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Contemporary Innovation Policy and Instruments:

Challenges and Implications

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Abstract

In this paper we review major theoretical (neoclassical economics, evolutionary, systemic and knowledge-based) insights about innovation and we analyse their implications for the characteristics of contemporary innovation policy and instruments. We show that the perspectives complement each other but altogether reveal the need to redefine the current general philosophy as well as the modes of operationalisation of contemporary innovation policy. We argue that systemic instruments ensuring proper organisation of innovation systems give a promise of increased rates and desired (more sustainable) direction of innovation.

Keywords: systemic instruments, innovation policy, innovation theory, policy mix, innovation system, sustainability

1. Introduction

Innovation policy is a means to influence innovation processes. It can be defined as integral of the state initiatives regarding science, education, research, technological development and industrial modernisation. It contains research and technology policy and overlaps with industrial, environmental, educational, labour and social policies (Kuhlmann and Edler, 2003: 620).

For long, innovation policy has been influenced by a linear model (LM) and a neoclassical economic (NC) perception of innovation[1] (Fagerberg, et al., 2005; Malerba and Brusoni, 2007) with the objective to increase the pace and intensity of technological development and with the set of tools that can be generally characterised as predominantly financial, focusing on R&D production and either supporting individual firms or, as in case of mobility grants, stimulating bilateral relations (Smits and Kuhlmann, 2004).

[1] According to the LM innovation is a process of discovery, in which new knowledge is automatically transformed into new products or processes via a sequence of fixed, linear activities (Smith, 2000). The NC perception of innovation further argues that uncertainty, inappropriability and indivisibility of scientific knowledge (the same as information) cause under-investments in R&D by private actors and a non-optimal allocation of resources for invention, a phenomenon also known as a market failure.

Over the last decades, however developments in innovation practice and theory revealed a necessity to redefine the overall philosophy and the modes of operationalisation of contemporary innovation policy.

On the practical side, societies that chose to develop sustainably became increasingly confronted not only with the pressing need to further enhance the innovation intensity of their economies but also with, perhaps even more urgent, necessity of giving the change - a desired orientation (Boekholt, 2002; Meyer-Krahmer, 2001; OECD, 2005, Elzen and Wieczorek, 2005). Furthermore, actors involved in innovation processes have become confronted with problems other than lack of funds for production and transfer of R&D such as poorly articulated demand, too weak networks hindering knowledge transfer or legislation favouring existing, often undesirable technologies and causing unwanted lock in of the systems (Jacobson and Johnson, 2000). These problems turned out to be beyond the reach of existing innovation policy instruments and difficult to explain by the widely used NC economic perception of innovation. Actors became in need of tools that can better assist them in dealing with the new problems in rapidly changing policy contexts (Smits, 2002; Boekholt, 2004).

On the theoretical side, already the 1970's economic crisis revealed serious shortcomings of the NC theories to explain innovation and technical change (OECD, 1971, 1980; Mytelka and Smith, 2002). The flaws motivated a number of studies in such disciplinary fields as evolutionary economics (Nelson and Winter, 1982), institutional studies (North, 1990) or economics of innovation (Kline and Rosenberg, 1986). The studies unveiled a number of new insights about innovation not being a linear, autonomous and deterministic process but rather interactive and marked by co-evolution of technological, scientific, institutional and societal aspects. The concept of knowledge has extended beyond the NC 'information' to also include tacit knowledge, asymmetric information - contrary to the NC incentive for a market failure - being a 'goodie' that stimulates novelty and variety (Metcalfe, 1995a; Chaminade and Edquist, 2006). It became further recognised that organisations do not innovate in isolation but in the context of an (innovation) system (Freeman, 1987) where systems' conditions have major impact on the firms' decisions and undertaken modes of innovation (Smith, 2000).

There is now a growing body of literature that attempts to relate these theoretical and practical developments to the advancement of innovation policy. One of its greatest achievements is that the innovation system has been recognised as a useful analytical framework for policy in a number of European countries (OECD, 2004, 2005; Trend Chart, 2006). It even triggered the development of new policy schemes that took a form of (national) innovation policy mixes[2]. However, some studies (Rossi, 2005) show that despite statements about the importance of systemic and evolutionary dimension of innovation, European policy makers continue to see it as a linear phenomenon. The policy mixes are dominated by the traditional, financial mechanisms and focus on production of new science instead of on improving the functioning of the entire innovation systems. The Dutch mix, for example, contains a high share (90%) of this type of tools (Trend Chart, 2006; Boekholt et al., 2001). With regards to sustainability, except for few discussions about the need for innovation policy to better coordinate with policy for sustainable development (Boekholt, 2002) - the economic growth objective dominates and the portfolio of tools aiming to stimulate innovation for sustainability suffers from a superiority of the traditional, economic tools (Rennings, 1998).

Two reasons can be identified as responsible for that: one is that most of the policy makers who administer innovation policy are trained in the spirit of the NC paradigm (Lundvall and Borrás, 1997; Nooteboom and Stam, 2008) and they have difficulties with translating the new insights into specific policy actions and tools. Second is that despite of the advances in connecting the development of theory with policy, the literature that aims to link theory with policy is (i) not systematic in terms of innovation insights it builds upon and (ii) selective with regards to the policy implications it focuses on. By this, consciously or not, implications for innovation policy

[2] The mixes are meant to target national innovation systems and are composed of both the traditional, fiscal as well as new tools such as foresights, benchmarking or public procurement

instruments are overlooked (Laranja et al., 2008) as is the changed - increasingly towards sustainability - policy context.

