National, Regional, and Sectoral Systems of Innovation – An overview

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Introduction

An innovation system:

> can be defined as a group of private firms, public research institutes, and several of the facilitators of innovation, who in interaction promote the creation of one or a number of technological innovations [within a framework of] institutions… which promote or facilitate the diffusion or application of these technological innovations (Beije, 1998: 256).

Innovation and innovation systems are becoming increasingly interesting to policy-makers for achieving their economic and social goals. Europe 2020[2], the European Union's key strategy for the current decade, aims to foster a smart, sustainable and inclusive economy. "Innovation has been placed at the heart of the strategy", as it provides the "best means of successfully tackling major societal challenges"(European Commssion, 2010: 2).

For ProGReSS partners, it is important to understand basic research on innovation systems, the policy-making perspective, and current innovation policies. An earlier report (Schrempf and Schroeder, 2013):

- summarised the economic situation in five countries (Ireland, Germany, UK, Spain, Italy) as well as summarising the European Union's economic situation;
- introduced the institutions involved in governing innovation;
- provided an overview of relevant strategies, as well as
- a brief summary of challenges and outlook.

Building on this work, the current report introduces the Systems of Innovation (SI) approach. The SI approach is the most favoured framework for describing, analysing, and understanding the process of innovation on various levels, and how it can be influenced by policy measures.

Responsible Research and Innovation (RRI) is about innovation that is ethically acceptable, sustainable and societally desirable (von Schomberg, 2013:63). Given Europe 2020's strategic aim to tackle major societal challenges through innovation, it is clear how an understanding of the SI approach is relevant to RRI. One could take for granted that innovation is undertaken in ethically acceptable ways and one could hope that the interests of future generations – as one example of sustainability considerations – will not be ignored, but it is the societal desirability criterion of RRI that creates the most serious possible tensions.

"Few would disagree that science and innovation should be undertaken responsibly. 'Responsible innovation' intuitively feels right in sentiment, as an ideal or aspiration" (Owen et al., 2013: 27). However, many efforts to achieve societal desirability by driving innovation

[2] http://ec.europa.eu/europe2020/index_en.htm

towards the common good through policy and funding measures are heavily criticized.[3] As early as 1962 such efforts were criticized, most famously by Michael Polanyi in *The Republic of Science* (Polanyi, 1962): "I appreciate the generous sentiments which actuate the aspiration of guiding the progress of science into socially beneficent channels, but I hold its aim to be impossible and indeed nonsensical." For a global network like ProGReSS working on RRI and in particular on societal desirability, it is important not just to examine the individual elements of RRI, but also to examine the surrounding policy and innovation landscape.

In this report, we introduce the basic ideas of the SI approach, followed by a brief outline of the three main sub-concepts of the framework. The National Systems of Innovation (NIS) and the Regional Systems of Innovation (RIS) approaches use geographic delineations to characterise the systems. The Sectoral System of Innovation (SSI) approach focuses on certain sectors of the economy, for instance, chemical engineering. In addition, we introduce a global innovation approach, 'inclusive innovation'. This is neither geographic nor sectoral, but focuses on one segment of end-users, namely those at the bottom of the economic pyramid. We conclude with some reflections on how the innovation approaches may be linked into RRI.

The Systems of Innovation Approach in General

The different SI approaches can be characterized and compared by investigating how they deal with the following six dimensions (Coenen and Díaz López, 2010):

1. System boundaries
2. Actors and networks
3. Institutions
4. Knowledge
5. Dynamics and
6. Policy implications

Apart from these dimensions, all three SI approaches share certain characteristics. They all focus on innovation and they all place great emphasis on the learning process (Johnson, Edquist and Lundvall, 2003) in which all actors involved (e.g. firms, consumers, universities, public organisations) experience a 'learning-by-doing' process or learn from each other by exchanging knowledge. Systems of innovation are always defined as complex systems (Metcalfe and Ramlogan, 2008), stressing their non-linear, systemic, interactive and evolutionary character (Tödtling and Trippl, 2012; Uyarra and Flanagan, 2013). Furthermore, the performance of all SI approaches is analysed in a similar way, namely through the ex-post, historical analyses of economic or innovative activity and knowledge diffusion (Godin, 2006). Such analyses are holistic and interdisciplinary, bringing together scholars and analysts from various disciplines (Johnson, Edquist and Lundvall, 2003) to account for the many, complex interactions in the system.

[3] A 2014 report from ProGReSS will summarise science and technology funding efforts, which try to drive research and innovation towards the common good, as well as summarise related criticisms.

The attractiveness of the concept to policy-makers is based on the fact that SI approaches can draw attention to weaknesses in the system (Soete, Verspagen and Ter Weel, 2010; p. 1162) and that scholars do not ignore the policy context.

Before we can go into detail about the individual SI approaches, it is important to define the term 'institution' (Korres, 2013). In the definition of 'innovation', which was used to introduce this report, reference is made to a framework of institutions. This could simply refer to private, semi-public and public organisations (narrow definition). However, a more useful definition in the context of RRI is a "relatively stable set[s] of mutually agreed rules and norms which are being created and reproduced by people, while they also, once in place, govern social life"(Grønning, 2008:3). As such, institutions include laws, social conventions, contracts, traditions as well as the above-mentioned organisations. In other words, they may take very different forms and be specific to a country, region or sector (Malerba, 2003). In this report, the term 'institution' refers to this broad definition unless otherwise explicitly indicated.

The Three Main Systems of Innovation Approaches

National Systems of Innovation

The concept of National Systems of Innovation was developed in the 1980s and is mainly associated with three authors: Freeman (1987), Lundvall (1992) and Nelson (1993). The concept provided a new approach to innovation and its governance and stimulation as compared to the more neoclassical, market failure approaches[4](Soete, Verspagen, and Ter Weel, 2010). Adopting a holistic view of innovation rather than focussing on isolated aspects of the process, the NSI concept emphasises the interaction of actors involved in innovation and analyses how these interactions are shaped by social, institutional and political factors (Fagerberg and Verspagen, 2009). The approach was remarkably successful in a short period of time and is now being used in academia and policy contexts (Teixeira, 2013). It is often used as an analytical framework (Sun and Liu, 2010) for studying the differences between countries concerning their production and innovation systems (Álvarez and Marín, 2010).

In order to understand the NSI concept, one can start with the work of the three 'fathers' of the term, mentioned above, also acknowledging, however, Friedrich List.

> The first person to use the expression 'the National System of Innovation' was Bengt-Ake Lunvall….However, as he and his colleagues would be the first to agree (and as Lundvall himself points out), the idea actually goes back at least to Friedrich List's conception of 'The National Systems of Political Economy' (1841), and this might just as well have been called 'The National System of Innovation' (Freeman, 1995:5).

Freeman (1987) employed the concept to describe and explain Japan's innovation performance. He specifically focussed on the interaction between technology, social

[4] Market failure approaches based on neoclassical theories argue that investment in R&D in order to generate innovation is below its optimal level when external effects of knowledge generation interfere (e.g. a third party profiting from the knowledge generated). Policy intervention is then justified if market failure is clearly identified and the measure taken can bring the market closer to its optimal state (Soete et al., 2010).

embeddedness, economic growth and system-enforcing feedback loops (Soete et al., 2010). The emphasis in his work was placed on four elements of the Japanese NSI:

- the role of policy (in particular the role of the Ministry of International Trade and Industry),
- the role of corporate research and development (R&D) in accumulating knowledge and developing advantages from it,
- the role of human capital, the organization of work and the development of related capabilities,
- and finally the role of industrial conglomerates in being able to profit from innovations emerging from developments along the entire industrial value chain.

