227; Edquist, 1997, 11; Trans-national and global SI are also discussed and mentioned in Cooke and Memedovic, 2003: 5-6, Braczyk et al., 1998: 414, Steg, 2005: 6, 44, Carlsson, 2006: 58, and Sharif, 2006: 756-757.

[121] Carlsson and Jacobsson, 1993; Carlsson and Stankiewicz, 1991; Carlsson et al., 2002; Carlsson, 2006: 58

Factory Automation (1993).[122] In *Differing Patterns of Industrial Dynamics: New Zealand, Ohio, and Sweden, 1978-1994*, Carlsson (1996) presents his sectoral cross-country analysis on differing industrial systems results that relate to different circumstances.[123] Without surprise, even Carlsson and Stankiewicz (1991) mention that technological systems have tendencies to be spatially correlated. According to these ideas, agglomerative phenomena such as Route 128 and Silicon Valley represent regional and not national systems. Additionally, technological systems can also be transnational and even global (*Figure 1, Appendix*). The boundaries rely on certain circumstances, such as capabilities, relationships, technologies, market requirements, interactions and even technological spillovers.[124]

A similar and complementing view within the economic literature is represented by the so-called *sectoral systems of innovation* (SSI) approach, which is mostly related to the publication of Breschi and Malerba (1997). In comparison to the national case, the authors focus on certain groups of firms and organizations, separated by sectoral perspectives (*Figure 1 and Table 2, Appendix*). In *Sectoral Innovation Systems, Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries*, Breschi and Malerba (1997) discuss about organizations, especially firms which co-evolve in specific sectors and which represent sources of new technologies and innovation.[125] Following their argumentation, sectoral systems have a knowledge base, technologies, inputs, and a (potential or existing) demand.[126] Malerba defines these sectoral systems and their dynamics by unique compositions of knowledge and technologies, by differing set-ups of actors, networks and institutions. These elements co-evolve over time and induce processes of change and transformation due to evolutionary assumptions.[127] Depending on the respective issue, sub-sectors, industries or broader sectors are of fundamental interest for analyses.[128] Furthermore, the dynamics and path-dependent processes within sectoral systems are consequently sector-specific.[129] However, Malerba himself makes the important assumption that the relationship between national institutions and sectoral systems becomes substantial.[130] The overlap of NSI and SSI is however subjective due to the flexibility of partial analysis. Identical to NSI, sectoral systems are also country-specific, unique and primarily independent of optimality requests.[131] Finally, the Schumpeter Mark I and II units can also alternate.[132] Interestingly, according to

[122] Carlsson, 1995; Carlsson, 2006: 56
[123] Carlsson, 1996: 220; Gregersen and Johnson, 1997: 482; Carlsson and Stankiewicz, 1991: 111
[124] Carlsson and Stankiewicz, 1991: 111; Sharif, 2006: 756; Carlsson, 2006: 58; Edquist (2001) similarly mentions functional boundaries (Edquist, 2001: 14).
[125] Edquist, 2005: 184; Breschi and Malerba, 1997; Malerba, 2005: 64; Carlsson, 2006: 58; Andersen et al., 2002: 185-186
[126] Malerba, 2002: 248; Malerba, 2005: 64-65
[127] Malerba, 1999: 4; Malerba, 2005: 66; Malerba, 2002: 250
[128] Malerba, 2005: 69
[129] Malerba, 2005: 68
[130] Malerba, 2005: 67
[131] Malerba, 2005: 69
[132] Malerba, 2002: 253; Malerba also makes the above mentioned distinction between creative destruction caused by Schumpeter Mark I innovators, and creative accumulation originated to Schumpeter Mark II units (Malerba, 2002: 253).

Malerba's view (2005), boundaries are often defined in local terms and consequently, the sectoral specialization defines the specialization of the whole geographical unit.[133]

> *"For example, machinery is concentrated in regional areas, traditional sectors define the specialization of industrial districts in Italy, sectoral specialization and local agglomeration overlap in Route 128 (for minicomputers) and in Silicon Valley (for personal computers, software and microelectronics) (Saxenian, 1994). More often in a sectoral system, one may find the coexistence of local, national and global boundaries: global for knowledge interaction; local for the labor market and national for some key institutions." (Malerba, 2005: 68)*

Relying upon these assumptions, a general classification scheme seems unreasonable and nonrelevant. Nevertheless, one could think about a formal model which centers knowledge spillovers, firm interaction and endogenously changing sectoral set-ups in a spatial perspective.[134]

Some of Malerba's assumptions were already pointed out by Keith Pavitt (1984), whose important work *Sectoral patterns of Technical Change. Towards a Taxonomy and Theory*, contributed in a very significant way to SI literature and, primarily, to the sectoral view of systemic innovation.[135] Pavitt's classification could be considered as one of several starting points of evolutionary sectoral analysis. His contribution to inter-sectoral linkages between different types of manufacturing industries and the existence of different major technological trajectories in the manufacturing sector redounded a lot to the literature.[136] Pavitt displayed a taxonomy of sectoral patterns of innovation that are related to industry specific trajectories and hence to path-dependencies of economic performance.[137] The interactions between sectoral patterns of innovation and national systems, and even the elementary role of inter-sectoral linkages, are of great importance.[138] In addition, he approached vertical up- and downstream linkages which connect the four identified industry types. Besides this classification, Pavitt's work also focuses on inter-sectoral exchange and flows of knowledge.[139]

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[133] Malerba, 2005: 68; see also Edquist, 2001: 14; In this view, the range and scope of the geographical unit is not accurately fixed.

[134] Recent publications combine NGT and NEG theory for modelling knowledge externalities, core-periphery structures and spatial location of the patent sector. However, these authors use representative consumers (Baldwin and Martin, 2004).

[135] Pavitt, 1984; Malerba, 2005: 64; Fagerberg, 2005: 16; Lundvall, 2007: 107

[136] Castellacci, 2006: 3; Fagerberg, 2005: 16

[137] Pavitt's original conceptualization distinguishes between four major sectoral patterns: (1) science-based industries, (2) specialized suppliers, (3) scale intensive productions, (4) and supplier-dominated sectors (Castellacci, 2006: 3; Fagerberg, 2005: 16).

[138] Fagerberg, 2005: 16; Malerba, 2005

[139] Castellacci, 2006: 4; Fagerberg, 2005: 16; In addition, the so-called "Chain-Linked-Model", introduced by Kline and Rosenberg (1986), focuses on user-producer interactions and relations (Lundvall, 2007: 108). Their contribution to non-linearity was just mentioned (chapter 2). Following Lundvall (2007), the work of Kline and Rosenberg (1986) represents an important contribution to the NSI concept (Lundvall, 2007: 108).

5 REGIONAL SYSTEMS OF INNOVATION

5.1 MAJOR IDEAS AND SEVERAL EFFORTS TOWARDS A FRAMEWORK

According to Scott and Storper (2003), it seems to be a fundamental mistake to consider globalization as a simple spreading out of economic activity into a fluid space of flows. Quite the contrary, globalization is supposed to be accompanied by agglomerative tendencies.[140]

> *"In sum, large-scale agglomeration – and its counterpart, regional economic specialization – is a worldwide and historically persistent phenomenon that is identifying greatly at the present time as a consequence of the forces unleashed by globalization. This leads us to claim that national economic development today is likely not to be less but rather more tied up with processes of geographical concentration compared with the past." (Scott and Storper, 2003: 582)* [141]

By focusing mainly upon national systems and systemic interaction at the nation-state and sectoral level, major regional phenomena and peculiarities that affect innovation seem to be suppressed and ignored.[142] As a result, some sub-groups within the innovation literature engage in extending and combining special theories and approaches related to spatial and regional analyses of innovation.[143] However, every step towards regional cases highlights several conceptual problems.[144]

First of all, NSI are theorized, conceptualized, and analyzed mainly at the macro-level which ignores phenomena at the meso-level.[145] This feature is a logical consequence due to the explicit aim of evolutionary approaches to compete with neo-classical macro-economics.[146] Institutional and organizational set-ups, linkages and flows within local and regional structures differ enormously from the national level and, moreover, regions within one country differ tremendously.[147] The second problem arises from the lack of essential data for empirical analyses at the sub-national level.[148] And thirdly, localized and inter-regional knowledge spillovers and pecuniary flows of knowledge influence and determine regional innovation performance.[149]

