

SYSTEMS OF INNOVATION: A SURVEY OF THE EVOLUTION

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Agenda

- 1. Introduction**
- 2. Systems of innovation (SI): first definition, roots and heritage**
- 3. National systems of innovation (NSI)**
- 4. Sectoral and technological systems of innovation (SSI, TSI)**
- 5. Regional systems of innovation (RSI)**
- 6. Boundaries and proximity**
- 7. Conclusion and Summary**

1. Introduction

Why advancing systems of innovation?

Main idea:

Creating a framework/ an approach in order to understand, describe and analyze innovation as a process of learning and interacting, based on knowledge, on heterogeneity of organizations and institutions, and on dynamic evolution in the course of time.

“...(a SI) 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)

“...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).

2. Systems of Innovation: roots and heritage

Intent and definitions of “systems of Innovation”?

“Innovation is shaped by *institutions and institutional change*. This process can be analysed in terms of national systems of innovation, reflecting that *nations differ in institutional set ups*” (Johnson, 1992: 23, 38).

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

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

“...the national institutions that determine the rate and direction of technological learning” (Patel and Pavitt, 1994)

“A national system of innovation is a set of institutions that contribute to the development and diffusion of new technologies and influence the innovation process, store and transfer the knowledge, skills and information” (Edquist, 1997: 14)

“...the network of public and private institutions that create, store and transfer the results of R&D into commercial innovations and affect the diffusion of new technologies.” (Mowery and Oxley, 1995: 60)

“...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)

“...a *set of interrelated institutions* [...] core is made up of those institutions that produce, diffuse and adapt new technical knowledge, be they industrial firms, universities, or government agencies (Niosi, 2002: 291).

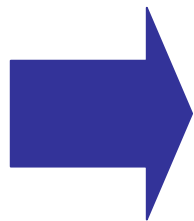
“The *links between these institutions consist of flows*: knowledge, financial, human (people being the bearer of tacit knowledge and know-how), regulatory, and commercial.” (Niosi, 2002: 291)

Many
definitions and contributions
during the last 20 years

2. Systems of Innovation: roots and heritage

Intent and definitions of “systems of Innovation”?

“...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**)



Importance of “organizations” and “institutions”, but literature unfortunately blurs the essential meanings
(**Edquist, 2005: 188**).

3. National systems of innovation: NSI

Is there a general definition of SI?

“They (organizations) are players or actors [...] firms, universities, venture capital organizations and public agencies responsible for innovation policy, competition policy or [...] 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)

2. Systems of Innovation: roots and heritage

Intellectual roots of SI: The Heritage of Schumpeter

Most authors within the academic community relate on:

“Theory of Economic Development” and *“Capitalism, Socialism and Democracy”*

Innovation as a **new product**, a **process**, or a **new combination**.

Five types: new products, new methods of production, new sources of supply, exploitation of markets, and new ways of organize business

Pioneers, early adopters and imitators

(see, for instance, Lundvall et al., 2002: 223; Lundvall, 2007; Edquist 2005; Fagerberg, 2005).

2. Systems of Innovation: roots and heritage

Intellectual roots of SI: The Heritage of Schumpeter

- Entrepreneurs, creative destruction and monopolistic Schumpeterian competition due to **small and medium enterprises (SME)**, “Wild Spirits”
- In-house corporate research and development activities, efforts of **large firms**, (also **MNE**)
- Contemporary authors: “**Mark I**” model of innovation and the “**Mark II**” case
- Today: **rather complements**

(Audretsch and Fritsch, 2002: 114; Cantwell, 2001: 3; Malerba, 2005: 382)

2. Systems of Innovation: roots and heritage

Intellectual roots of SI: The Heritage of Friedrich List

Friedrich List (1841):

“*The National System of Political Economy*” contributed a lot for a better understanding of innovation and innovation policy (**Freeman, 1995: 6**).

List’s national system of production:

A wider set of institutions at the national level, including education, training and supporting infrastructures, networks of transportation of commodities and people.

Accumulation of “mental capital”.

(see, for instance, Lundvall, 2007: 113; Freeman, 2002: 192; Cooke, 2001: 949; Lundvall et al., 2002: 214; Carlsson, 2006: 753; Sharif, 2006: 751).

2. Systems of Innovation: roots and heritage

The contribution of Evolutionary Theory:

The Schumpeterian ideas influenced:

“*An Evolutionary Theory of Economic Change*”, published by Richard Nelson and Sidney Winter (1982).