This paper focuses on the second issue. It aims to gather and review the new theoretical insights about innovation that appeared in the literature linking the development of the innovation theory since late 1970's with the advancement of innovation policy starting from 1990's in search for implications of these insights for the characteristics of contemporary innovation policy and instruments in increasingly sustainability oriented policy context.

The paper consists of 4 sections. Following this introduction, Section 2 presents an overview of the new innovation insights arranged along the Evolutionary-Structuralist (E-S) framework that distinguishes systemic, evolutionary and knowledge-based approaches. Section 3 is an analysis of the policy implications of the insights particularly for the characteristics of new policy tools and it reviews the extent to which current innovation policy instruments could be used to meet the new challenges. Section 4 proposes a definition and presents examples of systemic instruments. The paper concludes on the challenges for policy makers and on the modes of governance (Section 5).

2. New theoretical insights

The broad aim of the literature relating the development of innovation theory to the advancement of innovation policy[3] is to discuss the implications of the new innovation theory and particularly the innovation systems approach to policy. For example: Smith (1994) explores policy implications of the move to a knowledge-based economy by focusing on industrial innovation and diffusion policy at national and regional level. Lundvall and Borrás (1997) analyse the implications of the globalising learning economy for innovation policy. Smith (2000) analyse policy implications of viewing innovation as a systemic phenomenon specifically for the policy rationale and policy capabilities of firms. Kuhlmann (2004) looks into the rationales and evolution of public RTD

[3] For historical perspective of this development see Mytelka and Smith (2002).

policies in the context of their evaluation. Smits and Kuhlmann (2004) focus on the co-evolution of innovation theory, practice and policy and the possible role of parliamentary technology assessment in innovation policy. Metcalfe (2005) explores rationale for innovation policy in an advanced market economy. Klein-Woolthuis et al. (2005) based on the systemic view of innovation - set out a system failure framework for implementing innovation system-based strategies. Chaminade and Edquist (2006) analyse the use of the systems of innovation approach in innovation policy. Tidd (2006) reviews models of innovation and their empirical evidence to inform policy debate. Smits (et al., 2009) look at ways to improve public policy based on insights from innovation theory, practice and policy.

We reviewed this literature in search for the new innovation insights that the various authors found relevant for policy (Appendix 1) and which they build their arguments on. We identified the following generic set of insights: endogenousness, interactivity, path dependency and cumulativeness, (co-) evolutionary nature, uncertainty, collectiveness, multi-actor character, importance of: users, institutions, multiple kinds and forms of knowledge, knowledge diffusion and utilisation, learning; strategic and tailor-made information.

2.1 Evolutionary-Structuralist (E-S) framework

The insights have roots in various disciplinary traditions such as sociology (Granovetter, 1985), evolutionary economics (Nelson and Winter, 1982), institutional studies (North, 1990, Johnson 1992), economics of innovation (Mowery and Rosenberg, 1979; Kline and Rosenberg, 1986; Freeman, 1987; Freeman and Lundvall, 1988; Lundvall, 1992; Nelson 1993) and economics of knowledge (Dosi, 1996, Lundvall and Johnson, 1994; Cohen and Levinthal, 1990; Foray and Lundvall, 1996). Triggered by the deficiencies of the LM and the NC view of innovation, the disciplines coevolved and built on each other in their findings about long-term technological change and the impact of a stream of innovation on technologies. Altogether they are often referred to as post-Schumpeterian (Bach and Matt, 2005; Smith, 1994), evolutionary (Edquist, 1997), evolutionary-constructivist (Smits, 2002) or evolutionary-structuralist (Lipsey et al., 2005). Bach and Matt (2005) make a useful classification of these non-NC traditions into three broad categories: evolutionary, systemic and knowledge-based within an Evolutionary–Structuralist (E-S) framework. They argue (2005: 27) that together the categories help clarify the *general logic*, the *how it works*, and the *basic engine* of innovation and they lead to a different policy advice on how and when to use public policy to encourage technological change. We use this analytical division to first organise the insights and then to draw their implications for sustainability oriented innovation policy and instruments.

Following these lines, under *evolutionary aspects* of innovation we discuss: endogenousness, interactivity, path dependency and cumulativeness, (co-) evolutionary nature and uncertainty. The *systemic characteristics* encompass innovation as a process, which is: collective, multi-actor, with users emerging as an important source of innovation; and occurring in specific institutional and locational contexts. *Knowledge related aspects* emphasise the importance of: multiple kinds and forms of knowledge, knowledge diffusion and utilisation, learning; as well as strategic and tailor-made information. Table 1 presents the new insights organised along these three broad categories.

{Table 1 about here}

In the subsequent section we summarise the characteristics of each insight. Given the NC origins of the innovation theory, we discuss the findings in contrast to the LM and the NC logic of innovation. The policy implications of these insights will be discussed separately in section 3.

2.2 Evolutionary aspects of innovation (general logic)

Endogenousness, interactivity, path-dependency and cumulativeness, co-evolutionary nature, and uncertainty are the features of innovation that we discuss under the evolutionary heading.