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[140] Scott and Storper, 2003: 581; See also Malmberg and Maskell, 2005: 1, 14, and Audretsch and Feldman, 1999.
[141] Nevertheless, literature is still debating whether specialization or rather diversification comes to the fore. This issue will also be discussed in chapter 6.
[142] This perspective can be found in Hae Seo, 2006: 3, Cantwell, 2005: 557, Iammarino, 2005: 498, Evangelista et al., 2002: 174, Holbrook and Salazar, 2003: 2.
[143] See for instance Braczyk et al., 1998: 414, Cooke et al., 1997: 475, Holbrook and Salazar, 2003: 2, or Carlsson, 2006: 58. Furthermore, literature is extended by Evolutionary Economic Geography. This sub-approach combines insights out of New Economic Geography and systems of innovation literature (Boschma and Frenken, 2007: 635-649).
[144] Moreover, these issues prevail in mainstream economics and heterodox streams.
[145] The expression meso-level is mostly used to describe and entitle regional phenomena, industry-level analyses and urban studies.
[146] Sharif, 2006: 757
[147] Regional inequality and divergence is also approached by NEG-theorists in their core-periphery-models (Litzenberger, 2007).
[148] Evangelista et al., 2002: 173-174
[149] Glaeser et al. 1992: 1127; Audretsch and Feldman, 1999: 410; Greunz, 2005: 457; Narula and Zanfei, 2005: 328; Additionally Döring and Schnellenbach (2004) give an excellent review of the relevant literature on LKS and the most cited empirical studies (Döring and Schnellenbach, 2004: 2). Contrary, NEGG models approach LKS by using optimization calculus (Baldwin and Martin, 2004: 2671-2711).

Furthermore, to anticipate Cooke's contribution (2001) the theoretical and operational conceptualization of RSI contains five major key concepts. Besides the concept of the region, RSI also contain innovation, networks, learning, and interaction. Hence, the theoretical and analytical approach to RSI should deal with the ideas of evolutionary theory, regional science, the industrial district concept, theories of rationalization strategies, and some governance aspects.[150]

A wide range of contributions and constructive debates helped to get a better understanding of geographical and primarily local features of invention, innovation, adoption, and diffusion.[151] Additionally, RSI emphasize geographically localized features and capabilities, such as specialized resources, human skills, institutions, spillovers, and local shares of social and cultural values – generally speaking, local and regional capabilities and linkages.[152] Despite the broad interest on "footloose" manufacturing industries and fragmentation concepts in economic literature, regions, local buzz, and localized learning are nonetheless considered to be major influencers of innovation, growth, and competitiveness at the meso-level.[153]

Relying on Braczyk et al. (1998),

> *"...globalization strategies can be understood as organized efforts to utilize local and regional differences in a worldwide context. This necessitates the adaptation of objectives, possibilities and strategies to the given local contexts." (Braczyk et al., 1998: 414)*

As mentioned by some authors within the academic community, the explanatory capability of regional approaches suffers indeed from the lack of a homogenous and common operationalization across areas, territories and regions.[154] Essentially, RSI definitions and their transformation and realization into empirical research widely differ in the literature. Although Schumpeterian innovation scholars rely on similar ideas and relationships, they frequently mean different things. Similar to NSI and SSI, economists have to overcome and harmonize the big gap within and between analytical and theoretical systems.[155] Therefore, this section tries to summarize and review some of the major approaches and underlying theories, which are related to regional science and the geography of innovation (*Table 2, Appendix*).

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[150] Cooke, 2001: 953; Holbrook and Salazar, 2003; DeBrujin and Lagendijk, 2005

[151] Cooke et al., 1997: 476; Feldman, 1996: 71; Malmberg and Maskell, 2005: 2

[152] Malmberg and Maskell, 1999; De Bruijn and Lagendijk, 2005: 1155; Braczyk et al. 1998: 416; Cooke et al., 1997: 480

[153] This view is presented, for instance, in Braczyk et al., 1997: 423, Asheim, 2005: 299, Feldman, 1994: 13, Amesse and DeBresson, 1991: 374, Cooke and Memedovic, 2003: 3, Scott and Storper, 2003: 581, and Malmberg and Maskell, 2005: 4. In addition, "footloose" industries are also discussed in Lundvall (1992: 58-59). Some authors coined these paradox developments with the expression "glocalization" (Holbrook and Salazar, 2003: 3; Amesse and DeBresson, 1991: 374).

[154] Crescenzi and Rodríguez-Pose, 2005: 5; Cooke and Memedovic, 2003: 3; DeBrujin and Lagendijk, 2005: 1156; Moulaert and Sekia, 2002: 291

[155] This definitional and applied issue is cited by many authors. See Holbrook and Salazar, 2003: 9-10, De Bruijn and Lagendijk, 2005: 1156, or Moulaert and Sekia, 2002: 291.

To offer a first definition of RSI, one could follow the ideas of De Bruijn and Lagendijk (2005), Evangelista et al. (2002) and Iammarino (2005).

> *"The RIS concept, in line with that of the learning region, is the outcome of an intellectual debate at the intersection of two bodies of work, that on the organization and systemness of innovation on the one hand, and that on spatial agglomeration on the other hand" (De Bruijn and Lagendijk, 2005: 1155).*
>
> *"…a regional system of innovation may be defined as the localized network of actors and institutions in the public and private sector whose activities and interactions generate, import, modify and diffuse new technologies." (Evangelista et al., 2002: 174)*
>
> *"A RSI may thus be defined as the localised network of actors and institutions in the public and private sectors whose activities and interactions generate, import, modify and diffuse new technologies within and outside the region." (Iammarino, 2005: 499)*

In a more detailed manner, Asheim (1998) and Asheim and Gertler (2005) distinguish between three types of RSI. "Territorially embedded regional innovation systems" represent the first type of regional systems and seem to be similar to Cooke's (1998) "grassroots RIS". This type is defined by networking SME-firms with synthetic knowledge, localized learning processes that are influenced by geographical, social and cultural proximity. In this case, however, firms do not support and advance close linkages to knowledge organizations. Examples can be found in industrial districts of "Third Italy".[156] Secondly, the authors introduced the so-called "regionally networked innovation system". This type resembles Cooke's (1998) "network RIS" and describes firms and organizations within a specific region. However, these units have stronger linkages to R&D institutes. Furthermore, this RSI type seems to be similarly successful; regional clusters supported by an innovating surrounding.[157] Finally, the authors emphasize "regionalized national innovation systems" that are similar to Cooke's (1998) "dirigiste RIS", with strong influence by the nation-state. Parts of the industries and the institutional infrastructures are more integrated into national and trans-national systems. Thus, innovation activities are the product of cooperation with actors from outside. Related to more analytical-scientific knowledge inputs, this type of RSI rather supports cross-border interaction and knowledge flows. Economic agglomerations with a high degree of vertical subcontracting and trans-border interactions correspond to this taxonomy.[158]

[156] Asheim and Gertler, 2005: 300
[157] Asheim and Gertler, 2005: 301
[158] Asheim and Gertler, 2005: 301; Further substantial and complementary works on regional systems of innovation have been established for instance by Braczyk et al. (1998), Cooke et al. (1997, 1998, 2001), Iammarino (2005), Asheim and Isaksen (2002), Asheim (2004), Holbrook and Salazar (2003). Moulaert and Sekia provide an excellent summary on territorial innovation models (Moulaert and Sekia, 2003: 291). Obviously, this brief reference list is incomplete at any rate.

5.2 EVOLUTIONARY THEORY AND ECONOMIC GEOGRAPHY

Evolutionary theory and its assumptions on time-specific and time-irreversible routines, specific trajectories, knowledge, organizations, linkages, and institutional set-ups is frequently used to explain regional divergence and uniqueness. Thus, the majority of authors relate future development of a region to its technological, economic, political, cultural, and even social history.[159] Similar to the concept of "organizational memory" of Nelson and Winter (1982), these history-friendly dynamic features are specific and unique to each region and local network.[160] As a result of these assumptions, weaker regions seem to suffer from the absence and lack of essential corporate capabilities for innovation and "catching-up". This situation corresponds to inferior lock-ins of "low-road regions".[161] Inter-regional networking, global pipelines for extra-local knowledge flows that reinforce local learning, and knowledge spillovers from neighboring regions could compensate and overcome their weakness, as will be discussed later.