Industrial dynamics, knowledge-based firms, organizational memory, and differing technological regimes in the course of time

Bounded rationality, heterogeneous actors, and innovation as a collective process (**Hanusch and Pyka, 2007: 276-278**)

(Nelson and Winter, 1982: 258-9; Winter, 1984: 297); Contemporary authors are importantly inspired (Fagerberg, 2005: 17; DeBrujin and Lagendijk, 2005: 1154; Lipsey, Carlaw and Bekar, 2005: 31; Audretsch and Fritsch, 2002: 114;).

2. Systems of Innovation: roots and heritage

The contribution of neo-Schumpeterian economics:

“...neo-Schumpeterian economics today figures most in studies of innovation and learning behaviour at the micro level of an economy, in studies of innovation-driven industry dynamics at the meso-level, and in studies of innovation-determined growth and international competitiveness at the macro level of the economy.” (Hanusch and Pyka, 2007: 276)

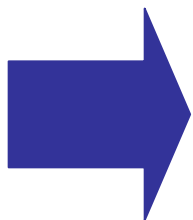
3. National systems of innovation: NSI

From the “linear model“ to systems:

Criticism on linear model of innovation and “big science”:
the “Manhattan Project”

Problems with (one-way) linearity:

- growth/ innovation results as simple chain reactions of R&D efforts and expenditures
- performance and innovativeness presented as a simple input-output-relation
- general chain of causation and identical stages
- without considering varieties, feedbacks and loops



“...innovation is neither smooth nor linear, nor often well behaved.” (Kline and Rosenberg, 1986: 285)

3. National systems of innovation: NSI

Who contributed to literature on NSI?

Freeman (1974), *“The Economics of Industrial Innovation”*
Expression *“systems of innovation”* (SI) in Lundvall (1985),
“Product Innovation and User-Producer Interaction”

Expression *“national systems of innovation”* (NSI):

Freeman’s (1987), *“Technology Policy and Economic Performance”*.

Freeman (1988), Nelson (1988) and Lundvall (1988), published in
Dosi et al. (1988), *“Technical Change and Economic Theory”*.

Complementary to Lundvall (1992): Nelson and Rosenberg (1993)
“Technological Innovation and National Systems”

Nelson (1993), *“National Innovation Systems: A Comparative
Analysis”*

Edquist (1997): *“Systems of Innovation. Technologies, Institutions
and Organizations”*.

(Cooke, 2003: 5; Edquist, 2005: 183-185; Fagerberg, 2002: 8; Fagerberg, 2005: 12; Steg, 2005: 5).

3. National systems of innovation: NSI

Confusion within literature on NSI?

Conceptual diffuseness within the SI literature:

Several SI definitions - nuances vs. core features

Economists mainly mean different things when referring to a national system of innovation (broader vs. narrow approaches)

Operational vs. theoretical system in the narrow/ broader sense

Systems of innovation as a “boundary object” (Sharif, 2006)

Emergence of SI in both, the academic literature and the policy sphere.

SI concept must be kept open and flexible (Lundvall, 2007: 99)

Do we have to draw a clear line and define clear boundaries?

(Edquist, 2005: 185; Lundvall, Edquist, Johnsson, 2003: 4)

3. National systems of innovation: NSI

Are there any optimal NSI?

Non-optimality of systemic interaction at all.

Conditions can change due to historical perspectives and evolutionary theory.

“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)