<u>Endogenousness</u> **-** Contrary to the NC view of technology as coming as manna from heaven **-** the evolutionary theory sees technology as embodied in physical and human capital. Change therefore cannot be seen as a response to exogenous incentives (Metcalfe, 1995a) but as an outcome of socio-

economic activities, determined by decisions taken by individuals in search of profits[4]. That makes the behaviour and the subsequent activities of agents critical for innovation and causes that the process of innovation does not always follow the linear path (Kline and Rosenberg, 1986) and is certainly not deterministic (Kuhn, 1962; Nelson and Winter 1977; Callon, 1992; Bijker et al., 1987; Rip 1978; Etzkowitz and Leydesdorff, 2000; Ziman, 2001). This contests the LM for two reasons. Firstly, because it disregards many feedbacks and loops that occur in different stages of innovation processes. Empirical evidence shows that arising problems frequently make actors reconsider earlier steps, which may also lead to innovation (we discuss this under the 'interactivity' heading below). Secondly, only a minority of innovations stem from scientific breakthroughs (see importance of various forms of knowledge in section 2.5) and result in a production of technical device. Practice shows again that firms plan many innovative activities in belief that there is a commercial need for them but they usually first mobilise accumulated skills and available knowledge before considering investment in research. They rarely use scientific discoveries as a basis for innovation (Kline and Rosenberg, 1986). Invention of new techniques thus often guarantees nothing (Smith, 1994; Tidd, 2006). Rather than new scientific discoveries, the determinants of a successful innovation are often organisational human skills, creativity as well as the ability of actors to identify opportunities and adapt to market conditions.

<u>Interactivity</u> – Innovation is a process of search with intense communication and continuous feedbacks (Kline and Rosenberg, 1986). Actors involved in the innovation processes often undertake actions contrary to the NC perfect competition – they cooperate (Smith, 2000) and network (Powel and Grodal, 2005) with each other at various levels (e.g. users with producers) and between different steps in the innovation process (Edquist, 2005). Cooperation and networking prove more advantageous than pure market competition (Lundvall and Borrás, 1997) for a number of reasons. They expose firms to novel sources of ideas, enhance transfer of knowledge, reduce

[4] Actors engage in innovation if they expect gains exceeding the expected personal costs. In case of climate change for individual innovators the perceived opportunities and gains from innovating for reducing climate change may be too distant and too uncertain. Governments could play a role through adjustments of policy objectives and creation of mechanisms that will help innovators appropriate benefits from innovating for this goal.

uncertainties and allow for division of innovative labour. Networking also helps companies increase their innovative capacities and achieve what they would not be able to reach on their own. This contradicts the NC spillovers and externalities because some knowledge is rather shared by firms to gain competitive advantage than hidden. According to Metcalfe (1995a) agents interact to choose between competing patterns of behaviour. The positive feedback mechanisms link this way the generation of variety to the exploitation of increasing returns - the selection environment (more widely conceptualised than the market mechanism with its traditional user-supplier interaction). Rosenberg (1976, 1982) further argues that interaction and feedback loops between various players shape major post-innovation improvements that are critical for innovations to be introduced to the market.

Path-dependency and cumulativeness - These features imply that historical patterns of technological development have impact on the speed and the nature of future technological change. In other words technological change follows specific pathways (technological trajectories, Dosi, 1982). rather than just being a random or simple reaction to the market demand, which to a great extent is determined and directed by the technologies already in use and the technological levels already achieved by firms and organisations (Dosi, 1988). An extreme example of path-dependency is a lock-in which is an outcome of interaction among the various actors and of alignment of their vested interests, further cemented by the economies of scale. Agents continue to use the existing technology (or existing frameworks within which solutions to problems are sought (Smits and den Hertog, 2007). This is even despite potentially more productive technologies or different ways of solving problems may exist. Alternatives are this way left without investigation causing that some of the possible (perhaps socially more desired) futures cannot even be envisaged. Path dependency suggests this way directionality of technological change, which to some extent is predetermined but not unchangeable. Especially technology in its earlier, premature stage of development can be influenced and more likely produce socially desirable spillovers than in the later, more specialised stage (Lipsey et al., 2005). It is thus much easier to prevent than to break lock-ins.

Path dependency and cumulativeness also reveal that actors, contrary to the NC optimising and representative agents, differ in terms of their competence, preferences, patterns of behaviour (Cohendet and Llerena, 1997) and context specific rationality (Lundvall and Borrás, 1997). Accumulation of knowledge and experience gives actors very different starting points and causes that their ability to innovate differs and is dependent on what they were doing in the past (Dosi, 1988). This diversity is a source of novelty and is thus fundamental for the dynamics of the innovation processes. In that view the NC assumption of innovation being a process where the outcome is determined solely by a combination of the effort and chance of firms, does not seem to hold.

(Co-) evolutionary nature– Innovation is a dynamic, evolutionary process involving elements of variety creation, retention[5] and selection (evolutionary model), (Nelson and Winter, 1982). The result of these forces is that the enduring relations and patterns of dependence and interactions are first established and then they evolve and dissolve as time passes by. That implies that despite the irreversible and locked-in nature of some of the innovation pathways - the de-alignment (Abernathy and Clark, 1985) or deconstruction of existing linkages and competencies and creation of new ones – does take place in the process of so-called creative destruction. New structures are created and replace the earlier systems. Metcalfe (2006: 105) argues that 'the modern capitalism provides good conditions for creative destruction because it is restless and has 'incessant capacity to transform itself from within in a continuous process of creative destruction. Innovation is restless because knowledge is restless and therefore the economies are never in equilibrium'. While under the NC model market fulfils the function of a selection environment, the evolutionary theory emphasises importance of institutional configurations (Nelson and Winter, 1982). Bijker (1995) further underlines the socio-cultural aspects and talks about a co-evolution of technology and society where a number of various actors want to influence the change for pursuing of their own goals. Actors' understanding of the developments, and their subsequent actions and choices contribute to these mutual interactions and co-evolution. In that sense also policymaking is a part of these co-

[5] Replication through reproduction or copying.

evolutionary processes and policy makers - one of the actors' groups who through their activities influence the way in which innovation unfolds (Rip, 2003; Smits and Kuhlmann, 2004).