For a structured presentation of the elementary contributions to regional systems of innovation, it seems absolutely necessary to distinguish between the various theoretical tribes, the underlying theories within regional science, and other agglomeration phenomena (*Table 2, Appendix*).

Relying upon Cooke (2001), regional systems are built upon the theory of agglomeration economics, the concept of the region, the well-known concepts of innovation, and the already presented systemic approach.[162] The emergence and diffusion of RSI resembles the theories on regional clusters, industrial districts and other territorial innovation models.[163] For this reason, scholars of RSI have to focus eminently on works of Alfred Marshall and his contributions to districts and an "industrial atmosphere".[164] Complementary to the "Marshallian industrial secrets", there exists a big pool of elementary works on geographical agglomerations.[165] Additionally, contemporary literature introduced more modern expressions such as competence clusters, competence networks, science parks, technology parks, science

[159] Braczyk et al., 1998: 416; Holbrook and Salazar, 2003: 8-10

[160] Braczyk et al., 1998: 416; Cooke et al., 1997: 480; Iammarino, 2005: 498; Hence, evolutionary economics and the idea of path-dependencies, technological trajectories, techno-economic paradigms, combined with institutional set-ups contribute a lot to the academic field (Lipsey, Carlaw and Bekar, 2005: 372; Hae Seo, 2006: 4; Feldman, 1996: 71; Hanusch and Pyka, 2007: 276; Feldman, 1994: 2; Holbrook and Salazar, 2003: 9; Cooke and Memedovic, 2003: 6; Moulaert and Sekia, 2003: 295).

[161] Cantwell, 2005: 558; Iammarino, 2005: 506

[162] Asheim, 2003: 5; Cooke et al., 1997: 480; Cooke, 2001: 949

[163] Asheim and Gertler, 2005: 299; Moulaert and Sekia, 2002: 291

[164] Marshall, 1949: 152-153; Feldman, 1994: 3; However, as noted by Moulaert and Sekia (2003), the industrial districts school and their contributions mainly started with Bagnasco (1977) (Moulaert and Sekia, 2003: 300).

[165] Besides the industrial district concept, literature also emphasizes on technical districts, the innovative milieu concept of the Groupe de Recherche Européen sur les Milieux Innovateurs (GREMI) (Moulaert and Sekia, 2002: 291), learning regions (Cooke, 1998; Asheim, 1995; Moulaert and Sekia, 2002: 293), and different cluster approaches (Marshall, 1891; Lasuén, 1973; Asheim and Coenen, 2004; Asheim and Isaksen, 2002; Cooke, 1998; Cooke and Memedovic, 2003; Saxenian, 1994; Saxenian, 1999; Feldman, 1994; Porter, 1998; Martin and Sunley, 2003). In Moulaert and Sekia (2003) industrial districts, innovative milieus, new industrial spaces, Porter's clusters, learning regions, and regional innovation systems are subordinated under the collective term "territorial innovation models" (TIM) (Moulaert and Sekia, 2003: 291-294). To my knowledge, there exist only few attempts to differentiate between these agglomeration phenomena.

cities, and technopoles.[166] Unfortunately, some expressions are only launched for political purpose.

Despite their different explanations, the just mentioned types of agglomeration represent similar but differing perspectives of location and territorial innovation advantages. Accordingly, these different forms of agglomeration should be unambiguously differentiated from existing RSI concepts.[167]

5.3 TOWARDS AN EVOLUTIONARY ECONOMIC GEOGRAPHY

Cooke (2001) explains the historical evolution and development path of the RSI concept almost entirely from a regional science and an economic geography point of view.[168] Following Cooke (2001), authors such as Lundvall are strangely dismissive towards the regional concept of innovation, arguing more on a "Listian national economy notion".[169]

> *"The region is increasingly the level at which innovation is produced through regional networks of innovators, local clusters and the cross-fertilizing effects of research institutions." (Borrás and Lundvall, 1997: 39)*
>
> *"The notion of RSI has emerged as a territorially-focused perspective of analysis derived from the broader concept of NSI: a RSI may thus be defined as the localised network of actors and institutions in the public and private sectors whose activities and interactions generate, import, modify and diffuse new technologies within and outside the region." (Iammarino, 2005: 499)*

As a consequence of these spatial issues, regional science also gained influence by country-specific works and analytical research on spatial production networks and localized systems of innovation. Different country-specific regional and local case studies can be founded.[170] These assumptions are underlined, e.g. by the research of Iammarino (2005), Evangelista et al. (2002) on the basis of the well-known example of divergent Italian regions. Institutional differences, historical evolution, and structural lock-ins affect regional competencies and regional growth in an important way. As a result, the so-called "Miracle of the Third Italy" seems to be a time-irreversible phenomenon, determined by structural lock-ins and specific trajectories.[171] As pointed out by Cooke (2001), some regional systems are better-equipped

[166] Hu, 2007: 77
[167] See also Moulaert and Sekia, 2003: 291, Iammarino, 2005: 499, Holbrook and Salazar, 2003: 10, DeBruijn and Lagendijk, 2005: 1154.
[168] Cooke, 2001: 949; Cooke and Memedovic, 2003: 3; Cooke's paradigm that outlines key characteristics of the governance structure (grassroots RSI/ network RSI/ dirigiste RSI) and the business innovation dimension (localist/ interactive/ globalized RSI) is often used for country specific purposes (Holbrook and Salazar, 2003: 12).
[169] Cooke, 2001: 949; Cooke and Memedovic, 2003: 1; In contrast to Cooke's estimations on Lundvall's opinion, Lundvall (2007) himself brings forward in a recent paper on NSI, that "*…there is a need to study not only the national level but also networks at, for instance, the local and regional level."* (Lundvall, 2007: 99). Similar arguments can be found in Borrás and Lundvall (1997), Amesse and DeBresson (1991), and Iammarino (2005).
[170] Cooke and Memedovic, 2003: 11; Cooke et al., 1997: 488; Holbrook and Salazar, 2003: 11
[171] Iammarino, 2005: 500-510; Cooke et al., 1997: 480; Evangelista et al., 2002: 176

than others and RSI tend to be located at different evolutionary points of systemic development.[172]

The cases of Emilia Romagna, Lombardia and Piemonte in Italy, the Midi-Pyrénées in France, California in the U.S., Singapore, and many other examples are approached by innovation scholars in many different but complementary ways (*Table 2, Appendix*).[173] An important work has also been done by Bjørn Asheim (2000) in analyzing SMEs in industrial districts in "Third Italy". Similar contributions followed by Bjørn Asheim and Lars Coenen (2004) on Nordic clusters. Similar to European studies on regional systems, Anna Lee Saxenian (1991, 1994) published famous articles on the case of Silicon Valley (CA) and Route 128 (MA). Similarly, Nancy Dorfman (1983) gained interest with her work on Route 128 and Alan Scott (1988) on Orange County (NY).[174]

Malmberg and Maskell (2005) argue that such local systems are determined by several dimensions of proximity. They emphasize that localized learning processes are heavily influenced by learning by interacting (vertical), learning by monitoring (horizontal) and some neighborhood-effects and local buzz (social dimension).[175]

Moreover, agglomeration phenomena are determined and differentiated by their composition of SMEs and MNEs and their underlying network set-ups.[176] It seems to be of great importance whether local firms are at the center of an agglomerated network, whether cities dominate a region, whether the region only serves as location site for production units within a dispersed network, or even whether the region represents a nodal point in a partly concentrated network.[177] Recent literature on Evolutionary Economic Geography is analyzing these issues.[178]

5.4 CONCEPTUAL AND EMPIRICAL PROBLEMS WITH MESO-LEVEL ANALYSES

Besides the above presented critical questions and suggestions, some authors challenge the way how agglomeration phenomena should be incorporated into SI conceptualizations.
Following several agglomeration phenomena, different RSI and geographically concentrated SSI exist within the same national institutional space. The differences are mainly determined

[172] Cooke, 2001b: 33; Cooke and Memedovic, 2003: 4
[173] Braczyk et al., 1998: 418; Cooke and Memedovic, 2003: 1
[174] Saxenian, 1991: 423; Feldman, 1994; Further storied examples of local agglomerations, technology parks and big city districts are for instance Cambridge (United Kingdom), Sophia-Antipolice near Nice (France), the M4 Corridor (United Kingdom), Tsukuba (Japan), Silicon Alley in New York (USA), or the Tsinchu Technology Park (Taiwan) (Feldman, 1996: 71-74; Cooke and Memedovic, 2003: 1).
[175] Malmberg and Maskell, 2005: 4-8
[176] Cooke and Memedovic, 2003: 11
[177] Storper and Harrison, 1991: 411
[178] See Boschma and Frenken (2006), Boschma and Frenken (2007) and Martin and Sunley (2007) for recent developments and modifications.

by regionally unique trajectories of capabilities, technology and knowledge diffusion. In this context, assumptions of an ideal SI seem unreasonable.[179]

Relying upon Cooke (2001) and some sub-groups within the academic community, the RSI approach may encompass many clusters and even bigger or smaller forms of industry and city agglomerations. Furthermore, the work of Cooke and his adherents contribute to a better understanding of the transformation, hierarchy, and order within and between agglomeration phenomena.[180] Anyhow, geography and innovation scholars accentuate several problems.