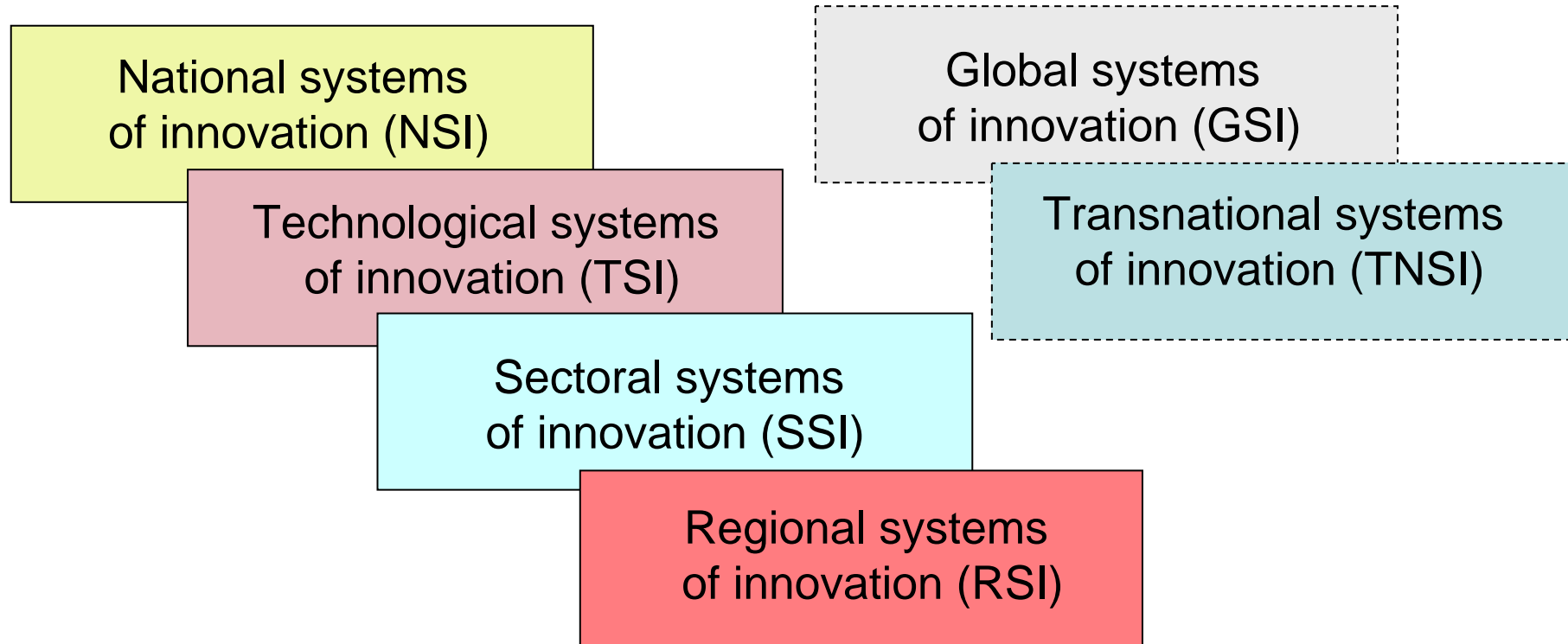
Federal structures differ in cross-country comparison.

“We do not even know whether the potentially ‘best’ or ‘optimal’ trajectory is being exploited at all, since we do not know which one it would be. This means that the notion of optimality is irrelevant in a system of innovation context.” (Edquist, 2001: 15)

(Cooke, 2001: 952; Cooke and Memedovic, 2003: 3; Lundvall, 2007: 107; Johnson, 1992: 23, 38; Edquist, 2005: 185, 193).

3. National systems of innovation: NSI

On the way towards complementary systems:



*“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); Freeman (1995); Freeman (2002); Malerba (2005); Cooke and Memedovic (2003)

4. Sectoral and technological systems of innovation

Why fostering sectoral systems of innovation?

“...leaving the geographical dimension, we can also talk about sectorally delimited systems of innovation, i.e. systems that include only a part of a regional, a national, or an international system.” (Edquist, 2001: 14)

“Hence, specific technologies or product areas define the boundaries of sectoral systems, [...] but they must also be geographically delimited.” (Edquist, 2001: 14).

The structures and types of networks and relationships differ between sectoral systems (Lundvall, 2007: 108).

4. Sectoral and technological systems of innovation

Sectoral systems of innovation

Breschi and Malerba (1997): “*Sectoral Innovation Systems, Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries*”.

Organizations, especially firms co-evolve in specific sectors and represent sources of new technologies and innovation

Sectoral systems of innovation have a knowledge base, technologies, inputs and a (potential or existing) demand.

Industries (sub-sectors) or broader sectors of fundamental interest for analysis (**Malerba, 2005: 69**).

(Edquist, 2005: 184; Breschi and Malerba, 1997; Malerba, 2005: 64-65; Malerba, 2002: 248)

4. Sectoral and technological systems of innovation

What are technological systems?

Carlsson and Stankiewicz (1991):

“On the nature, function, and composition of technological systems”

Focusing on technological systems by centering technology fields

Interestingly:

technological systems are spatially correlated and agglomerative phenomena like Route 128 or Silicon Valley represent regional, not national systems

5. Regional systems of innovation

Why focusing regional systems of innovation?

NSIs are theorized, conceptualized and analyzed mainly at the macro-level, ignoring phenomena at the meso-level.

Institutional set-ups, organizations, linkages and flows within local and regional structures differ enormously from the national levels.

Regions within one country differ tremendously in their local set-ups (institutions and organizations).