Like Freeman, Lundvall (1992) emphasises the role of interaction for the production and the dissemination of new and valuable knowledge, shifting away from a sectoral view towards a broader view of the national institutional environment. Emphasizing the role of the nation state, Lundvall outlines three major building blocks of an NSI (see **Fig. 1**). The first building block deals with the sources of innovation and the actions of agents which lead to innovation, such as learning and exploration. The second building block distinguishes between two types of innovation, namely radical and incremental innovation. Finally, non-market institutions form the third building block. For these, Lundvall distinguishes between user-producer interaction as an important form of knowledge exchange and institutions and their uncertainty reduction function[5]. These institutions play a particularly central role in the NSI concept (and in all other SI frameworks).

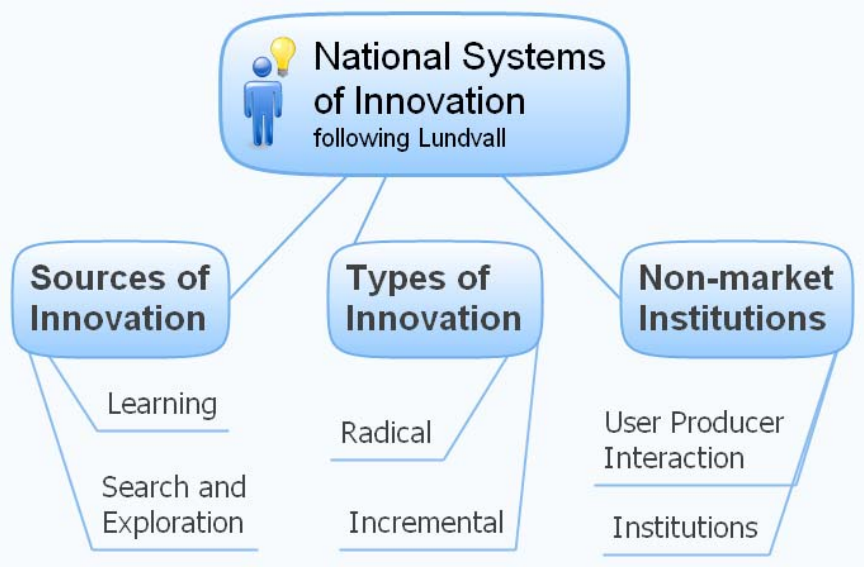

Fig. 1: National Systems of Innovation building blocks according to Lundvall (1992)

The third main author in the field, Richard Nelson (1993), focuses on the set-up of actors and how and why they collaborate. He is mostly interested in the institutions working in the science and technology sector or supporting it, especially universities conducting R&D.

[5] Patent laws, for instance, reduce the risk of not being able to protect new knowledge, guaranteeing appropriate return on investments, which are necessary to generate the protected knowledge.

Based on these three major contributions, the NSI approach has been developed further over the past 20 years, and is now considered "one of the most important concepts to emerge in the field of innovation studies" (Martin and Bell, 2011: 896). The concept is widely used in country strategies for innovation – in both developed and developing countries. The first developing country to utilise the NSI concept in developing its overall innovation strategy was South Africa.[6] Current work draws on Nelson when analysing the institutions of an innovation system and how the system is organized, and on Lundvall when the focus is on knowledge creation and learning. In the latter case, the learning society, which creates knowledge, is considered the most important resource of an innovation system and learning its central mechanism. From this starting point, the notion of the knowledge economy was developed (Godin, 2006). Looking at both streams, five main elements of the concept emerge following the comprehensive overview of the NSI concept by Luc Soete (2012).

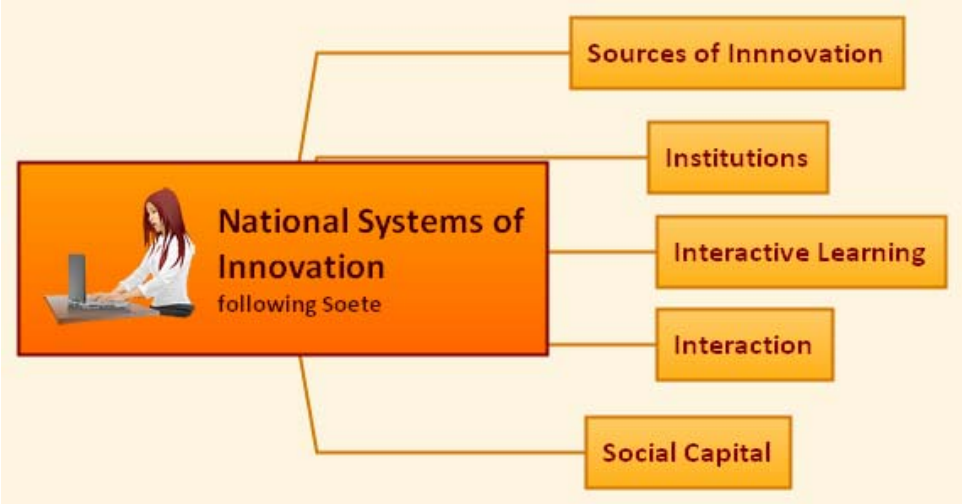

Fig. 2: National Systems of Innovation according to Soete (2012)

Firstly, the *sources of innovation* are of great importance in NSI. Classical economics approaches to innovation had relied mostly on an analysis of R&D. However, it is not only R&D that is crucial in innovation. Producer-consumer relations (Lundvall, 1992) provide a source of innovation, as do the purchase and availability of equipment and the training of workers. Thus innovation occurs in production, distribution, and consumption (Godin, 2006).

Secondly, *institutions* and how they shape the interactions between actors within the system are of central importance. Market and non-market institutions constitute the national innovation system (OECD, 1999), providing the framework for governments to implement policies in order to influence the process of innovation (Metcalfe, 1995). The importance of institutions can be illustrated by a quote from Warren Buffett, the most successful investor of the 20th century. He said: "If you stick me down in the middle of Bangladesh or Peru, you'll find out how much this talent is going to produce in the wrong kind of soil" (Singer, 2009: 43). In a country without reliable governance structures, somebody with the same talent who works just as diligently might still end up extremely poor. The importance of institutions must therefore not be underestimated. It is these institutions which are a preferred target of policy intervention at the national level.

[6] The NSI became the central organising concept in the White Paper (Kaplan, 1999)

Interactive learning is the third element. It emphasizes the importance of continuous learning in order to adapt to changes. This also demonstrates the connection of the NSI to concepts such as human resource management, labour market institutions and learning capacities of firms (Arundel, Lorenz, Lundvall and Valeyre, 2007), as well as to absorptive capacities[7] (Nooteboom, 2000) of firms and the economy as a whole.

Interactive learning is also closely connected to the fourth element, which is *interaction*. Since innovation is considered to take place almost exclusively within interaction, successful systems of innovations are capable of producing an environment of continuous knowledge production, knowledge use and innovation. However, the interaction is mostly coordinated by institutions and thus an institutional environment which leads to inefficient coordination of interactions may cause failure of the whole innovation system.

Finally, *social capital* (most importantly trust) is considered to be an important element in the NSI approach. It is argued that, the greater the degree to which institutions in a system are advanced, the more social capital in the form of trust they show. Trust in turn has a positive influence on the rate of innovation since trust reduces the risk that accompanies innovation and especially the risk of financing innovation (Soete et al., 2010). Fig. 3[8] depicts the connections between the main elements of the NSI approach according to a study by the OECD (1999). It shows how the NSI approach connects to other systems of innovation (see subsequent sections) and shows the factors which are influencing the system (outer ring).

[7] "The ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990: 128).