> *"Typically, this type of innovation systems analysis is the most specific both in terms of identifying geographic places and the actors (industries and firms) operating within those places. One serious problem with this area of research is the flexible definitions of clustering and the lack of agreement on appropriate measures of the scale of the phenomena (sub-metropolitan through to national macro clusters)." (Wixted, 2006: 9)*

A similar opinion is presented by Holbrook and Salazar (2003), who mention that the differences between RSI and clusters may not be clear at all. Following their definitions, a RSI could also be defined as a "cluster of clusters".[181] Hence, many locations and regions represent large and spanning complexes that consist of different industries and more than one economic cluster.[182] Cooke et al. (1997) and Cooke (2001) assume that there exists no successfully developed regional innovation system at all.[183]

> *"…within NSIs there are, prospectively, mosaics of more or less developed RSIs and, for reasons to be discussed, the latter seem likely to develop in importance, especially in Europe but conceivably also in other advanced economies." (Cooke et al., 1997: 477)*

Again the circumstance highlights the necessity of distinguishing between the theoretical and analytical sphere. The theoretical framework represents a logical construct, whereas the analytical system analysis refers to real phenomena and empirical comparisons.[184] In fact, operational systems vary because there exists no established agreement of how to define a region, a system or the major dimensions of partial system analysis.[185] In spite of the figured issues, regions, geographically-concentrated industries and metropolitan agglomerations are attracting increasing interest in different academic streams.[186]

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[179] Saxenian, 1999; Asheim and Gertler, 2005: 309; DeBruijn and Lagendijk, 2005: 1155
[180] Cooke, 2001b: 23; Cooke and Memedovic, 2003: 1-2
[181] Holbrook and Salazar, 2003: 10
[182] Cooke and Memedovic, 2003: 3; Due to this point of view, some authors prefer the definition of spatially concentrated sectoral systems of innovation (SSI) to RSI.
[183] Cooke, 2001b: 38; Cooke and Memedovic, 2003: 22
[184] Cooke and Memedovic, 2003: 6
[185] Consequently, some sub-groups state that operational and analytical system concepts do not need to feature clear-cut boundaries, identical compositions of actors, or equal network set-ups for analytical purposes (Cooke and Memedovic, 2003: 6). Additionally, NEG-adherents highlight these problems for empirical and conceptual work (Behrens and Thisse, 2006: 1).
[186] Cooke and Memedovic, 2003: 3

5.5 CONNECTIONS OF LOCAL SYSTEMS WITH NSI

As mentioned before, RSI are embedded in NSI in certain and specific ways. Some authors treat RSI as major linkages between the particular national system at the macro level, and, on the other hand, local clusters and districts at a very local scale.[187]

> *"It should not be forgotten, however, that nether-regional systems of innovation and economies of agglomeration have always under-pinned national systems from the beginning of the industrial revolution. […] Nevertheless, the interaction of national systems both with nether-region systems of innovation and with transnational corporations will be increasingly important, as will be the role of international cooperation in sustaining a global regime favourable to catching up and development." (Freeman, 1995: 21)*

Thus, some authors focus on the complementary relationships of NSI and RSI. Following Asheim and Gertler (2005), the region seems to represent an important level of economic processes between the national level and the level of individual clusters and firms. Consequently, regions are essential influencers at a subnational-level.[188] Regrettably, the institutional framework becomes less clear when moving downward from NSI to RSI and local issues.[189] Admittedly, some authors criticize the idea that national systems of innovation should be considered as a simple sum of regional systems and consequently they accuse the systems of innovation approach to be to a large extent nationally biased.[190] Moreover, different types of regions are related to unique set-ups and imply non-equal functional relationships of RSI and NSI.[191]

With respect to the uniqueness of local and regional set-ups, important insights on the structure of RSI emanate from works on governance structures. Such contributions on federal and local institutions and relationships are provided, for instance, by Holbrook and Salazar (2003) in the exemplary case of the Canadian Federation.[192] In such cases, RSI may differ in their capability of attracting federal R&D expenditures and national investment. Federations with certain combinations of autonomous and shared governments importantly determine regional and local performance in the course of time. In addition, the majority of S&T policy is formulated and decided at the national and supra-national level, although industrial development and innovation results are strongly regional in nature.[193] Consequently, the

[187] Freeman, 1995: 21; Holbrook and Salazar, 2003: 5; These ideas are also mentioned in Asheim and Coenen, 2004: 10, Iammarino, 2005: 498, Borrás and Lundvall, 1997: 39, Asheim and Gertler, 2005: 302, and Crescenzi and Rodríguez-Pose, 2005: 5.
[188] Asheim and Gertler, 2005: 299; Crescenzi and Rodríguez-Pose, 2005: 5; Cooke and Memedovic, 2003: 1
[189] For this reason, an exact definition of RSI and its boundaries (chapter 6) seems challenging and nearly impossible (Holbrook and Salazar, 2003: 1).
[190] Iammarino, 2005: 498; Analogous ideas are approached by Holbrook and Salazar (2003).
[191] Cooke and Memedovic, 2003: 4
[192] Holbrook and Salazar, 2003: 5
[193] Holbrook and Salazar, 2003: 2; this fact represents one incentive for policy makers to apply to geographically oriented policy instruments.

spatial effects of governmental policy promote regions in an unequal manner and could support core-periphery developments.[194]

6 OPENNESS, BOUNDARIES AND TACIT KNOWLEDGE

6.1 PROXIMITY, EXTERNALITIES AND GEOGRAPHY OF INNOVATION

A salient feature and additional issue is the fact that greater distance tends to decrease the frequency of economic activities and interactions among organizations and individuals. For this reason, intellectual and innovative activities can be enormously influenced by economic and geographical proximity.[195] This phenomenon is excellently phrased by Krugman (1991):

> *"Step back and ask, what is the most striking feature of the geography of economic activity? The short answer is surely concentration." (Krugman, 1991: 5, cited by Audretsch and Feldman, 1999: 410)*

Several sub-groups within the contemporary literature contribute to agglomeration economics in different ways and refer to the legacy of Marshall (1920), Young (1928) and other economists.[196] The assumption of economies external to the firm but internal to the industry achieved famous status as the so-called "MAR externalities".[197] Technological externalities are also modeled within the New Growth Theory.[198] Indeed, the concept of perfect knowledge externalities provoked substantial criticism.