Problems with national systems and systemic interaction at the nation-state and sectoral level:



Several major regional phenomena that influence innovation processes seem to be suppressed and ignored

(Joung Hae Seo, 2006: 3; Cantwell, 2005: 557; Iammarino, 2005: 498; Evangelista, Iammarino, Mastrostefano and Silvani, 2002: 174; Holbrook and Salazar, 2003: 2)

5. Regional systems of innovation

The Emergence of regional systems of innovation

Remarks of Freeman and Lundvall:

“It should not be forgotten, that nether-regional systems of innovation and economies of agglomeration have always underpinned national systems...” (Freeman, 1995: 21)

“...the interaction of national systems both with nether-region systems of innovation and with trans-national corporations will be increasingly important...” (Freeman, 1995: 21)

“...a need to study not only the national level but also networks at, for instance, the local and regional level.” (Lundvall, 2007: 99).

“The region is increasingly the level at which innovation is produced through regional networks of innovators, local clusters and [...] research institutions.” (Lundvall and Borrás, 1999: 39)

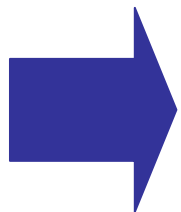
5. Regional systems of innovation

Problems and challenges with RSI?

Regrettably, the institutional framework becomes less clear when moving downward from NSI to RSI/ local issues (**Holbrook and Salazar, 2003: 1**).

The meaning of the expression “region” is not clearly defined (**Freeman, 1995: 20**).

The **geographical boundaries** of regional innovation systems (RSI) are regions **within countries** or include **parts of different countries** (Edquist, 2001; Cooke, Gomez Uranga and Etxebarria, 1997; Braczyk, Cooke and Heidenreich, 1998; Asheim, 1999 and Cooke, 2000).



A clear-cut definition of RSI and its (spatial and functional) boundaries seems **challenging**

5. Regional systems of innovation

Problems and challenges with RSI?

Further problems within the RSI conceptualization:

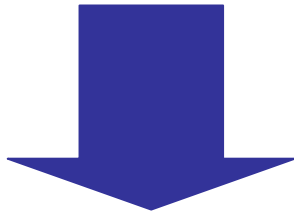
- The lack of essential data at the sub-national level for empirical analyses and comparisons
- Measurement and modelling of:
 - inter- and intra-regional knowledge spillovers (due to proximity)
 - inter- regional knowledge flows
 - localized learning capabilities and absorptive capacities

(Evangelista, Iammarino, Mastrostefano and Silvani, 2002: 173-174; Greunz, 2005: 457; Narula and Zanfei, 2005: 328,...).

5. Regional systems of innovation

How to build regional systems of innovation?

The theoretical and operational approach on RSI contains *several ideas and key concepts*:



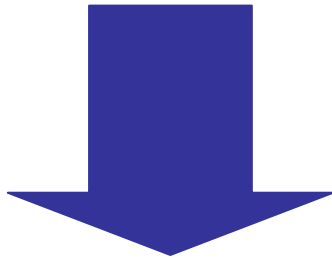
- (1) the concept of regions
- (2) evolutionary (history friendly) theory of innovation
- (3) networks and linkages
- (4) interactive learning and knowledge-based economies

5. Regional systems of innovation

RSI vs. other territorial innovation models

RSI as outcome of an **intellectual debate on:**

1. Organization, evolution and systemness of innovation
2. spatial agglomeration of economic activity (innovation)



Resulting problem:

Organizational hierarchy of these phenomena? How to classify and subordinate RSI and agglomeration phenomena?

RSI vs. districts vs. cluster vs. learning regions vs. milieus?

(Marshall, 1890/ 1920; Marshall, 1949: 152-153; Freeman, 1991: 501; Feldman, 1994: 3; De Bruijn and Lagendijk, 2005: 1155)

6. Can we define boundaries of SI?

RSI, externalities and spillover

Proximity and tacitness:

Strong connection:

Spatial concentration of economic activity and innovation by introducing **tacit and codified knowledge** (Polanyi, 1966)

An Important remark of Lundvall:

*“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 simplified treatment of knowledge as a public good, such as it is a concern in Neoclassical Economics, is intellectually no longer rewarding. Instead, the **tacit, local and complex character of knowledge is emphasised.**”* (Hanusch and Pyka, 2007: 282)

6. Can we define boundaries of SI?

Do knowledge flows and spillovers blur spatial and functional boundaries?