[8] Please note that here the term 'institution' is used as a synonym for organisations rather than rules and norms.

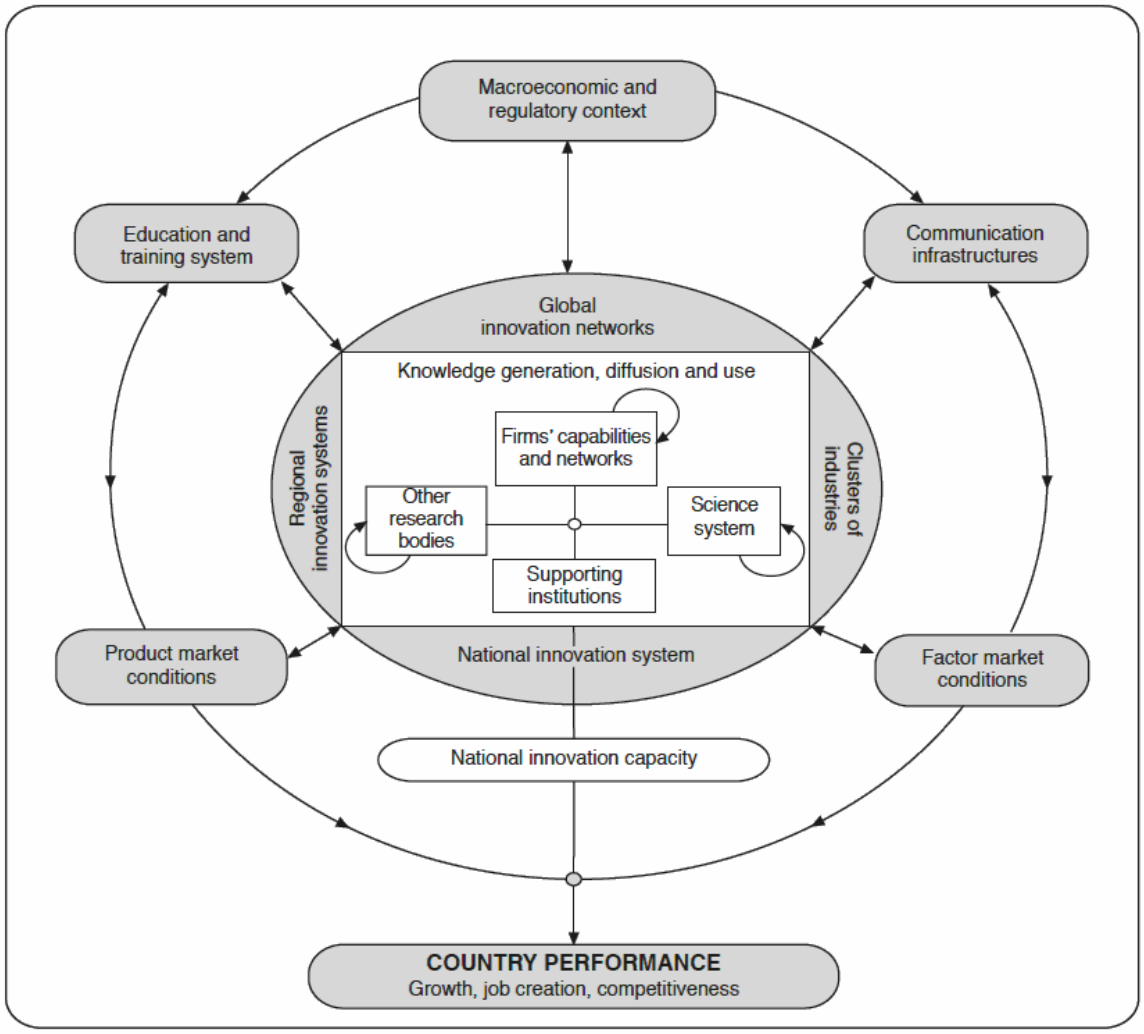

Fig. 3: The National Systems of Innovation Concept (OECD, 1999)

The NSI approach has found acceptance amongst policy-makers, as it provides a more comprehensive approach with more opportunities for input than is provided by the traditional market failure approach, which includes correction through policy intervention,. Thus, the NSI approach was used on a national level, for instance in Sweden and Finland, and on a supra-national level, for instance at the OECD (OECD, 1997, 1999).

The more comprehensive nature of the NSI approach has two positive consequences for policy intervention. The use of policy instruments can be justified more broadly, for instance in the case of stimulating university-industry collaborations. In a market-failure approach, this would be justified by the need for public investment when the market fails (e.g. universities), whereas in the NSI approach influencing the distribution of knowledge and increasing the capabilities of firms could serve as an obvious justification. Secondly, as policies are part of the complex, interactive system, policy-makers cannot design the system top-down as was the case with the market failure concept. Unforeseen repercussions of the top-down approach need to be avoided through more evenly based interactions and communications (Soete et al., 2010). In this regard, the NSI approach is more democratic than the traditional approach.

There are, however, a number of shortcomings of the NSI approach. Since the NSI approach (like all SI approaches) is not a formal one, there is no agreement on what has to be taken into account and what needs to be analysed when looking at a national innovation system. Furthermore, the NSI approach, despite having been worked on for more than two decades, still remains 'under-theorized' in terms of a lack of common definitions and terminologies. Based on the fact that the concept evolved around empirical studies of well-developed systems (e.g. Japan), critics argue that the NSI approach is mainly an ex-post analysis framework, which means that developments have already taken place and are later analysed. This approach lacks the possibility of ex-ante system building (Johnson, Edquist, and Lundvall, 2003). In other words, if a good system, framework or institution exists, the NSI can draw attention to it and explain why it is good. As such, if one country has developed a good framework, others may be able to learn from it, depending on the degree to which their existing institutions and social practices are similar. Reflecting on Buffett's comment about Bangladesh and Peru, it might be difficult to develop well-functioning innovation institutions based on experiences from, say, Japan or Germany.

A further challenge for the NSI approach can be seen in the increasing innovation activities, which do not require research (Cowan and van de Paal, 2000), especially those activities connected to the ICT and internet sector in a globalised economy. These global developments limit the effectiveness of national policies (Soete et al., 2010).

Regional Systems of Innovation

The NSI approach assumes homogeneity within countries, but this is not necessarily the case. On many indicators (e.g. economic performance, poverty, R&D investment) areas within countries can differ significantly (see Bavaria versus Saxony-Anhalt in Germany, for instance). As a result, researchers and scholars of innovation systems have developed a regionally-based approach of innovation system thinking, with 'regions' usually referring to a geographical area within a country. The research focus in the Regional Systems of Innovation (RSI) concept therefore rests on the relationship between technology, innovation and industrial location (D'Allura, Galvagno, and Mocciaro Li Destri, 2012). This spatial concentration remains important for innovative activities, despite the argument that modern information and communication technologies would render spatial distances between communication partners unimportant (Asheim and Gertler, 2005). Silicon Valley is normally used as the prime example for a region with great innovative potential.

Even though many aspects of the NSI approach can be applied at the regional level, the RSI approach differs decisively from the former (Korres, 2012, 2013). The internal organisation of firms, the relationships between firms, the role of the public sector and public policy as well as the institutional set-up of, for example, the financial sector, are amongst the features that can be explored in detail at a regional level. At a national level these aspects could differ considerably.

The RSI approach thus highlights the regional dimension of the production and the exploitation of new knowledge, thereby helping to explain regional differences in innovation capacity and economic strength.