Uncertainty - Innovation is uncertain and a process of trial and error (Rosenberg, 1995). This is for two reasons which make innovation almost per definition susceptible to intervention. One - because of involvement of humans who come from various perspectives, who function under conditions of bounded rationality, who are led by various objectives (also different learning objectives) and who cannot fully predict the outcomes of their actions and decisions. Second - because of a non-linear, non-deterministic and (co-) evolutionary character of innovation. 'Uncertainty implies not only a simple lack of information about occurrence of known events but more fundamentally entails the existence of problems whose solution procedures are unknown and it is impossible to precisely trace consequences to actions' (Dosi, 1988: 222). This makes innovations unforeseen events, based upon 'imperfect conjectures' (Metcalfe, 1995a). Even if successful in the market they may have an unpredictable life and they may vary considerably in economic effect over time (evolution of a mobile phone or the camera industries serving as examples). In the NC theory the non-perfect situations are considered risky. Contrary to an uncertain situation, however, risky circumstances allow for delineation of all likely futures which makes risk insurable and uncertainty not (Lipsey et al., 2005). Despite that, decision making under uncertainty is not blind – agents do look forward and anticipate future events based on past evidence and the current behaviour of economy. They also experiment and learn by making choices, trying options, going back, redefining strategies and trying again in expectation of gains that would exceed their expected personal costs. Given that large leaps involve exposures to many large uncertainties, so does the attempt of pushing the technological development off its established trajectory, actors frequently prefer pursuing incremental innovation and exploit the potential of technology within its existing path (Lipsey et al., 2005).

2.3 Systemic characteristics of innovation (how it works)

Systemic perspective of innovation developed by strongly building on the findings of the evolutionary theory. Some of the insights discussed above are often discussed in the literature as systemic and vice versa. Our selection of systemic characteristics of innovation is therefore subjective: (i) collective, (ii) multi-actor, (ii) with users emerging as an important source of innovation; and (iii) occurring in specific locational and institutional contexts that influence the operation of innovation systems.

Collectiveness - Building on the increasing understanding of the evolutionary and institutional aspects of innovation, a concept of an innovation system (IS) has been developed (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist 1997). Metcalfe (1995b) defined a system of innovation as '… a 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 that define new technologies'. An innovation system consists of: actors (and networks), institutions and interactions (Edquist, 1997). Some authors like Smith (1997) emphasise importance of physical and knowledge infrastructure as a structural dimension of an innovation system. The approach came to light in the 1980's and became to be seen as an alternative to the NC attempts to explain innovation and technological change. By emphasising that innovation is an outcome of numerous complex interactions among the elements of a system where learning processes and knowledge sharing among heterogeneous actors play a critical role – it shifted the focus of analysis away from individual actors (firms) to networks of organisation (Chaminade and Edquist, 2006). It also directed policy attention to other problems than market failure, namely the systemic problems[6] that hinder the operation and the development of an innovation system (OECD, 1997; Smith, 2000; Jacobsson and Johnson, 2000; Klein-Woolthuis et al., 2005; Chaminade and Edquist, 2006, 2007). The problems showed the need for a different type of tools for enhancing innovation intensity and direction, that is instruments that would operate at the level of a system (Metcalfe, 1995b) as opposed to traditional tools supporting its individual elements. By this the problems defied the non-context specific, one-size-fits-all NC policy advice. In the NC theory there is, namely, nothing that

[6] E.g. institutional problems, network problems or capabilities problems.

differentiates economies (no different technologies, no specific institutions, all actors are the same etc). Instead there is an assumption of a (non-existent from the evolutionary, systemic perspective), welfare maximising equilibrium with a market failure rationale to remove any divergences from this equilibrium through support to R&D. What needs to be recognized however is that technological knowledge does create beneficial externalities, which is a sufficient argument to further encourage R&D beyond the levels provided by the incentives of the free market (Lipsey et al., 2005). In that sense the systemic rationale complements the NC market failure.

<u>Multi-actor character</u> – Innovation is a joint activity of a growing number and variety of heterogeneous actors. By this it links strongly to the ‘ interactivity’ and ‘collectiveness’ insight discussed earlier but here we want to emphasise the variety and capabilities of actors participating in innovation processes. Next to companies also knowledge institutions, intermediary organisations, governments and policy makers all contribute to the innovation processes (Smits and den Hertog, 2007) in their own capacity and often with changed roles. Next to the discussed earlier differing competence, rationality, patterns of behaviour and traditional conflicts of interests, Kuhlmann (1998) points at (i) the incompatible societal communication codes as well as (ii) contradictory nature and complexity of institutionally anchored ‘frames’ of action of the involved actors. In the result, actors perceive the policy situation differently and they have different perception of problems. That implies that despite that innovation builds upon differences in understanding and reading of publicly available information (Metcalfe, 2006), a certain degree of coordination of information levels is necessary to help actors communicate and co-operate, develop common language and modes of interpretation as well as trust to overcome uncertainties (Lazaric and Lorenz, 1997; Lundvall and Borrás, 1997). In other words innovation systems need conditions in which all its elements are fully networked but preserve their specialised functions. This is because exploiting positively the differences between actors but maintaining the variety increases the total capability of the system (Gheorgiou, 2006).