Proximity and tacitness:

Proximity facilitates knowledge creation, exchange and diffusion, and additionally, inter-regional flows of knowledge via “pipelines” and absorption capacities reinforce knowledge bases (at home).

“...all the best-known studies on localised knowledge spillovers 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).

See, for instance, Maskell and Malmberg (1999), Maskell and Malmberg (2005), Greunz (2005), Paci and Usai (2000), Cooke (2001), Audretsch (1998), Audretsch and Feldman (1999), Carlsson and Stankiewicz (1991), Lundvall (2007), Breschi and Lissoni (2001), Powell and Grodal (2005), Crescenzi and Rodríguez-Pose (2005), and many others.

7. Summary and Conclusion

- Systems of innovation as a focusing device in order to understand, explain, analyze and model innovation as a complex process
- Systems of innovation go **beyond industry policy**
- **Core:** heterogeneity, history friendly approach, organizations and institutions, learning as a process, interaction and knowledge
- **Theoretical vs. operational systems:**
SI as “boundary objects” due to different targets and definitions
- **Non-optimal systems** of innovation:
Uniqueness, heterogeneity and events related to evolutionary theory

7. Summary and Conclusion

- Combining complementary concepts of systemic innovation: analyzing the **micro-, meso-, and even macro-level features** of innovation (NSI, TSI, SSI, RSI); multi-level analyses
- **Spatial boundaries of (regional) systems of innovation blur due to inter-regional knowledge flows, and additionally, due to spillovers (codified vs. tacit knowledge; local and trans-border spillovers, spatial, technological and organizational proximity of innovative activities)**
- **Spatial and functional boundaries are unique**

7. Summary and Conclusion

Future tasks and challenges for research

- different types of externalities vs. RSI and regional innovativeness
- spatial centres of RSI: urban areas/ cities or artificial centers such as “Silicon Valley”
- firm size, spatial combination of firms (SME, MNE) and spillovers
- ICT vs. tacit/ codified knowledge
- ICT vs. regional divide and absorption capacity
- federal structure and innovativeness (NSI, SSI, RSI)
- hierarchical classification of agglomeration phenomena
- market-led process of agglomeration vs. policy instruments and incentives

Thank you for your attention!

5. Regional systems of innovation

RSI, externalities and spillover

“Localization externalities”:

- intra-industry specialization
- Marshallian externalities (later: MAR-externalities)
- industry specific knowledge
- markets for specialized labour, forward and backward linkages and suppliers, knowledge spillovers between firms
- only firms in the same industry are able to internalize these externalities
- regional concentration of a particular industry

(Paci and Usai, 2000: 2; Breschi and Lissoni, 2001: 5; Greunz, 2005: 468; Audretsch and Vivarelli, 1995: 256)

5. Regional systems of innovation

RSI, externalities and spillover

“Urbanization externalities”:

- inter-industry spillovers
- Jacobian externalities (Jacobs, 1969)
- Jacobian diversification
- knowledge spills between complementary industries
- Ideas/ knowledge developed by one industry can be applied in other industries
- diversified local production structure

(Paci and Usai, 2000: 2; Breschi and Lissoni, 2001: 5; Greunz, 2005: 468; Audretsch and Vivarelli, 1995: 256)

6. Can we define boundaries of SI?

RSI, externalities and spillover

First pillar in literature:

- knowledge as a public good
- knowledge spillovers are not locally bounded because they can freely move across borders
- wide and broad diffusion of knowledge

Second pillar in literature:

- idea of spatial, technological, organizational proximity and costly transmission of knowledge across space
- strong distance decay effects support phenomena of spatial concentration
- trust and relationships

(Maskell and Malmberg, 2005; Hanusch and Pyka, 2007: 282; Paci and Usai, 2000: 3; Crescenzi and Rodríguez-Pose, 2005: 6;; Greunz, 2005: 465; Jaffe et al., 1993; von Hippel, 1995).

4. Sectoral and technological systems of innovation

Similar concepts: Pavitt's Taxonomy (1984)

Keith Pavitt (1984): *“Sectoral patterns of Technical Change. Towards a Taxonomy and Theory”*

Four major sectoral patterns:

(1) science-based industries, (2) specialized suppliers, (3) scale intensive productions, (4) and supplier-dominated sectors.

He contributed to the systemic literature and primarily to the **sectoral view of systemic innovation**

(Castellacci, 2006: 4; Fagerberg, 2005: 16; Pavitt, 1984; Malerba, 2005: 64; Lundvall, 2007: 107).