RSIs usually consist of a set of interacting private, semi-private and public organisations, interacting within an institutional framework. This framework supports the generation, exploitation and dissemination of knowledge and thus supports innovative activities on a regional level (B. T. Asheim, Coenen, and Svensson-Henning, 2003; Cooke, 2004; Doloreux, 2003). The RSI approach was developed mainly by scholars of geographic economy who were trying to understand the special role of institutions and organisations in the regional concentration of innovative activities (Asheim et al., 2003; Asheim and Gertler, 2005). At the same time, other closely connected concepts emerged such as the regional clusters (Porter, 1990), industrial districts (e.g. Becattini, 2004; Scott, 1988), Technopole[9] (e.g. Benko, 1991), learning regions (e.g. Florida, 1995) and innovative milieu (Maillat, 1995; Crevoisier, 2004).

There have been several attempts to understand and structure the research conducted under the umbrella of RSI (see for example D'Allura et al., (2012) and Asheim and Gertler (2005)). According to Doloreux and Parto (2005), RSI research focuses on three main dimensions:

- firstly, the interactions between the actors of the innovation system in relation to the exchange of knowledge;
- secondly, the set-up and the role of institutions supporting knowledge exchange and innovation within a region; and
- thirdly, the role of RSI in regional innovation policy-making.

Fig. 4 depicts the concept of RSI, showing the main actors and dimensions and how they interact.

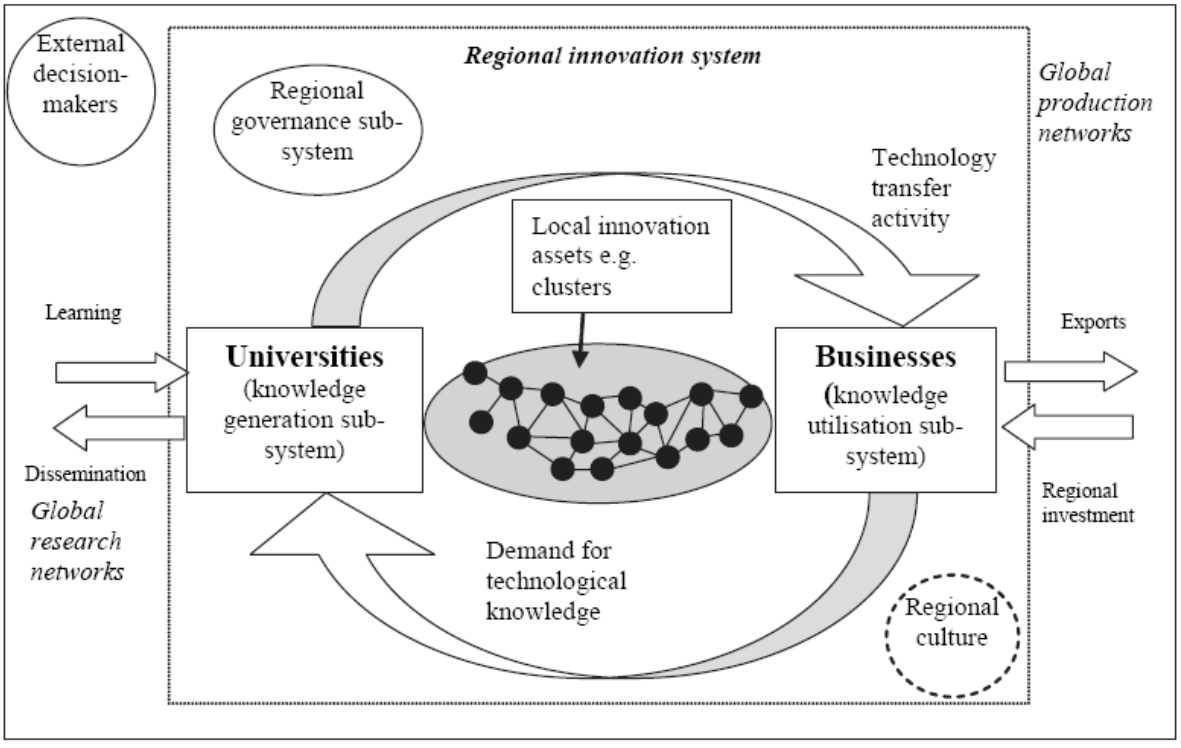

Fig. 4: An ideal-type Regional Innovation System (according to Cooke and Piccaluga, 2004)

[9] A Technopole describes an institutional environment fostering innovation, technology transfer and university/industry collaboration. Universities and private companies are the central players in the Technopole.

Knowledge exchange through interaction of actors

The first dimension focuses on the generation and exchange of knowledge within the region. Innovation is increasingly based on interactions and knowledge exchange between the various actors involved in the innovation process, such as firms (large and small), customers, research organisations (e.g. universities and research laboratories) and public agencies (e.g. technology transfer centres). Spatial proximity becomes important when one considers the idea that only small parts of innovation-relevant knowledge can be codified and thus shared easily over long distances, whereas the exchange of tacit knowledge (Polanyi, 1966) requires short distances and face-to-face interactions which in turn facilitates learning-by-interacting (Asheim and Gertler, 2005). As such, it is clear that the advantage of regional collaborations over national collaborations is the increased possibility for face-to-face interactions.

Within the RSI approach, interaction takes place in various forms, but most importantly in the form of organisation-to-organisation interaction within a network, which gives innovation its systemic dimension (Lundvall, 1992). The relationships within these networks show some degree of interdependence and – most importantly for the RSI approach – are very often regionally contained. This is especially true for cases in which partners are more specialised and have a more specific knowledge base. Such specialisation is associated with a high degree of tacit knowledge, and thus face-to-face interaction and trust-based relations become increasingly important (Asheim and Gertler, 2005). It is the interactive learning in regional contexts and the dissemination of 'sticky'[10] knowledge which make the regional concentration of actors the best environment for an economy which is knowledge- and thus innovation-driven (D'Allura, Galvagno, and Mocciaro Li Destri, 2012). Given that innovation is an interactive and dynamic process which relies on the learning in networks (Lundvall, 2002), it is often argued that being locally embedded is especially important for small- and medium-sized companies (SMEs) (Audretsch and Feldman, 1996), and that communication within the networks is susceptible to a distance decay function (Howells, 1999).

The strong focus on regional networks and on learning within these networks has also been criticised: Hess (2004) and Grabher (2006) warn of a danger of over-territorialisation and a tendency to neglect the importance of non-local links (to other regional systems, to the national and the global systems), whilst at the same time over-stressing the benefits of proximate relationships. This exposes the danger of lock-ins and a reduction in the capacity of the region to adapt to changes (Grabher, 1993).

The importance of institutions for regional innovation

The second dimension is concerned with the institutional set-up of a region, supporting the creation and dissemination of knowledge. Here, institution again refers to the broader definition, and hence 'institutions' include, for instance, laws, regulations, traditions and also governmental organisations. According to Uyarra and Flanagan (2013), the institutional environment in which the different actors are embedded is at the very heart of discussions on inter-firm relationships and thus of the RSI framework. The emphasis on institutions was mainly advanced in economic geography through the 'institutional turn'. Institutions are said to have great impact on firms in terms of how they interact with each other and, most importantly, in terms of how networks between them become established and function

[10] Tacit (un-codified) knowledge is considered ‚sticky', i.e. regionally bound by the context in which it is used.

(Uyarra and Flanagan, 2013). Local innovation networks are supported by these institutions, thereby supporting the firms involved, particularly SMEs (Cooke and Morgan, 1993). Asheim and Gertler (2005) underline the importance of institutions with their definition of RSIs as "institutional infrastructure supporting innovation within the production system of a region" (p. 299). This regionally dense institutional set-up which can often be found in successful RSIs was described by Amin and Thrift (Amin and Thrift, 1995) as institutional 'thickness'.