Importance of users - Innovation is marked by growing involvement of better-informed and more demanding users (Silverstone and Hirsch, 1992; Grupp, 1992; Smits and Boon, 2008) – as an outcome of the interplay between technology push and demand pull (Kline and Rosenberg, 1986; Lundvall, 1985). Von Hippel, (1988) emphasises the crucial role that users play in innovation processes by pointing at 90-100% range of ideas for innovative products and services in medical technology field coming from users. The role of frequent interactions and feedback processes between users and producers is further emphasised by authors like Mowery and Rosenberg (1979), Rip and Kemp (1998), Gibbons et al., (1994), Freeman and Lundvall (1988). The reason for these interactions is the need on the part of users to have more impact on the innovation process and on the part of producers of innovations – to gain better social acceptance for their innovations, access to tacit knowledge and to the creativity of potential users (Smits and Boon, 2008). Users can also help indicate the market demand for innovations. Their involvement especially in the early stages of technological development may enhance innovation because 'users sharpen their demands about technologies and express them during the development of new technologies' - the process called demand articulation[7] (Boon, 2008: 18). The NC theory does not differentiate between the varying roles of actors in innovation processes.

Importance of institutions – There are many definitions of institutions including one that considers market as the most fundamental institution of modern Western economies (North, 1981). The most commonly used in the innovation studies encompasses a set of common habits, routines, shared concepts used by humans in repetitive situations organised by rules, norms and strategies[8] (Crawford and Ostrom, 1995). So defined institutions (hard – regulations, norms or obligations and soft – social norms, ways of conduct etc) are said to have three basic functions: (i) providing information and reducing uncertainty; (ii) managing conflicts and collaboration; (iii) providing stimuli. The NC approach does not recognise the specific role of institutions as a selection

[7] Precisely it is defined as an iterative, inherently creative learning process in which stakeholders try to address what they perceive as important characteristics of, and attempt to unravel preferences for an emerging innovation (Boon, 2008).
[8] As opposed to institutions meant as organisations (such as firms, universities, state bodies, etc), which are formal structures consciously created with an explicit purpose (Edquist, 1997). We consider them as actors.

environment. Moreover, by being applicable for all circumstances and at all times it suggests that innovation policies do not depend on any of the institutional or locational set ups. This is at odds with the observation that various public bodies implementing the policies do have different institutional capabilities determined by e.g. constitution, power relations, quality of labour force, accumulated knowledge or experience in operating the countries specific policy instruments (Lipsey et al., 2005). Despite application of same policies and instruments, the outcomes of public organisations' activities differ significantly accounting for varying levels of innovation[9] as shown in the studies comparing various innovation systems. Lipsey et al. (2005) say that policies are as good as those who administer them. Dosi and Orsegnio (1988) compare the role of institutions to that of maximisation in NC model. They consider them factors of behavioural order and stability in patterns of economic activity. Institutions further matter for conduct and performance, they regulate interactions between agents and they frame the conditions for application of new knowledge (Metcalfe, 2006). Being channels of resources they may influence the amount of funds allocated to innovation (Edquist, 1997). Institutions therefore do not necessarily have to be a rigid obstacle (when too stringent, too weak or absent) but a stimuli for directing innovation processes and systems.

2.4 Knowledge related issues (basic engine)

Knowledge based aspects of innovation emphasise significance of: multiple kinds and forms of knowledge; knowledge diffusion and utilisation; various sorts of learning; availability and access to strategic and tailor-made information.

Multiple kinds and forms of knowledge **-** The knowledge basis of innovation is one of the most basic realisations about the nature of innovation that has been fuelled by, among others, the developments during and after the WWII when first scientific advances made major contributions to

[9] Lipsey et al., (2005) argue that this is the lack of institutions (also meant by organisations such as universities) that support accumulation of knowledge and development of carriers and propagators of knowledge, which is the main reason why West got rich and e.g. China did not manage to first store and then exploit all its major advances in the field of mechanics science.

both the war craft and the reconstruction processes. The oil crisis of 70's further reinforced the need for using the scientific knowledge and technological advances to restore economic growth and create jobs. The 90's however brought a growing attention to non-technological innovations and non-scientific forms of knowledge such as service, organisational, soft skills and competencies (Borrás, 2003). Of particular importance became tacit as opposed to codified knowledge[10] (Polanyi, 1978). According to Metcalfe (2006) knowledge is only in the minds of individuals where new ideas and concepts emerge. Knowledge therefore is only tacit, never codified. What is codified and can be articulated and transferred is information. Information however is only a public representation of individual knowledge. That means that in the knowledge-based/learning economy crucial elements of knowledge remain specific and tacit and deeply embedded in individuals, organisations and locations. Being acquired in interaction and in combination with creativity and imagination of individuals - access to tacit knowledge is only possible through a process of interactive learning (Lundvall and Borrás, 1997) and provided that actors are capable of identifying and articulating their knowledge needs. In some sectors such as nano-technology or pharmaceuticals thanks to clearly articulated needs and close cooperation with users innovation is making better use of the scientific advances (Boon and Smits, 2008). The NC pure markets with optimising agents create no conditions for interactive learning and by this do not allow for utilisation of other than scientific types of knowledge.

<u>Knowledge diffusion and utilisation</u> – This issue emphasises the importance of not only knowledge acquisition and production but also its exploitation (Borrás, 2003). Lundvall and Borrás (1997, 23) argue that 'the key economic performance is no longer a given knowledge base nor information access capacities as such but the capability of actors to exploit these optimally by quickly adapting to continually changing market conditions and by developing new capabilities when old ones become useless'. The LM and the NC theory by focusing on the production rather than utilisation of knowledge create a very incomplete basis for policies, which thus miss instruments supporting diffusion and exploitation of various types of knowledge.

[10] Implicit and explicit according to Jensen et al., (2007).

Learning – Lundvall (2007) argues that while knowledge is the most fundamental resource in the modern economy, learning is the most important process. Innovation is rooted in various sorts of learning at various levels and in different parts of economy (high, low tech sectors) (see Fig. 1).