Paci and Usai (2000) discuss two essential streams in the economic literature. The first sub-group assumes technological progress and knowledge as a pure public good and hence, knowledge spillovers are perfect and not locally bounded. Thus, they expect a wide and broad diffusion of knowledge between and within geographical units. On the contrary, a second pillar within the literature defends the idea of spatial proximity and costly transmission of knowledge across space. This group emphasizes distance decay effects of knowledge

[194] Feldman, 1996: 72; Holbrook and Salazar, 2003: 2-3; Iammarino, 2005: 498; For this reason see also Braczyk, Cooke and Heidenreich, 1998; Cantwell, 2005: 559; DeBruijn and Lagendijk, 2005).
[195] Malmberg and Maskell, 1999: 172; Geographical proximity and the influence on knowledge diffusion are also discussed in Asheim and Gertler, 2005: 291, Holbrook and Salazar, 2003: 14, Cooke and Memedovic, 2003: 9, DeBruijn and Lagendijk, 2005: 1154, Greunz, 2005: 450, Gertler, 2003: 75-99, Leamer and Storper, 2001: 649, Feldman, 1996: 71, Feldman, 1994: 2-8, Krugman, 1991: 5, Glaeser et al., 1992: 1127, Audretsch and Feldman, 1999: 410, and Leamer and Storper, 2001: 649.
[196] Hanusch and Pyka, 2007: 277
[197] MAR externalities correspond to the contributions of Marshall (1891), Arrow (1968), and Romer (1986, 1990).
[198] Greunz, 2005: 449, 467; Van der Panne, 2004: 594; Hu, 2007: 78; Besides knowledge externalities and LKS, scholars mainly discuss three additional explanations and ideas on agglomeration phenomena that are in the spirit of Alfred Marshall (1920): (1) local specialization and intra-industry agglomeration, (2) local supply of non-traded inputs by specialized suppliers, and (3) a skilled local labor pool (Hu, 2007: 78; Marshall, 1949: 152-153; Feldman, 1994: 3; Freeman, 1995: 21; Greunz, 2005: 450). Numerous studies have applied these MAR externalities, also known as intra-industry advantages, to get a better understanding of industry concentration, industry dynamics and the existence and development of metropolitan cities. Within literature, Henderson (1986), Glaeser et al. (1992), Krugman (1991), Black and Henderson (1999) and Fujita et al. (1999) are mostly cited. A survey on these empirical studies on LKS can be found, for instance, in Audretsch and Feldman (1999), Döring and Schnellenbach (2004), and Greunz (2005).

diffusion which support the just mentioned phenomena of spatial concentration and LKS.[199] Furthermore, this stream in literature differentiates between "MAR externalities" which refer to intra-industry specialization and "Jacobian externalities"[200] which specify inter-industry externalities.[201]

Both externality concepts seem to play the essential roles in the formation and exponential growth of agglomeration phenomena. Thus, these two types of LKS represent the rationale behind the economic and political attempts to create agglomeration incentives. According to this thinking, politicians apply spatial S&T-policy in order to establish technology parks, clusters, and science cities. However, one must annotate, that MAR externalities are almost entirely allocated to industrial agglomerations, and thus to intra-industry specialization and decreasing competition. Accordingly, only firms in the same industry are able to internalize these externalities.[202]

In contrast, Jacobian externalities represent inter-industry knowledge spillovers that originate from increasing geographical diversity and diversified local production structures. As a result, knowledge spills between different industries. Hence, accumulated knowledge of a specific industry can be applied in other industries.[203]

Moreover, firm size and spillovers are conjointly researched. Related to the analytical and operational system research, within and between countries, the local proportion of SMEs and MNEs within geographical areas represents an enormous tribe of innovation research.[204] The empirical fact that SMEs seem to be engines of innovative activity in several industries and regions, despite the lack of tremendous R&D spending, propels economic research in order to find the elementary drivers of regional innovative activity. The presented concept of spillovers and externalities could give a possible answer.[205]

> *"The empirical evidence presented in this study helps to resolve the seeming paradox posed by the recent wave of literature suggesting that small firms might be at least as innovative as their larger counterparts in certain industries. […] Thus, our findings suggest that small firms are able to innovate by exploiting knowledge created outside of the firm. In particular, research associated with universities apparently provides a fertile environment for small-firm innovative activity. […]While a link between R&D spillovers from universities to small firms has already been identified in the United States, it was not known whether such research externalities also existed in Europe. The results of this paper suggest that not only do such R&D spillovers exist but that they*

[199] Paci and Usai, 2000: 3; Crescenzi and Rodríguez-Pose, 2005: 6; Greunz, 2005: 465; Malmberg and Maskell, 2005: 2
[200] This definition goes back to the contribution of Jane Jacobs (1969) on urban LKS.
[201] Glaeser et al., 1992: 1127; Audretsch and Feldman, 1999: 410; Breschi and Lissoni, 2001: 29; Paci and Usai, 2000: 2; Döring and Schnellenbach, 2004: 2; As mentioned by some authors, common synonyms are "localization externalities" and "urbanization externalities". Nevertheless, some authors define MAR externalities and Jacobian externalities as dynamic externalities, whereas localization determinants only represent pecuniary externalities.
[202] Paci and Usai, 2000: 2; Breschi and Lissoni, 2001: 5; Greunz, 2005: 468
[203] Jacobs, 1969; See also Glaeser et al. 1992: 1127, Audretsch and Feldman, 1999: 410, Breschi and Lissoni, 2001: 4, Scott and Storper, 2003: 582, Greunz, 2005: 468 and Athreye and Werker, 2004: 513. It is obvious that the full scope of the LKS debate cannot be discussed in this paper.
[204] Audretsch and Vivarelli, 1996: 249-250; Scott and Storper, 2003: 583
[205] Audretsch and Vivarelli, 1996: 250; Breschi and Lissoni, 2001: 1; See also Cooke and Memedovic, 2003: 7, and Scott and Storper, 2003: 183.

are much stronger for small firms than for their larger counterparts." (Audretsch and Vivarelli, 1995: 256)

With reference to Greunz (2005), geographical and technological proximity seem to have important influence on intra- and inter-regional knowledge spillovers and flows of tacit (implicit) knowledge.[206] This idea of a very tacit and local nature of knowledge is analyzed in the next section with reference to some important and seminal contributions.

All the presented assumptions induce several severe problems in the context of RSI. Following Holbrook and Salazar (2003), urban areas and cities could represent the spatial centers of RSI.[207] In addition, many regional studies on districts, milieus and clusters normally explain incentives and causes of agglomeration on the basis of the just mentioned localization advantages and externalities, never mind, if these localized knowledge spillovers are of inter- or intra-industry type (*Table 2, Appendix*).[208]

6.2 INTRODUCING BOUNDARIES AND TACIT KNOWLEDGE

On expounding the various problems and conceptual ambiguities of the different systems of innovation frameworks, one should also refer to the major issues related to spatial borders and knowledge flows. These problems challenge both the analytical and theoretical sphere. Interorganisational networks and transborder linkages have grown considerably in their importance over the last decades, as mentioned by several authors.[209] Recent empirical studies and theoretical contributions in the spirit of RSI and the geography of innovation are, to an increasing extent, focusing on these intra- and inter-regional relationships. Especially their interest in trans-border interactions and inter-regional knowledge flows is highly visible.[210] This assumption is likewise supported by Cooke (2001), who highlights the hard feature that regional innovation does not operate in an insular way. Global, national and even local factors, especially agglomeration tendencies and inter-regional relationships affect innovation processes.[211] Consequently, these trans-border activities, geographical boundaries, such as national borders, are not always the appropriate ones for structural analyses in terms of an open system perspectives. However, empirical research on NSI still raises many questions related to feasible indicators and their coherence.[212] In some way, the spatial and functional

[206] Greunz, 2005: 458; Holbrook and Salazar, 2003: 10; Iammarino, 2005: 500; Audretsch and Vivarelli, 1995: 256
[207] Holbrook and Salazar, 2003: 14
[208] This dissent is, for instance, stated by Glaeser et al. (1992), Audretsch and Feldman (1999), Döring and Schnellenbach, 2004: 2, and Breschi and Lissoni (2001): *"…all the best-known studies on localised knowledge spillovers (LKS) (as surveyed by Feldman, 1999) seem to be unanimous in concluding that knowledge spillovers, either intra-industry or inter-industry, are important and strongly bounded in space."* (Breschi and Lissoni, 2001: 5)
[209] For an overview, see for instance Malmberg and Maskell, 1999: 172, Powell and Grodal, 2005: 79, Cooke et al., 1997: 485, Scott and Storper, 2003: 585, Steg, 200: 43, Leamer and Storper, 2001: 649-655, and also Gertler, 2003: 79.
[210] Greunz, 2005: 450
[211] Cooke et al., 1997: 480; Cooke, 2001b: 37
[212] Holbrook and Salazar, 2003: 9-11; Cooke and Memedovic, 2003: 10; Evangelista et al., 2002: 173; Carlsson and Stankiewicz, 1991: 111

boundaries of NSI can be defined comparatively easier than in the regional case because of well-established administrative state borders. This issue counts for both, theoretical and empirical research.