The institutional set-up is often used to develop typologies of RSI, of which many types can be found in the literature (Tödtling, Lengauer, and Höglinger, 2011). One of the most prominent typologies of RSI was suggested by Cooke (2004), distinguishing three types of RSI based on the prevailing type of governance in the system.

In the first type, called *grassroots*, in which action is initiated predominantly at a local level, financing is provided by local banks; the research has an application and a near-market focus; the specialisation of companies shows a great variety; cooperation between companies is high, and the main coordination mechanism is the market. Important examples can be found in the regions Emilia-Romagna (Italy) and the Silicon Valley (USA) (**Fig. 5**).

Fig. 5: Silicon Valley

At the other end of the spectrum, one finds the *dirigiste* type. Here, activities are initiated centrally; funding is provided at the national level; the research is basic and innovation is upstream-oriented; the degree of specialisation is high, and regional cooperation is low and state-coordinated. One prominent example can be found in the Midi-Pyrénées region (France) (**Fig. 6**).


Fig. 6: Midi-Pyrénées

In between these two types, the *integrated* RSI depicts multi-level initiatives; funding is provided by various partners; research and innovation is a mix between applied and basic, and one can observe an upstream and downstream orientation. Firms are specialised to a medium degree, and regional cooperation takes place in networks, which are associatively coordinated. Prominent examples can be found in the Steiermark (Austria) (**Fig. 7**) and Baden-Württemberg (Germany).


Fig. 7: Steiermark

Based on the notion of institutional thickness, Tödtling et al. (2011) distinguish between 'thick' RSI, which can often be found in metropolitan areas such as the Vienna region, and 'thin' regions such as can be found in the Salzburg region. Differentiating factors are the number and size of knowledge-generating and knowledge-disseminating organizations (universities, private and public research organisations), the number of firms and the degree of activity within their networks. They argue that clustering in 'thin' regions is lower; firms are less specialised, and the density of research and supporting organizations is low, resulting in an overall lower level of innovative activity and weaker learning preconditions.

The focus on institutions has also been criticised, especially when it is undertaken exclusively. Gertler (2010) points out that, whilst the role of institutions within RSI is of great importance, it remains poorly understood. Often, an a-historic view is taken, ignoring and underestimating the role of the historic context, i.e. the emergence, evolution and disappearance of institutions. The role of institutions is also too often reduced to a list of functions. Even if one has a good list of functions, it would be incorrect to conclude that these functions (such as knowledge production) are the sole *raison d'être* for the respective institution (Uyarra and Flanagan, 2013). Likewise, it is also questionable whether all systems would consist of the same institutions fulfilling the same roles (Cooke, 2001), for instance intellectual property rights in one region of one country could be more important to innovators than in another region of a different country. The functions of institutions are often different from the intended ones (Flanagan, Uyarra, and Laranja, 2011) or overstated, underestimating the role of agents (Flanagan et al., 2011). Whilst this second approach to RSI, with its focus on institutions, provides many important indicators of what works in innovation and what does not, an exclusive focus is not always helpful.

RSI and innovation policy

The role of policy in the RSI approach is the **third important dimension** - one can even say that RSI is both a theoretical concept as well as a policy objective (Cooke, Uranga, and Etxebarria, 1997). It is the policy level at which the national system exerts huge influence over the regional systems (Korres, 2013). One major example of the application of the third dimension of RSI approach can be found in the structural policy of the European Union. Fig. 8 shows the innovative activities of all 250 regions of the EU. Differences are tightly monitored in the long-running Community Innovation Survey (CIS), the results of which are published yearly in the Regional Innovation Scoreboard of the European Commission.[11]

[11] http://ec.europa.eu/enterprise/policies/innovation/files/ris-2012_en.pdf.

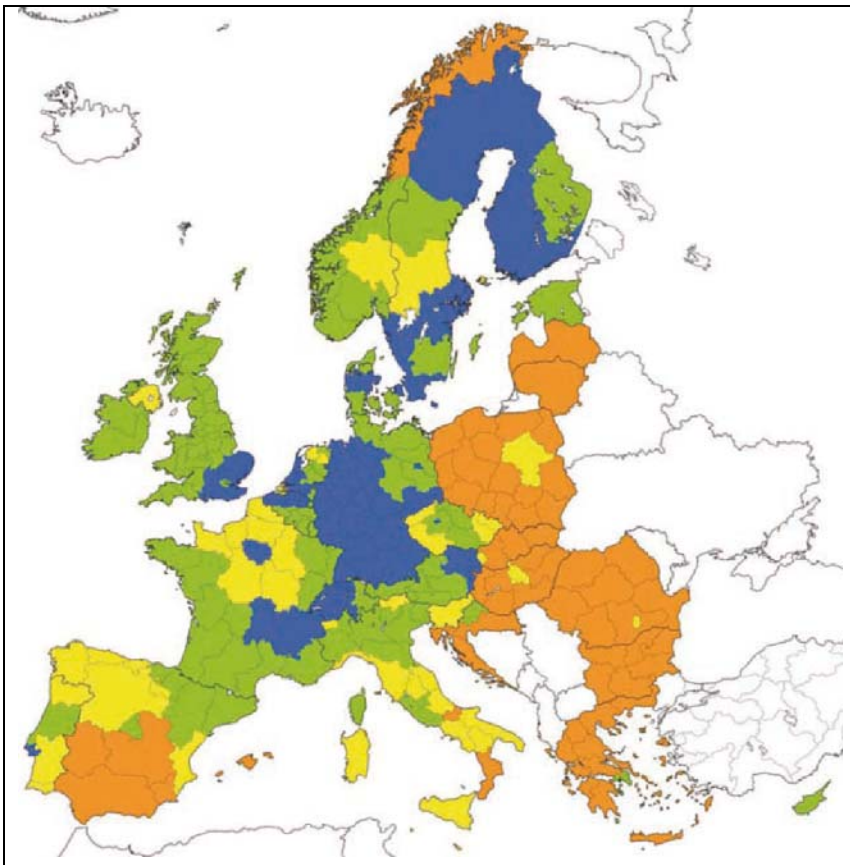

Fig. 8: Innovation regions of the European Union (European Union, 2012)

As the map shows, innovative activities are geographically distributed in an uneven manner, both within countries and even more so within the EU. The same is true for networks and how they function and evolve over time. Applying different policy approaches at a regional level within the same country may lead to regions learning from each others' experiences. Such a regional approach is also capable of bringing policy measures closer to citizens, in accordance with the principle of subsidiarity, and it bridges the gap between the supra-national level of the EU and the regions (Korres, 2013).

One major contribution of the RSI concept to the innovation system debates is the idea that there is no single one-size-fits-all policy. Policy instruments should always be context-specific and need to be adapted to the regional circumstances. Policy intervention in the RSI context mostly targets system failures, trying to facilitate the effective functioning of complex interactions between the various actors in the regional system. Policies at the regional level may target the regional set-up at various points, for instance they may affect all actors of a region or just firms or even single persons. The measures implemented can help companies to overcome a shortage of competencies; they can introduce hard institutions such as laws, or tackle soft institutions such as the willingness to take risks. They may even intervene at the network level, helping to overcome lock-in effects (e.g. where two partners have been working with each other in stagnation to the exclusion of others), or helping to initiate more collaborative activities in order to assist companies in finding sources of complementary knowledge (Asheim, Bugge, Coenen, and Herstad, 2013).