{Figure 1 about here}

The different types of learning activities may lead to different patterns of innovation and technological development (Malerba, 1992). Learning is an important outcome of interaction and feedback. It refers to building new competencies and establishing new skills and not solely getting access to (Lundvall and Borrás (1997). It increases actors' creative capacities and helps them better exploit the available knowledge. Learning through experimentation stimulates actors to phrase questions, to articulate their demands and to develop strategies - critical for coping with uncertainty. Learning can also help with formulating the way in which technology can contribute to solving societal problems (den Hertog and Smits, 2004) and it plays a major role in the development of systems (Archibugi et al., 1999). Empirical research confirms that firms that engage in R&D without establishing organisational forms which promote learning and who neglect customer interaction are much less innovative (Jensen et al., 2007). Capability to learn is therefore increasingly seen as the most important factor behind the economic success of agents (Lundvall and Johnson, 1994). NC economics neglects 'learning as a competence building'. It understands learning as either getting access to more information or treats it as a black box phenomenon. The concept of equilibrium is also highly disputable in this context because if it does exist – then this is the state with no need or incentives for learning (Lundvall, 2007).

Strategic and tailor-made knowledge - Over the last years knowledge bases have changed considerably: they are broader, more complex and there are multiple sources of knowledge. The amount of information is enormous and rapidly growing. Also the various and many actors involved in innovation processes have different information needs. The concern thus is no more information scarcity but on contrary - the overload and the growing need to select the type of information that meets the needs of actors (Smits and Kuhlmann, 2004). Codified knowledge further does not mean free access – it often requires additional skills such as knowing the code to make it meaningful (Dosi, 1996). That entails the necessity to not only identify but also process the information to make it useful. A precondition for provision of useful knowledge is that actors are able to identify and articulate their knowledge needs. Such articulation most often happens in the process of interaction and interactive learning.

Table 2 summarises policy relevance of the insights about innovation that the NC economics theory fails to acknowledge.

{Table 2 about here}

3. Policy implications

The purpose of the earlier section was to highlight the differences in which the NC and the more recent perspectives (evolutionary, systemic and knowledge based) see innovation and technological change. Here, in this section we follow the logic of the E-S framework while drawing four types of implications of the new insights for: policy objective, theoretical model, rationale and instruments. We observe that the NC, evolutionary, systemic and knowledge-based views are complementing each other.

3.1 Policy objective

The NC theory suggests conditions under which innovation can be maximised by influencing the amount of R&D. The driving philosophy is how to gain more with less. The major focus of policies based on these approaches is to influence the pace of technological development. Evolutionary theory, recognising cumulativeness, path dependency and importance of context in innovation processes, points policy attention to the possibility of influencing also the direction of change through e.g. prevention of undesired (from societal perspective) lock-ins. Systemic perspective complements the NC and evolutionary view by making the general logic more concrete: it directs policy attention to the functioning of innovation systems (Edquist, 2005) and the need of steering their development along selected objectives (e.g. sustainable development). According to the knowledge based view it is possible through effective exploitation of various types of existing knowledge or creation of new knowledge resources.

3.2 Theoretical model

Regarding the theoretical model on which innovation policies rest – evolutionary, systemic and knowledge-based perspectives clearly show that the LM - through its ignorance of interactions and feedbacks, lack of attention to non-scientific knowledge - proves insufficient in grasping the real nature of innovation and for that matter fails to properly support policy. Furthermore, both the LM as well as the NC approach, by being general, applicable in all countries and at all times, overlook institutional and locational context specificity of innovation. The evolutionary and systemic approaches confirm that context does matter for policy. For example the country's governance and political system cause that policies are administered differently in various locations. While evolutionary view emphasises processes of variety generation, retention and selection[11] as important in fuelling innovation (evolutionary model), the systemic perspective goes further by proposing an innovation system as a useful unit to analyse these processes (innovation system model) where, according to the knowledge based view, knowledge and learning play critical role in systems development (knowledge/learning based innovation system model). Such a model makes a far more concrete and informative framework for policy makers than the LM.

3.3 Policy rationale

The encouragement of science-based advances with public funds is still needed because the new (inter-)national knowledge has major positive externalities (Lipsey et al., 2005). In many instances however, the market failure rationale proves insufficient or even loses its ground. What, for example, creates imperfection from the NC perspective (asymmetry in information, varying behaviour of agents or uncertainty) is often seen by the evolutionary theories and knowledge-based perspective as a source of diversity and a driving force of innovation. It cannot, for that matter, be considered a failure and cannot be corrected by allocation of public resources to the production of new knowledge. Also the ‚failure' part of the concept is highly contested. When technology changes endogenously

[11] Metcalfe (1995a) argues that policies influence variety generation while politics influence selection processes.

and in conditions of uncertainty there is no optimality and no equilibrium and so optimum allocation of resources or optimal policies are not possible either[12]. It is impossible to talk about a failure then. Metcalfe (1995a) also shows that innovation and the NC optimality are fundamentally incompatible. The systemic perspective suggests ways to go beyond the market failure rationale and makes the evolutionary view of innovation more 'operational' by directing policy attention to the systemic problems hindering the functioning and the development of innovation systems such as interaction problems or institutional problems. Knowledge based view pays particular attention to problems of exploitation of various types of knowledge and demand articulation.

3.4 Policy instruments

Instruments are what policy has at disposal to reach the selected objectives. Changes in the policy objective, model or rationale automatically imply the need to revise the existing instruments portfolio and the mode of their application. The systemic perspective clearly suggests the need for a coherent and orchestrated instruments portfolio operating at the level of innovation system and addressing its systemic problems. Smits and Kuhlmann (2004) labelled such tools 'systemic instruments'. The NC innovation policy instruments are rather individually used and aim to influence the pace of technological development by correction of market failures. As much as support to R&D is still valuable, the evolutionary, knowledge based and systemic perspectives emphasise importance of also other conditions that are essential for the operation of sustainability oriented innovation systems and which should therefore be supported by the new generation of policy tools. The summary in Table 2 is useful in identifying these additional conditions.