As already mentioned, the meaning of the term "region" is not clearly defined in the economic literature.[213] When economists assume open systems, regional boundaries and spatial settlements underlie dynamic processes and seem to be fluent.[214] As expected, regional set-ups can advance and change in economic, political, geographical, social, and generally speaking, systemic and hierarchical perspectives. Thus, boundaries of SI seem to be vague and blurred.[215]

Furthermore, the ICT revolution created knowledge infrastructures, such as pipelines for trans-border knowledge flows that facilitate the search, combination and recombination of different types of knowledge and information beyond boundaries.[216] Consequently, there is still a fruitful debate concerning the influence of geographical, technological, organizational and social proximity. This question is discussed in respect of the ongoing tendencies towards interconnected and footloose firms due to cyberspace.[217] Interestingly, literature and research cannot clearly answer whether cyberspace really substitutes proximity.

To achieve a strong connection between spatial proximity of economic activity and innovation results, scholars simply introduce the assumption of tacit and codified knowledge, as for instance recently mentioned by Lundvall (2007):

> *"A key difference between firms, sectors, regional and national systems is the role played by respectively codified and tacit knowledge in the innovation process." (Lundvall, 2007: 103)*

The idea of tacitness goes back to Michael Polanyi's (1966) work, *The Tacit Dimension*. He introduced this crucial distinction between tacit (implicit) and codified (explicit) knowledge. The underlying "stickiness" is mainly supported by three assumptions: (1) difficulties in exchanging knowledge over long distances, (2) a context-specific nature that needs common social, organizational and even institutional set-ups, and (3) the necessity of organized learning processes.[218] If there is an increasing belief in stickiness and thus a substantial need of geographical, technological, or even organizational proximity for economic interaction, tacit knowledge and implicit face-to-face contacts and "handshakes" can explain economic agglomeration phenomena and the geography of innovation.[219] The

[213] Freeman, 1995: 20
[214] Edquist, 2001: 2
[215] Cooke and Memedovic, 2003: 3; Carlsson and Stankiewicz, 1991: 103; However, fuzzy boundaries are always built upon fuzzy partial system views.
[216] Fagerberg, 2006: 21; Greunz, 2005: 450; Leamer and Storper, 2001: 652; Gertler, 2003
[217] Greunz, 2005: 465; Cooke, 2001: 965; Malmberg and Maskell, 2005: 1
[218] Polanyi (1966); For an overview, see additionally Hanusch and Pyka, 2007: 282, Senker, 1995: 426, Gertler, 2003: 77, Winter, 2005: 35, Malmberg and Maskell, 1999: 172, Döring and Schnellenbach, 2004: 4, or Malmberg and Maskell, 2005: 4.
[219] Malmberg and Maskell, 2005: 4-6; Gertler, 2003: 77; Carlsson and Stankiewicz, 1991: 104; Lundvall, 2007: 103; Greunz, 2005: 460; Summaries and discussions on this issue can also be found, for instance, in Breschi and Lissoni (2001), Powell and Grodal (2005), Crescenzi and Rodríguez-Pose (2005), Greunz (2005), and Iammarino and McCann (2006).

concept of tacitness is also used, for instance, by Audretsch (1998), and Malmberg and Maskell (1999) in connection with the already presented concept of LKS.

> *"…the theory of knowledge spillovers, derived from the knowledge production function, suggests that the propensity for innovative activity to cluster spatially will be the greatest in industries where tacit knowledge plays an important role. […] it is tacit knowledge, as opposed to information, which can only be transmitted informally, and typically demands direct and repeated contacts." (Audretsch, 1998: 23)*

> *"Though often overlooked, a logical and interesting consequence of the present development towards a global economy is that the more easily codifiable (tradable) knowledge can be accessed, the more crucial does tacit knowledge become for sustaining or enhancing the competitive position of the firm […] In other words, one effect of the ongoing globalisation is that many previously localised capabilities and production factors become ubiquities. What is not ubiquified, however, is the non-tradable/ non-codified results of knowledge creation – the embedded tacit knowledge that at a given time can only be produced in practice. The fundamental exchange inability of this type of knowledge increases its importance as the internationalisation of markets proceeds." (Malmberg and Maskell, 1999: 172)*

Consequently, local collective learning processes and localized knowledge creation, which are mainly based upon tacit knowledge, may represent an important premise for the competitiveness and attractiveness of spatially concentrated regions.[220] In addition, regions, industry-specific agglomerations, and even RSI are caught between two different developments that, once again, transform them into "boundary objects". On the one hand, trans-border flows of knowledge support the idea of a certain degree of openness and absorption capacity of regional systems of innovation.[221] This idea is also formulated by Camagni (1991):

> *"…technological innovation […] is increasingly a product of social innovation, a process happening both at the intra-regional level in the form of collective learning processes, and through inter-regional linkages facilitating the firms access to different, though localised, innovation capabilities." (Camagni, 1991: 8)*

On the other hand, institutional, social, technological, geographical boundaries, tacitness of knowledge, and consequently the (different) needs of proximity could diminish a broad diffusion and exchange of knowledge. Tacitness then could decrease inter-regional and inter-sectoral interactions. This feature is also displayed by some sub-groups within the literature.

> *"This is fundamental to Lundvall and Johnson's (1994) learning economy thesis, and is especially well reflected in their concept of "learning through interacting". When one combines these two features of the innovation process – the centrality of "sticky", context-laden tacit knowledge and the growing importance of social interaction – it becomes apparent why geography now "matters" so much." (Gertler, 2003: 79; see also Asheim and Gertler, 2005: 293)*

[220] This conclusion can also be found in Paci and Usai, 2000: 5, Malmberg and Maskell, 1999, Crescenzi and Rodríguez-Pose, 2005: 5-6, Asheim, 1995: 8, Malmberg and Maskell, 2005: 4-6, and Hanusch and Pyka, 2005: 11.
[221] Asheim and Gertler, 2005: 292-293; Malmberg and Maskell, 2005

Consequentially, spatially concentrated SSI and RSI seem to be determined by both features. Proximity facilitates local knowledge creation and its exchange and diffusion. Additionally, inter-regional flows of knowledge via pipelines reinforce the stock of available knowledge.[222] If core-periphery formation is unwanted, the necessity of face-to-face-interaction may foster policymakers to enhance the mobility of human capital.

Nevertheless, the existence of inter-regional knowledge flows and especially the effect of externalities should not be considered to be totally free of charge. This assumption is emphasized, for instance, by Greunz (2005):

> *"Absorption capacity is a necessary condition for the region to capture knowledge created elsewhere and to benefit from knowledge spillovers. In this sense, public policy should mainly focus on the underlying conditions of absorption capacity such as the development of highly qualified human capital, the promotion of life-long learning […], especially in less favoured regions." (Greunz, 2005: 465)* [223]

Some authors additionally suppose that regions sometimes suffer from the lack of these absorptive capabilities and capacities. These local circumstances are path-dependent. RSI and local SSI then could generate networks for advancing their capabilities.[224] As a result, the transfers of knowledge seem to be productive and necessary if organizations, such as firms, are able to combine different capabilities.[225] Besides this point, the degree of openness of these local SSI and RSI is essential for catching-up trials and future economic development (*Figure 1, Appendix*).

Besides these points, the success of regional networks depends to an increasing degree on the regions' capability to adjust as a "nodal point" within national and trans-national production and knowledge systems.[226] Especially those regions which suffer from weak and not well-established supportive organizational set-ups may benefit from inter-regional knowledge flows and spillovers.[227]

7 SUMMARY AND CONCLUSIONS

This survey primarily attempts to give a literature review and to highlight the tremendous quantity of contributions which established, diffused and extended the systems of innovation concept within the economic literature and policy sphere.

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[222] In addition, Asheim and Gertler (2005) analyze some varieties of the classical taxonomy that classify industrial knowledge into analytical (scientific) knowledge, which heavily depends on codified knowledge flows. Synthetic knowledge, in contrast, is mainly influenced by tacit knowledge. Once again, similar to the latter assumptions, stickiness and localized knowledge represents the rationale for geography of innovation (Asheim and Gertler, 2005: 296; Powell and Grodal, 2005: 76; Crescenzi and Rodríguez-Pose, 2005: 6; Iammarino and McCann, 2006: 1021).

[223] One could also interpret this criticism that public policy should only support and underpin localized developments without energetic and active purpose.