Criticisms of the RSI approach's focus on policy mainly target the risk of normative thinking and the danger of overestimating the capabilities of regional innovation policies. When a normative view is adopted, there is a danger that one may draw implications from stylised constructs, often drawn from empirical case studies, and try to reproduce them. This line of reasoning would ignore the importance of bottom-up processes, initial conditions and the context- and time-specific notion of regional systems. Policy-makers may be tempted by the RSI approach to act in disregard of these specific features, expecting that they can act effectively independent of the context and overestimating the role of innovation for regional development (Uyarra and Flanagan, 2013).

Sectoral / Technological Innovation Systems

Unlike the innovation system approaches described in the previous sections, which both rely on a spatial dimension to define their boundaries, the sectoral as well as the technological innovation system approaches adopt a certain technology (spanning multiple sectors) or the sector in which it is used (including various technologies) as their system boundary. The notion that particular sectors have different technological trajectories was first spelt out by Dick Pavitt (1984). Pavitt developed a taxonomy according to the sources of technology, the requirements of users and the appropriability regime. The taxonomy was four-fold:

- Supplier-dominated sectors – mostly traditional manufactures such as textiles and agriculture, which rely on outside sources for innovation
- Scale-intensive large firms producing basic material and consumer durables such as autos, white goods; sources of innovation are both internal and external to the firm
- Specialised suppliers – producing technology to be sold to other firms
- Science-based 'high tech' goods which rely on in-house and publicly funded research eg. pharmaceuticals

The concept of sectoral innovation systems was further developed by Malerba (2002), whereas the development of the technological approach can be traced back to Carlsson and Stankiewicz (1991). Both concepts are, compared to the NSI and the RSI approaches, more weakly developed and have a smaller overall impact. In both approaches links between firms and other organisations are portrayed as occurring as a result of the technological interdependence of their knowledge (Chang and Chen, 2004).[12] **Fig. 9** depicts the relation between national (NSI), sectoral (SSI) and technological (here TS) systems of innovation.

[12] For a detailed discussion about the communalities of and differences between the two concepts please see Coenen and Díaz López, 2010.

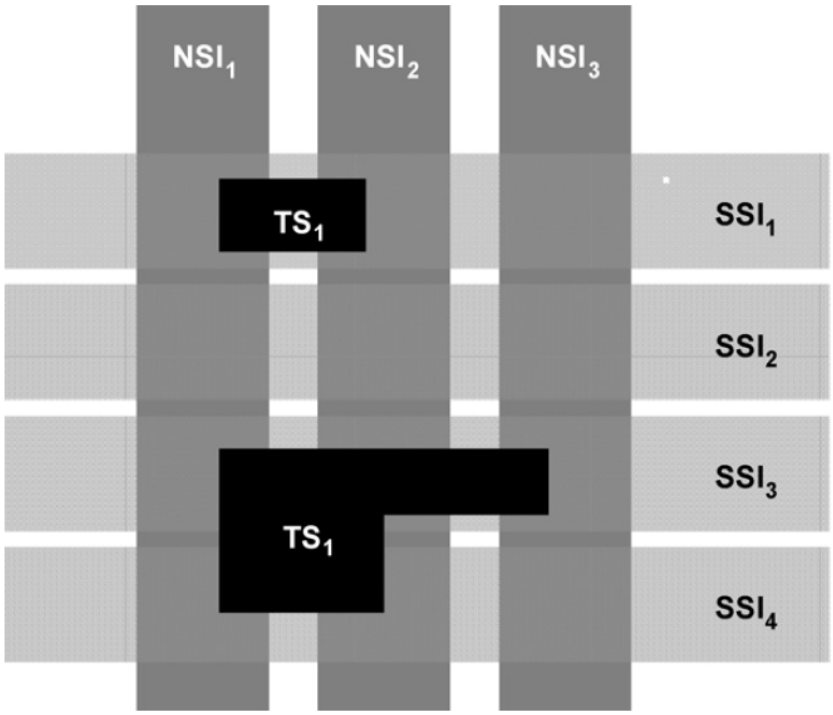

Fig. 9: Sectoral (SSI) and National (NSI) Systems of Innovation and Technology Systems (of Innovation) (TS) (Markard and Truffer, 2008)

Carlsson and Stankiweicz (1991) define the Technological System as networks of agents, who act in a specific technology area within which a particular institutional set-up exists. They conceptualize their approach with four main elements:

- economic competence, which describes the firm's competencies,
- clusters and networks, which are important because innovation happens in interaction and networks are an alternative governing instrument,
- institutions, which act as 'signposts' and provide stability for firms (Coenen and Díaz López, 2010), and finally
- development blocks, which create tension of alternating strength, thereby creating development potential, i.e areas of technological development which relate to each other in various ways and induce innovation by evolving in various ways.

The SSI concept of Malerba (2003) consists of three building blocks, which are the knowledge and technological domain, the actors and networks, and the institutions:

The *knowledge and technological domain* is the domain in which the boundaries of the system are defined, and these are unlike the boundaries in the NSI/RSI approach dynamic and thus are part of the analysis. System boundaries are also defined by links and complementarities among artefacts (e.g. a product or a technology) and activities, and are either static or dynamic.

The *actors and networks* within a sector are heterogeneous in type and include, for instance, individuals, firms, and semi-public or public organisations. Learning processes, behaviour, objectives and competencies are connected via market and non-market relationships. Firms,

however, are at the centre of the concept due to their primary influence on innovation, rendering other organisations as secondary (Coenen and Díaz López, 2010). The notion of heterogeneity of actors also applies to consumers, i.e. demand is also structured and influenced by consumer interaction, competencies and institutions. Consequently, relationships and networks are sector-specific, according to the sectoral knowledge base, learning processes, basic technologies, links and complementarities.

Industry from an SSI Perspective – the example of the French automotive industry

Oltra and Jean (2009) investigate the French automotive industry, applying the SSI perspective by developing three building blocks:

- Technological regimes
- Demand conditions
- Environmental and innovation policy

In their analysis they show how the technological regime together with the prevailing demand leads to a technological inertia. Innovation and environmental policy are then used to overcome this situation and foster the development of low emission vehicles by influencing the demand and the technological regime.

As in all SI approaches, institutions also play a major role in the SSI concept and shape the actions and interactions of agents in the system and help to guide the behaviour of agents in a certain direction (Coenen and Díaz López, 2010). However, national institutions affect the sectors differently. Regulations such as property rights and patenting rules may favour one sector (e.g. the pharmaceutical industry) and hamper another (e.g. the food industry). These effects may also vary across countries. For instance, European pharmaceutical companies benefit from the changes brought about by the TRIPS[13] regime, whilst Indian generic drug manufacturers are badly affected by TRIPS. The influences of national institutions on sectoral systems and vice versa are mutual, with a very important industry sector possibly shaping national institutions.

Sectoral systems are also prone to change which may be caused by the technology and learning regime in the sector, and by the patterns of innovation. A change in the knowledge base may lead to consolidation within the sector if a new dominant design becomes established, or may cause major changes in the industrial set-up if new competencies are required. The iPhone would be an example of a dominant design. Another source of change is the structure of consumer demand, which may cause new firms to enter the system, possibly changing it considerably. Overall, these dynamics are of a co-evolutionary nature, evoking change at the levels of technology, knowledge, actors and institutions.

Implications for policy-makers from the SSI approach are manifold. The variables associated with success of policy intervention may be different, requiring a good understanding of the co-evolutionary processes within any technology sector. If policy interventions are very non-

[13] The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is an international agreement negotiated through the World Trade Organization (WTO), which applies minimum standards of patent protection globally.

specific or are being enacted at a national level, then they may have drastically different impacts across sectors. For instance, policy measures that aim to foster network activities may not cause any effects, or may even cause negative effects, in sectors where market coordination is the prevailing mechanism. As a result of the different effects, a comparative analysis of the sectors is required in order to identify how the institutional configuration may evolve based on the policy intervention. Nevertheless, the same sector in a different country may still perform differently since the national context is also important.