3.4.1 Conditions to be supported by the new policy tools

The evolutionary perspective explains the general logic: systems evolve along a specific path. The accumulated (soft, organisational) skills and knowledge of agents, asymmetry in available information and the uncertainty about the future play important role in the generation of diversity. To gain advantage and to reduce the uncertainty agents interact with each other, exchange

[12] Lipsey et al. (2005) suggest that policies in such conditions should be based on measurement, theory and subjective judgement.

knowledge and experiment with various options. Particular locational and institutional set-ups further create specific selection environment, which altogether contribute to a build up and stabilisation of the systems. Systems under certain conditions can get locked-in but the lock-in may be untimely or undesirable from the sustainability perspective. On the other hand, however, the evolutionary theory suggests that systems have a natural capacity to de-align in the process of creative destruction. In that view and based on the evolutionary insights summarised in table 2, the following conditions can be identified:

- Creation of conditions for learning and experimenting (to increase learning capabilities of actors and generally, to stimulate human and physical capital);
- Stimulation of interactions and networking;
- Prevention of undesired lock-in or creation of conditions for dealignment and creative destruction;
- Stimulation of relevant (hard and soft) institutions;
- Provision of infrastructure for strategic intelligence (to assist actors in reducing uncertainties).

The systemic perspective, next to delineating the boundaries of the systems also clarifies how innovation systems work. Basic property of the systems is that they have a certain degree of self-organisation. This is an emergent property of group behaviour, which implies that systems behaviour cannot be predicted by studying the behaviour of any number of its (isolated) elements (Lipsey et al., 2005). Systems have to be looked at as entities that operate based on collective actions of its elements. That means that despite the self-organising nature, to reach consciously chosen objectives such as sustainable development - systems need to be organised and coordinated. That involves ensuring presence of all relevant elements, developing their capacity and stimulating their mutual compatibility. Following these lines and based on the systemic insights summarised in table 2 the subsequent specific conditions can be identified as important for policy to support:

- Stimulation of participation of relevant actors (esp. users);

- Management of interfaces among the various heterogeneous actors (to motivate interactions and networking);
- Stimulation of presence of relevant (hard and soft) institutions;
- Prevention of too weak or too strong institutions;
- Stimulation of physical and knowledge infrastructure.

The knowledge based view help to realise that various types of knowledge (not only R&D, codified science) constitute the engine of systems' evolution. Availability of strategic knowledge and its effective exploitation within a system are particularly significant for its evolution provided actors are able to articulate their knowledge needs and there is infrastructure that assists them in this process. In that view and based on the knowledge related issues of table 2 following set of policy relevant conditions can be identified:

- Stimulation of infrastructure for exploitation of various types of knowledge (also basic R&D);
- Creation of conditions for learning and experimenting (to increase learning capabilities of actors), especially for articulation of demand, visions and strategies development;
- Provision of infrastructure for strategic intelligence (to assist actors in identification and selection of information they need).

Since many of the above identified conditions overlap, below we present a refined list of 8 conditions that are important to stimulate by policy instruments in order to support the development and sustainable orientation of innovation systems:

1. Prevention of undesired and untimely lock-in or stimulation of creative destruction;
2. Management of interfaces among actors;
3. Stimulation of participation of relevant actors (esp. users);
4. Creation of conditions for learning and experimenting esp. for demand articulation and vision development;
5. Stimulation of presence of hard and soft institutions;

6. Prevention of too weak and too stringent institutions;
7. Provision of infrastructure for strategic intelligence;
8. Stimulation of physical and knowledge infrastructure (R&D).

In the following section we discuss ways to operationalize the conditions and we analyse the extent to which existing traditional policy tools can be used for that purpose. Table 3 summarises the main policy implications of the E-S perspectives as compared to the traditional, NC approach.

{Table 3 about here}

3.4.2 How to operationalize the conditions?

1. Prevention of undesired and untimely lock-in or stimulation of creative destruction

This condition is about supporting new innovations that not only play a role in building entirely new systems but that can also break old consistuencies. It is particularly important for directing innovation and technological development in a sustainable direction because it helps to clarify the undesirability of lock-ins[13] such as fossil-fuel-based mobility system causing major environmental footprint.

Strategies supporting this condition include long-term perspectives, visions and openness to new ideas and solutions. Openness can give rise to structure formation and to structural change (Edquist, 1997). The more open the system or the firm to the outside incentives – the less the chance of its being excluded from promising new paths of development that emerge outside. For policy makers – it means keeping an eye on the openness of the system to avoid the situations when innovation activities are restraint by the path dependency (Fagerberg, 2005). Also important is identification of change agents as well as support to- and protection of- alternatives until they show their potential but are still in a relatively generic state (role of Constructive Technology Assessment – CTA, Smits and den Hertog, 2007; Strategic Niche Management – SNM, Kemp et al., 1998). That refers also to

[13] According to Meijer, (2008) the Dutch sustainable energy projects have difficult time because of so-called political uncertainty. The sustainability issues are not clearly outspoken at this level and the reliability of the governmental decisions is not high (with frequent and unexpected changes in policy) creating very un-favourable conditions for innovation in this field.

the unpredicted markets that emerge sometimes out of the blue and are unnoticed or not preferred by the players (Tidd, 2006). Policy makers may be required to e.g. adapt to shifts in technologies and in demand through making choices as to whether further support the existing system or to support the development of radically new technologies. On the other hand, untimely procurement decisions can lock-in the economy before the potential of the alternatives have been properly explored (Lipsey et al., 2005).