[224] Iammarino, 2005; Greunz, 2005; Asheim and Gertler, 2005

[225] Powell and Grodal, 2005: 77; Crescenzi and Rodríguez-Pose, 2005: 16

[226] Heidenreich, 2004: 369

[227] Cooke and Memedovic, 2003: 4

Besides nation-state issues, important and challenging conceptualizations at the technological, sectoral, regional, trans-national and global level have been increasingly supported by various adherents during the last twenty years. However, accuracy, attention, foci, and objectives extremely differ within the discussed literature, due to differing partial-analytic views and intentions (*Figure 1 and Table 2, Appendix*). The existing ambiguity and the expounded dissents are not only related to the diverse definitions and understandings of the terms "organizations" and "institutions". This paper also approaches the assumption that the system concept represents a "boundary object", captured between differing academic objectives and prescribed S&T-goals.

It is also emphasized that systemic interaction and path-dependent processes affect innovation in a country-specific and unique way, assuming non-optimality of systems. Besides definitional difficulties, organizational and institutional set-ups vary to a high extent among countries and regions. Institutions such as laws, norms, rules and routines are not unique. Consequently, concepts of systems of innovation widely differ in their potential dimensions due to subjective partial analysis. As shown by evolutionary economists and analyzed by contemporary research, historical events and economic activities induce trajectories which are time-irreversible. This feature applies, above all, on systemic and localized learning, on knowledge creation, and its diffusion and exchange.

The studied different levels of SI which have been analyzed in *chapter 3, 4 and 5* do not support a consistent and general definition, but the presented conceptualizations have their own authorizations. Finally, the discussed conceptual differences evolve from different objectives. Additionally, the conceptualizations are rather complements. Depending on the particular interest, the complementary approaches and underlying theories should be combined to avoid one-way insights from regions, nations and trans-border-interactions. These ideas would cause a combination of micro-, meso- and even macro-level analyses. This necessity is moreover justified by the dilemma that nation-state activities, sectoral and technological events, and regional features can not be clearly separated and independently analyzed. Thus, geographical agglomerations correspond to a certain regional system of innovation. However, these spatial phenomena also have to be analyzed in a sectoral manner.

Future research efforts should increasingly engage in analyzing and theorizing the peculiar relations between RSI, SSI and NSI. Additionally, economists have to survey if RSI and spatially concentrated SSI are superior, in a hierarchical sense, to production clusters, districts and other forms of economic agglomeration. Moreover, academic research should challenge the different types of externalities that can occur within SI. Furthermore, researchers should feel defiant to study if the core of SI is in some cases rather related to metropolitan areas and cities. In addition, scholars should further on examine knowledge spillovers between SMEs, and even MNEs. Although these questions are primarily empirical ones, economic theory would also benefit.

Anyhow, economic literature on SI is still lacking of a variety of formal and mathematical models that combine ideas out of economic geography and endogenous growth theory with evolutionary assumptions. These ideas and comments represent severe issues and an existing dissent within the economic literature, especially covering the problem of defining and analyzing boundaries of SI. In this regard, the definition of a region and its boundaries represents a hard challenge in formal modeling and empirical research (*Figure 1, Appendix*).

Moreover, researchers should increasingly focus on inter-regional and inter-industry knowledge flows, international and global knowledge pipelines, and primarily on knowledge flows between different agglomerated SI. Scholars should also study how these locally concentrated systems could be modeled, analyzed and compared. Therefore, New Economic Geography Growth models (NEGG) and Evolutionary Economic Geography (EEG) can both contribute with simulation studies. Consequently, the paper centers the substantial necessity for analyzing the linkages, relationships, subordinations and the order within and between RSI, SSI and NSI. This consideration also counts for the trans-national, respectively global case.

Finally, growth theorists and economic geographers are challenged to analyze various problems linked to the concept of tacit knowledge: its production and allocation, its absorption, diffusion and exchange.

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APPENDIX

"...the network of institutions in the public and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987: 1)

"...a system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state. […] This implies, for example, that a foreign-owned firm will be part of two different national systems – its home country and its host country." (Lundvall, 1992: 2, 18)

"...all interrelated, institutional and structural factors in a nation, which generate, select, and diffuse innovation." (Johnson, 1992: 39)

"...the set of institutions whose interactions determine the innovative performance of national firms." (Nelson and Rosenberg, 1993: 4)

"...the national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society." (Edquist and Lundvall, 1993)

"...a national system of innovation is the system of interacting private and public firms, universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, production, financing or regulation." (Niosi et al., 1993)

"...the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning or the volume and composition of change generating activities in a country. (Patel and Pavitt, 1994)

"A national system of innovation is that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies." (Metcalfe, 1995: 38)

"...the network of public and private institutions within an economy that fund and perform R&D, translate the results of R&D into commercial innovations and affect the diffusion of new technologies." (Mowery and Oxley, 1995: 80)

"...a system which includes all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations." (Edquist, 1997: 14)

"...the network of institutions in the public and private sectors of each country that support the initiation, modification and diffusion of new technologies." (Cantwell, 1999: 238)

"...beyond firms, other factors and actors play a role in favoring the diffusion and economic exploitation of knowledge, such as the presence of networks among firms, appropriate financial institutions, technical agencies and R&D public infrastructures, the capacity of the education and training system to up-grade and re-shape skills and competences, and the presence of appropriate and effective innovation policies." (Evangelista et al., 2002: 173)

"NSI is thus a set of interrelated institutions; its core is made up of those institutions that produce, diffuse and adapt new technical knowledge, be they industrial firms, universities, or government agencies. The links

between these institutions consist of flows: knowledge, financial, human (people being the bearer of tacit knowledge and know-how), regulatory, and commercial." (Niosi, 2002: 291)
"The innovation system approach considers innovation as an interactive process among a wide variety of actors." (Malerba, 2005: 65)
"... there seems to be general agreement that the main components in SIs are organizations – among which firms are often considered to be the most important ones – and institutions. However, the specific set-ups of organizations and institutions vary among systems." (Edquist, 2005: 189)
"...set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and [...] it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts, which define new technologies." (Carlsson, 2006: 58)