2. Systems of Innovation: roots and heritage

Intent and definitions of “systems of Innovation”?

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Intent and definitions of “systems of innovation”?

Some definitions:

“Innovation is shaped by institutions and institutional change. This process can be analysed in terms of national systems of innovation, reflecting that nations differ in institutional set ups” (Johnson, 1992: 23, 38).

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

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

3. National systems of innovation: NSI

From the “linear model“ to systems:

- Types, directions and levels of interaction, linkages and various kinds of knowledge mostly neglected
- OECD reports (1963 - 2000): Shifts towards systems of innovation (OECD Report, 1990, 1997)

“...innovation is neither smooth nor linear, nor often well behaved.” (Kline and Rosenberg, 1986: 285)

(OECD, 1997: 9-12; Edquist, 2005: 183; 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; Lundvall, Edquist and Johnsson, 2003: 4; Etzkowitz and Leydesdorff, 1998: 195-197; Cooke and Leydesdorff, 2006: 11; Lundvall, 2007: 100)

3. National systems of innovation: NSI

Who contributed to literature on NSI?

NSI literature developed, fostered and highly influenced by:

- Bengt-Åke Lundvall (1988, 1992): learning by interacting
- Richard Nelson (1988, 1993): institutions and evolution
- SPRU – Science Policy Research Unit, in Sussex (UK)
- IKE-Aalborg-Group

Expression “*systems of innovation*” (SI):

Lundvall (1985), “*Technology Policy and Economic Performance*”.

Expression “*national systems of innovation*” (NSI):

Freeman’s (1987), “*Technology Policy and Economic Performance*”.

3. National systems of innovation: NSI

Confusion within literature on NSI?

Do we have to draw a clear line and define clear boundaries?

“...(SI) 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).

Similar: SI must be kept open and flexible (to some extent) (Lundvall, 2007: 99).

3. National systems of innovation: NSI

On the way towards complementary systems:

Local production systems and agglomerations:

Silicon Valley, Route 128,): Sectoral specialization and local agglomeration **causes overlap**.

Severity in making explicit distinctions between sectoral and local indications and perspectives

Thus, systems of innovation should be regarded on different levels (Freeman, 1995).

(Freeman, 1995; Malerba, 2005: 400; Scott and Storper, 2003: 582; Saxenian, 1994: 4).

4. Sectoral and technological systems of innovation

Sectoral and technological systems of innovation

*“This framework (SSI) has been inspired by **evolutionary theory** and the **innovation system approach**.”* (Malerba, 2005: 64).

*In particular, the notion of **sectoral systems of innovation complements other concepts** such as **nationals systems of innovation...**”* (Malerba, 2005: 64-65).

Industries (sub-sectors) or broader sectors of fundamental interest for analysis (Malerba, 2005: 69).

5. Regional systems of innovation

Problems and challenges with RSI?

Further problems within the RSI conceptualization:

“...this type of innovation systems analysis is the most specific in terms of identifying geographic places and the actors...” (Wixted, 2006: 9)

“One serious problem with this area of research is the flexible definitions of clustering and the lack of agreement on appropriate measures...” (Wixted, 2006: 9)

5. Regional systems of innovation

Territorial (innovation) models in literature:

- **Industrial districts**

(Marshall, 1920/ 1943; Bagnasco, 1977; Piore and Sabel, 1984; Brusco, 1986; Sternberg, 1995...)

- **Technical districts, new industrial spaces**

(Scott and Storper, 1988; Storper, 1997;...)

- **Innovative milieus**

(GREMI, Aydalot, 1986; Braczyk et al, 1998; Cooke, 2001; Moulaert and Sekia, 2003; Camagni, 1991, Florida, 2002;...)

- **Learning regions**

(Cooke, 1998; Morgan, 1997, Moulaert and Sekia, 2003;...)

- **Regional systems of innovation**

(Cooke, 2001; Cooke et al., 1997; Braczyk et al., 1998;...)

- **Cluster**

(Enright, 1994; Marshall, 1920; Saxenian, 1994; Feldman, 1994; Porter, 1990; Moulaert and Sekia, 2003,..)

5. Regional systems of innovation

Additional questions related to RSI:

- Composition of SMEs and MNEs and their underlying network set-ups
- Important whether local firms are at the centre of an agglomerated network
- whether cities dominate a region
- whether the region only serves as a location site for production units within a dispersed network
- whether the region represents a nodal point in a partly concentrated network

(Storper and Harrison, 1991: 411; Cooke and Memedovic, 2003: 11).