One last important policy aspect to consider within the SSI approach is the role that policy can play in times of radical change in a sector. Governments can play an active role in supporting the change by acting, for instance, as a lead user of the new technology. This may help to overcome sectoral inertia caused by reactive rather than active responses to technological changes (e.g. the use of alternative drive systems such as the fuel cell in public transport).

Both the technological and the sectoral concepts of innovation can be criticized on various levels, beginning with the boundary setting. The SSI approach is characterized by – as stated above – dynamic boundaries mainly based on existing products, which may cause problems when new products emerge. The understanding of institutions in both approaches lags a system perspective, especially when compared to the spatial systems of innovation approaches. The knowledge and learning perspective in the SSI/TSI concept is biased towards technological learning, whereas social learning is usually not sufficiently considered. The SSI approach has also been criticized for its inability to account for the emergence of new technologies and sectors and for its focus on incremental changes. At the level of concept validation the TSI approach depends upon purposefully designed data sets, in contrast to the SSI approach, which can draw from existing datasets structured according to the NACE[14] nomenclature (Coenen and Díaz López, 2010).

Inclusive Innovation

Following the Millennium Development Goals, which sought to improve the economic and social position of the poor, there has been an upsurge of interest in 'pro-poor' or 'inclusive' growth. Since innovation plays a key role in growth and in determining the character of growth and the distribution of its benefits, increasing attention has been paid to innovation policies and practices that have the potential to impact positively on the poor.

Definition

The term 'inclusive innovation' is now very widely employed. International agencies such as the World Bank have embraced the term and the United Nations Development Programme (UNDP) maintains an International Policy Centre for Inclusive Growth headquartered in Brasilia, Brazil. A large number of governments, notably in developing countries – for

[14] Statistical classification framework developed by the EU which allows the classification of economic activity (e.g. the number of firms) in sectors, thus making statistics comparable.

example India[15] and Thailand[16] - have developed or are in the process of developing explicit policies focused on inclusive innovation. China's 12th Five Year Plan (2011 -2015) shifts the focus from pursuing economic growth to sharing the benefits of development with all people and innovation has a key role to play in this. Research organisations, such as the Global Research Alliance, have placed inclusive innovation at the centre of their objectives (Global Resarch Alliance, 2013).

However, there is no agreed definition of the term 'inclusive innovation' and indeed there are a variety of similar terms that are employed in different contexts. These terms include:

- pro-poor innovation
- below the radar innovation
- bottom of the pyramid innovation
- grassroots innovation
- Jugaad or frugal innovation.

(Horton, 2008; Kaplinsky et al., 2009)

However, what all of these terms have in common is that they refer to the production and delivery of innovative solutions to the problems of the poorest and most marginalised communities and income groups. Some definitions require that the poor are, in some way, actively engaged in the innovation process itself. A broad definition would therefore be: "Inclusive innovation is the means by which new goods and services are developed for and/or by the billions living on the lowest incomes" (Foster and Heeks, 2013:1)

In a recent review, Kaplinsky offers the following definition of inclusive innovation: "Inclusive innovations may be new to the sector, new to a country or new to the world and may involve a variety of excluded populations. These innovations may foster inclusion in production, in consumption, in the innovation process itself and by promoting the agency of the excluded. They may also contribute to environmental and social sustainability" (Kaplinsky, 2013).

It is possible to conceive of a number of different levels at which 'inclusivity' could potentially operate:

- The poor being engaged in the definition of the problems to be addressed such that the innovation is relevant to the needs of the poor
- The poor being actively engaged in some manner in the development and application of innovative solutions to their problems
- The poor being engaged in the adoption, assimilation and diffusion of innovative solutions to their problems
- The poor being engaged in the impact of innovation such that the innovation outputs maximise the consumption and/or incomes of the poor (Foster and Heeks, 2013).

[15] The Indian government characterised the 2010-2020 decade as the "Decade of Innovation" and created the National Innovation Council in 2011, with a specific brief to promote inclusive innovation at the national and state levels (Kaplinsky, 2013).
[16] Heeks, Amalia, Kintu and Shah, 2013

Some protagonists and advocates of inclusive innovation look to the inclusion of poorer people as active participants in the processes of innovation (Cozzens and Sutz, 2012). This perspective also defines inclusive innovation in terms of the innovation process and not merely in terms of the outcome. It seeks innovative activity that, in some way, has the potential to enhance the capacities of poor people. As a result, they would not merely be passive recipients of innovation but instead be actively engaged. Through this engagement they would be in some way 'empowered.' The active engagement of the poor in the innovation process finds its strongest expression in grassroots or community innovation movements. "Grassroots innovation movements seek innovation processes that are socially inclusive towards local communities in terms of the knowledge, processes and outcomes involved." (Smith, Fressoli and Thomas, 2013:1). Moreover, the grassroots innovation movement, such as the Social Technology Network in Brazil (RTS, Reed de Tecnologia Social) sees the engagement of the poor as having the potential to effect political transformation. This perspective "sees technology projects as seeding progressive social transformation in communities" (Smith et al., 2013:3).

Origins and Motivation

The modern origins of inclusive innovation can be traced to the appropriate technology (AT) movement associated with Schumacher. Schumacher's work "Small is Beautiful" (Schumacher, 1973) gave rise to the birth of the Intermediate Technology Development Group (ITDG) in the UK. Innovation was seeking to engage communities from 'the bottom up', defining their problems and seeking technology solutions that were appropriate to their needs – small-scale, affordable, easily serviced etc. The primary actors were not-for-profit organisations(NGOs). The modern successors to the appropriate technology movement are to be found in not-for-profit community-based innovation networks such as the Honeybee Network in India.

More recently, profit-motivated firms, located in both developed and developing countries, have recognised that innovation focused on the needs of the poor can be profitable. The expanding incomes of millions of poor consumers that are most evident in China, but also in many other countries of the world, have encouraged businesses to innovate so as to meet the needs of this fast-growing market – resulting in the reorientation of business strategies for innovation. This so-called 'gold at the bottom of the pyramid' was given expression in the writings of Prahalad (Prahalad and Hammond, 2002; Prahalad, 2005). These consumers, while still extremely poor, collectively have considerable buying power. They are seeking products that are affordable, that are robust, that are compact etc. – i.e. products that are in a myriad of ways suitable to the needs and situations of the poor.

These customers have attracted the attention of the large multinational corporations centred in the developed countries. A wide variety of products have emerged that are specifically targeted at the needs of poor consumers.

Inclusive innovation – An example

General Electric (GE) has developed a heart monitor designed by engineers in Bangalore, India, as a portable diagnostic tool for use in Indian villages. The product is light, has a built-in battery to cater for lack of reliability in electricity and it costs US$2,500, an 80% price reduction on the earlier much bigger and bulkier equipment. Nor will the new monitor be only for use in India. GE will be importing the monitor for use in the United States.

GE's strategy of 'innovating-up' from low-income to high-income markets has been adopted by a number of the world's largest corporations such as Proctor and Gamble, Unilever, Renault, Nestle and Philips. These firms are innovating to meet needs of poorer consumers and then adding features to these innovations in order to meet the needs of consumers in developed countries.

There is a strong demand for cheaper and more robust products for lower income consumers even in developed countries and the demand for more affordable products has been increasing, particularly since the onset of the global financial crisis.