TABLE 1: SELECTED DEFINITIONS OF SYSTEMS OF INNOVATION IN THE LITERATURE

SOURCE: AUTHOR'S OWN ILLUSTRATION

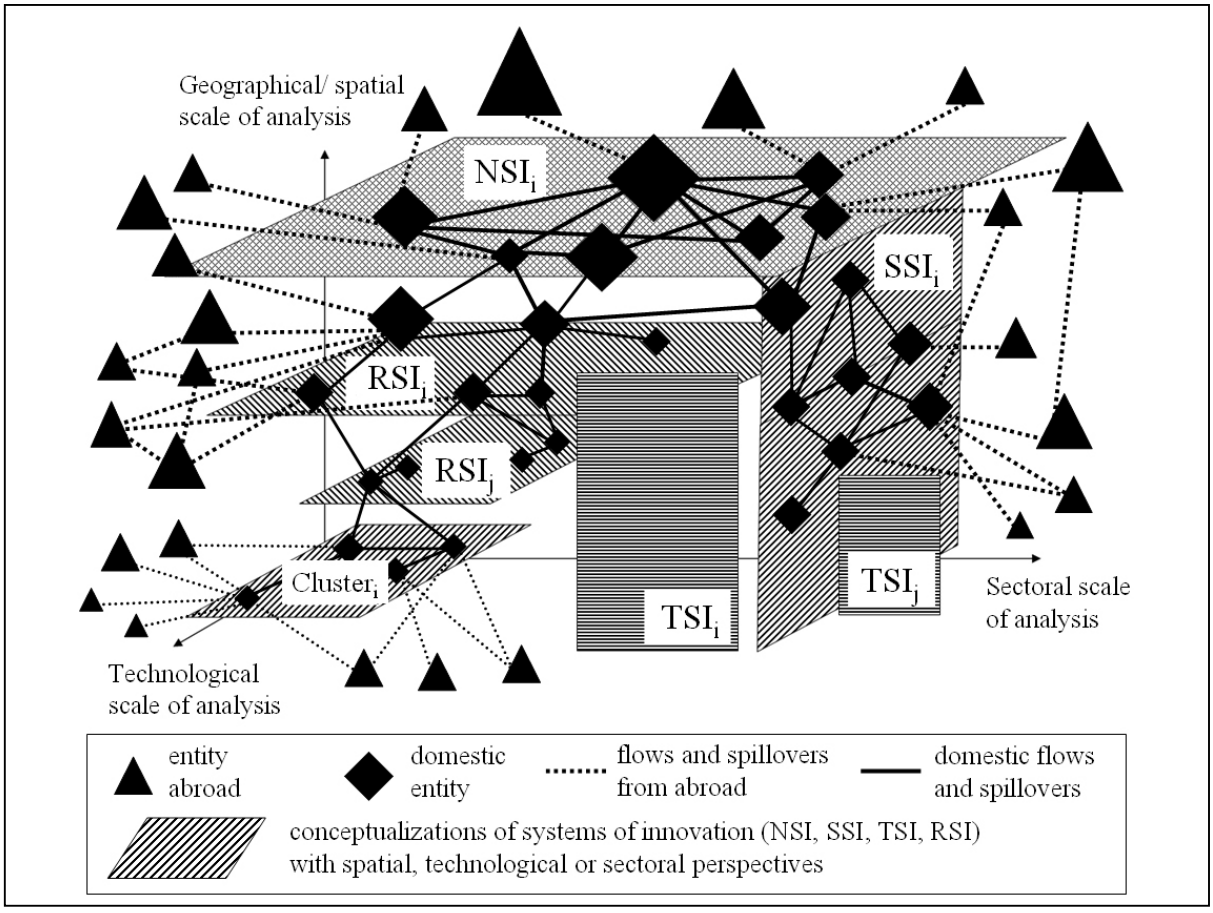

FIGURE 1: CONCEPTUALIZATIONS OF SYSTEMS OF INNOVATION

SOURCE: AUTHOR'S OWN ILLUSTRATION

THEORETICAL APPROACH	CERTAIN KEY POINTS	SELECTED REFERENCES
CLASSICAL AGGLOMERATION THEORY, GEOGRAPHICAL ECONOMICS	• External economies of scale • Urbanization vs. localization economies • Labor market pooling, input sharing, technology spillovers, diversity • Agglomeration and industry location • Inter-industry linkages and interdependencies • Industrial complex analysis, growth poles	THÜNEN (1826), MARSHALL (1920), WEBER (1929), OHLIN (1933), HOOVER (1937), MARSHALL (1949), ISARD (1956), PERROUX (1970); see MOULAERT AND SEKIA (2003) and SCOTT AND STORPER (2003) for detailed reviews
INDUSTRIAL DISTRICT, TECHNOLOGICAL DISTRICT, INNOVATIVE MILIEU	• Agglomeration and industry location • Italian Industrial Districts (SMEs), Third Italy • Innovative Milieu, France (GREMI)	CAMAGNI (1991), ASHEIM (1995), MOULAERT AND SEKIA (2003), IAMMARINO (2005)
FLEXIBLE SPECIALIZATION SCHOOL	• From economies of scale to flexible forms of industrial organization • Post-Fordist production • Localized interdependencies, proximity • Embedding the economic within the social, cultural and institutional structures • Industrial organization and business culture	BRUSCO (1982), PIORE AND SABLE (1984), SCOTT (1988), SAXENIAN (1991), SAXENIAN (1994), STORPER (1995)
NATIONAL INNOVATION SYSTEMS (NSI)	• Nation-state level analysis and theorizing • Learning, interaction of organizations • Institutional and organizational set-ups • Trajectories and path-dependencies • Knowledge (input), learning (process)	FREEMAN (1987), DOSI ET AL. (1988), LUNDVALL (1988), LUNDVALL (1992), NELSON (1993), NELSON AND ROSENBERG (1993), NIOSI ET AL. (1993), PATEL AND PAVITT (1994), FREEMAN (1995), EDQUIST (1997), OECD (1997), FREEMAN (2002), LUNDVALL ET AL. (2002), EDQUIST (2005), FAGERBERG (2005), FAGERBERG (2006), SHARIF (2006), LUNDVALL (2007)
SECTORAL INNOVATION SYSTEMS (SSI)	• Sectoral partial analysis, theorizing • Knowledge (input), learning (process) • Sectoral perspective; industry set-up • Sectoral knowledge base • Geographical-concentrated sectoral systems	PAVITT (1984), BRESCHI AND MALERBA (1997), MALERBA (1999), BRESCHI AND MALERBA (2001), MALERBA (2002), MALERBA (2005), CASTELLACCI (2006)
TECHNOLOGICAL INNOVATION SYSTEMS (TSI)	• Knowledge (input), learning (process) • Technological perspective • Technological knowledge base	CARLSSON AND JACOBSSON (1993), CARLSSON AND STANKIEWICZ (1991), METCALFE (1995), CARLSSON (1996), CARLSSON ET AL. (2002), CARLSSON (2006)
REGIONAL INNOVATION SYSTEMS (RSI), LEARNING REGIONS	• Local and regional issues of the geography of innovation • Knowledge economy; localized knowledge • Knowledge and collective learning • Tacit vs. codified knowledge • Localized patterns of knowledge creation, diffusion, learning and innovation • Localized knowledge spillovers • Regional capabilities, absorptive capacity	COOKE ET AL. (1997), ASHEIM (1998), BRACZYK ET AL. (1998), COOKE AND MORGAN (1998), COOKE (1998), MALMBERG AND MASKELL (1998), COOKE (2001), ISAKSEN (2001), LEAMER AND STORPER (2001), ASHEIM AND ISAKSEN (2002), EVANGELISTA ET AL. (2002), HOLBROOK AND SALAZAR (2003), SCOTT AND STORPER (2003), ASHEIM AND GERTLER (2005), IAMMARINO (2005), MALMBERG AND MASKELL (2005), CRESCENZI AND RODRIGUEZ-POSE (2006), IAMMARINO AND MCCANN (2006)
CLUSTER APPROACH	• Competitiveness, specialization and competition • Clusters and regional competitive advantage • Cooperation and rivalry • Regional resources and infrastructure	PORTER (1990), PORTER (1998); for a critical survey see MARTIN AND SUNLEY (2003)
DYNAMIC EXTERNALITIES,	• Knowledge spillovers and endogenous growth • Ideas, education, research, and institutions	MARSHALL (1920), JACOBS (1969), ROMER (1986), LUCAS (1988), GLAESER ET AL.

(LOCALIZED) KNOWLEDGE SPILLOVERS	• MAR externalities vs. Jacobian externalities • Monopoly vs. competition • Diversification vs. specialization • Geographical proximity • Technologically and geographically mediated knowledge spillovers • Empirical research vs. theorizing	(1992), HENDERSON ET AL. (1995), AUDRETSCH AND FELDMAN (1996), AUDRETSCH (1998), AUDRETSCH AND FELDMAN (1999), FELDMAN (1999), FELDMAN (2000), PACI AND USAI (2000), BRESCHI AND LISSONI (2001), ATHREYE AND WERKER (2004), DÖRING AND SCHNELLENBACH (2004), GREUNZ (2005)
NEW ECONOMIC GEOGRAPHY (NEG)	• Pecuniary externalities • Agglomeration economies and diseconomies • Agglomeration and regional distribution of income and wealth; core-periphery structure • Increasing returns and imperfect competition	KRUGMAN (1991), VENABLES (1996), FUJITA AND THISSE (2002), BEHRENS AND THISSE (2006); see LITZENBERGER (2007) for a detailed literature review; see BOSCHMA AND FRENKEN (2006) for a critical survey
NEW ECONOMIC GEOGRAPHY GROWTH MODELS (NEGG)	• Transaction costs of ideas; technol. externalities • Core-periphery structure and endogenous growth • Global and localized knowledge spillovers • Agglomeration and regional distribution of innovative activity (patents) • Increasing returns and imperfect competition	BALDWIN AND FORSLID (1999), BALDWIN AND MARTIN (2004)
EVOLUTIONARY ECONOMIC GEOGRAPHY (EEG)	• Agglomeration and spatial distribution of economic activity, growth differences • Tacit and codified knowledge • Learning, routines, regional capabilities • Appreciative theorizing and formal modeling	BOSCHMA AND FRENKEN (2006), BOSCHMA AND FRENKEN (2007), MARTIN AND SUNLEY (2007)

TABLE 2: SUMMARY OF THEORETICAL APPROACHES AND STUDIES TO AGGLOMERATION AND THE GEOGRAPHY OF INNOVATIVE ACTIVITY

SOURCE: AUTHOR'S OWN ILLUSTRATION