Moreover, inclusive innovation is not confined to consumer needs. A wide variety of cheaper, more robust and smaller-scale machinery that is focused on poorer producers is now on the market, particularly within China and, to a lesser extent, India. Designed and developed in developing countries initially for domestic consumers, these products are increasingly being exported to other developing countries where producers have similar needs. As a result, capital goods imports by developing countries from other developing countries have been increasing very rapidly and now exceed capital goods imports from developed countries.

Much of the innovation in products focused on poor consumers and producers has been led by firms based in developing countries. Innovation is most effective when producers are in close cooperation with consumers/customers. For this reason, firms based in the developed countries increasingly undertake innovation directed at developing country consumers in developing countries. However, firms that are based in developing countries are often in a better position to gauge the needs of consumers. These firms are rooted in the political and economic context; they are more familiar with the challenges posed and they can act more swiftly to meet demand. As a result, it is often developing country firms that are at the forefront of innovating products that are appropriate to poorer consumers. For example, the Chinese white goods firm Hazier dominates the Chinese home market for refrigerators and washing machines

> "…by developing a superior understanding of the wide variety of Chinese consumers' needs and meeting those needs with quality consumer products. ….Through market research, Haier discovered that Shanghai residents had crowded living conditions and that there was little space for a large refrigerator. As a result, Haier designed a smaller refrigerator only for the Shanghai market, and sales subsequently surged." (Khanna and Palepu, 2004:7)

Haier divides its customers into 70 different market segments – far more than its Western competitors. When they noticed that a farmer in rural China complained that his washing machine clogged up when he used it to wash his potatoes, Haier adjusted the design so that they now offer a washing machine that washes both clothes and potatoes. When Haier noticed that half of rural households kept their washing machines outdoors, they manufactured a line in plastic so as to avoid rusting. This acute sensitivity to local conditions, unmatched by its Western competitors, has also helped Haier's worldwide expansion.

The rise of innovative firms in developing countries, which are focusing their activities on poorer consumers and smaller and less well endowed producers, receives an additional impetus from increased public spending and support for R&D in developing countries. In some countries, the increase in spending on innovation has been rising dramatically – by almost 20% per annum in China, for example.

Furthermore, a number of the 'new' technologies, most particularly in ICT, offer considerable opportunities to develop products that are appropriate to the poor. The M-Pesa mobile money[17] is an excellent example. M-Pesa was developed in Kenya and launched in 2007 as a money transfer and micro-financing service. By mid-2012, there were 19.5 million users, transferring US$8 billion per annum, equivalent to 24% of GDP and transfers were growing at 40% per annum. Key ingredients of the success were very small-scale distribution networks of agents – nearly 50,000 in 2012 - which penetrated deep into poor urban and rural communities. These embedded intermediaries adapted their business models, retailing patterns, and support and service offerings so as to meet the precise needs of the market. Moreover, these intermediaries were able to feed back information about customer needs to the lead firms who made a number of adjustments to further enhance demand. The customer feedback via embedded intermediaries resulted in a whole series of minor incremental innovations which collectively made M-Pesa so successful in that it met, rapidly and effectively, the needs of the population who are overwhelmingly poor.[18]

In some areas of vital concern to the poor, neither private firms nor government nor some combination thereof have been able or willing to undertake the research necessary to develop new products. This is most evident in respect of drugs to combat key diseases that afflict the poor – where the development costs are high and the returns are long-term and very uncertain. In order to meet this need, new forms of organisation have been developed to undertake and manage innovation. This entails cross-country collaboration between governments, research institutions, firms, philanthropists and NGOs. These global health initiatives are exemplified in the International AIDS Vaccine Initiative (IAVI) and the Malaria Vaccines Initiative (MVI)[19] or in reform plans such as the Health Impact Fund (Banerjee, Hollis, & Pogge, 2010).

[17] M-Pesa customers can convert e-cash on their phones to real cash and they can transfer e-cash from their account to that of another account holder via SMS.

[18] For a discussion on Why M-Pesa Outperforms Other Developing Country Mobile Money Schemes see word press blog Richard Heeks (2012).

[19] For a discussion of these two global initiatives and the different ways in which they mange the innovation process, see Chataway, Hanlin, Mugwagwa, and Muraguri (2010).

The Policy Challenge

As outlined, inclusive innovation – very broadly innovation directed at meeting the needs of the poor – has received considerable impetus globally, most particularly in relation to the needs of the poor in developing countries. Inclusive innovation has the potential to make a major contribution to improving the situation of the poor and providing them with new consumption and production opportunities. But, of course, major challenges remain. At the government level particularly, there is a lack of clarity as to how inclusive innovation is to be assessed and measured and therefore what resources should be devoted to it. In addition, identification of the constraints on inclusive innovation and the design of innovation policies that address these constraints is still very much a work-in-progress.

Moreover, not all of the poor are experiencing the benefits of inclusive innovation. The needs of subsistence farmers or of subsistence communities that have no substantive disposal income cannot be met via the market. There are no incentives for private businesses to allocate resources to meet these needs. Moreover, by contrast with consumers engaged in the market, the needs of these poor consumers and communities cannot be expressed via market signals.

Their needs are implicit and have to be made explicit, and this requires expenditure of public resources. These consumers need 'voice.' Moreover, since these poor consumers and communities are also producers (albeit for subsistence) any enhancement of their welfare will entail enhancing their capabilities and providing incentives. Non-market-based pro-poor innovation, if it is to move beyond charity and become sustainable, will therefore necessarily entail expenditures of public funds and an active engagement in the innovation process on the part of the poor.

Conclusion

Responsible Research and Innovation (RRI) imports ethical values into research and innovation. The three innovation approaches introduced in this report (national, regional and sectoral) are not explicit as to the precise content of such values. One might infer that growth, employment, economic efficiency and such like are aimed at as desirable outcomes, but which moral considerations are linked to these economic objectives remains implicit. In the case of inclusive innovation, the link to moral considerations is overt and explicit. By using the term 'inclusiv'', inclusive innovation strives for equality, the uplifting of the poor and ultimately the human right to access the fruits of science and innovation (Article 27, United Nations, n.d.). Given their main objectives, it is no surprise that the UNDP is heavily involved in discussions about inclusive growth and inclusive innovation (United Nations, n.d.-b):

- Fighting poverty
- Building democratic societies
- Preventing crisis, enabling recovery
- Protecting the environment
- Halting & reversing HIV/AIDS
- Empowering women
- Growing national capacity

UNDP Objectives

RRI is about policy. RRI is not something that will happen of its own accord. It will require facilitation. All innovation concepts introduced in this report offer a broad range of policy opportunities, mostly targeted at the institutions within the system. These can include, but are not limited to, legal rules and norms at the national level; fostering collaboration between industry and universities at the regional level; the introduction of new rules or standards for certain technologies at the sectoral level, and support for public-private partnerships in inclusive innovation.

For ProGReSS, the possibility of driving innovation towards societally desirable goals is of particular interest. To recall, in Europe, the concept of RRI has most prominently been defined as:

> a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and *societal desirability* of the innovation process and its marketable products (von Schomberg, 2013: 63, our emphasis).

Whilst it is crucial that innovation is undertaken in an ethically acceptable manner, this is only one prerequisite for making a positive contribution to enhancing the quality of human life. Likewise, the avoidance and management of unintended negative consequences is insufficient for taking full responsibility for the proper conduct of science and innovation. Today it is important to guide innovation, especially publicly funded innovation, towards positive outcomes that can improve human lives (Ozolina et al., 2012: 8). In this regard, a lot can be learned from inclusive innovation. However, all approaches to innovation are potentially important in terms of efforts to drive innovation towards societally desirable goals. These approaches provide conceptual frameworks and the tools required to make policy decisions in regard to innovation in highly complex, non-linear and interactive systems.

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