Narrowly focused policy interventions at the level of individual actions are unable to overcome lock-ins and support self-organisation of new constituencies (Edquist, 1999). They may, however, be used as building blocks of systemic instruments to support these processes. Examples of such tools include: foresights, debates and discourses, experiments with new applications, demonstration centres, technology promotion programmes, procurement tools, political tools such as awards and honours for innovation novelties, fiscal incentives such as loans and taxes for innovative projects or research on new technological applications.

2. Management of interfaces among actors

This condition refers to coordination of actors' information levels, levelling off the societal communication codes, moderation, provision of negotiation conditions, orchestration of conflicting interests; creation of reliability and trust to overcome uncertainties (Kuhlman and Shapira, 2006). Management of interfaces is therefore not only about stimulating exchange of knowledge but also about building bridges between the various players. According to Kuhlmann (2001), successful policymaking means re-framing of stakeholders perspectives and common creation of consensus in innovation systems. Policy evaluation procedures are a good example of communication medium that can be used in moderation and negotiation. Governmental research policy administrators have a role play as moderators performing objective evaluations to motivate debates facilitating decision-making (Kuhlmann, 1998).

Other existing mechanism that could be used to support this condition include: bridging instruments (cooperative research programmes, centres of excellence, competence centres, researchers mobility, collaboration schemes); new forms of public private partnerships (ppp) that are enlarged, institutionalised and international (Narula and Hagedoorn, 1999), consensus development conferences, science shops, technology transfer, thematic networks, clusters, sectoral forums.

3. Stimulation of participation of relevant actors (esp. users)

Methodologically, this condition can be compared to organisation of a transition arena in transition management – a platform bringing together a heterogeneous set of actors, each acting on the basis of their own vital interests and expectations with sometimes opposing objectives and varied capacities. Good organisation of stakeholders' participation is a critical condition for various processes of first- and second- order learning. It requires, on the one hand, an open process in which actors are receptive for new claims and ideas and, on the other hand, an argumentative process in which actors become aware of the assumptions on which their own, and others, claims are based (Van de Kerkhof and Wieczorek, 2005). Organisation of national innovation systems is in the interest of governments. Their role in this process however is not that of a commander but a facilitator, providing conditions for a self-organisation of systems that have the potential to assist in achieving the selected objectives.

Individual tools that can be of use in such a process include: scientific workshops, public debates, (inter-) national conferences, thematic meetings, transition arenas, clusters and intelligent participatory approaches.

4. Creation of conditions for learning and experimenting esp. for demand articulation and vision development

To increase learning policy instruments should stimulate: interaction, experimentation, voluntary exchange of knowledge but also traditional R&D. Forecasting, scenario building, search for possible applications are especially useful mechanisms in supporting processes of demand articulation and vision development.

Examples of other, individual tools stimulating this condition include: trainings, education programmes, cooperative programmes, user surveys, articulation discourses, policy labs (Smits and Kuhlman, 2002; Glasbergen and Smits, 2003), backcasting and brainstorming.

5. Stimulation of presence of hard and soft institutions

This condition refers to the organisation of specific innovation systems by ensuring factual presence of hard and soft institutions. The issue of their quality and impact on the direction of systems - is dealt with under the following point. For the development of hard institutions: rules, principles, rights, etc, the role of government is quite critical. The government may pass new laws which speeds up some procedures and facilitates change through e.g. creation of new markets. By this the governments support not only variety but also institutional capacity to adapt to change. International law has been particularly effective as a driver of change towards sustainability at states' level through harmonisation of- and influence on- the domestic legal systems. Through international law for example, the governments have the possibility to geographically enlarge the markets and allow various domestic activities to connect and gain in power.

Hard institutions, law in particular is a reflection of a general social consensus and has historically been based on social customs and religion. Many of the core values in modern law can be traced back to the cultural principles of societies (Gupta, 2006). In that sense, soft institutions such as customs, normative values, ways of conduct are precursors of hard institutions and play an equally important role in facilitating or hindering change. Civil society increasingly shapes these norms through their debating and interpretation. Once adopted norms and regulations shape human behaviour.

Individual tools through which the presence of hard and soft institutions can be stimulated include: awareness building measures, information and education campaigns, public debates, lobbying.

<u>6. Prevention of too weak or too stringent institutions</u>

Institutions if too strong they have the power to stabilise and lock existing systems in. Malerba (1997) talks about an appropriability trap caused by too stringent hard institutions that hinder innovation as much as those of too weak character. If too weak they may either cause decomposition of established systems or prevent the build up of new consistuencies. Role of various actors is here critical – they may influence hard (governments) and soft (consumers, NGO's, industry) institutions so that they facilitate innovations in a sustainable direction.

Existing tools that have the potential to stimulate either one are: regulations (public and private); limits; obligations; norms (product, user); agreements (voluntary); patent laws; standards; taxes; rights; principles; non-compliance mechanisms; customs; normative values; ways of conduct; as well as information campaigns and lobbying.

<u>7. Provision of infrastructure for strategic intelligence</u>

This condition concerns availability of- as well as a rapid and easy access to- a specific type of knowledge, namely strategic. Provision of infrastructure for strategic intelligence translates to identification of sources such as TA, explorations, evaluation research and benchmarking, and their connecting as well as enhancing accessibility for actors (clearing house). It can also concern the development of a player or a facility that meets the need for strategic information of the involved players (Smits and den Hertog, 2007). Policy is also challenged to facilitate actors in articulation of their demands and development of strategies. Centres (specialising in strategic intelligence) and knowledge transfer mechanisms (with special role of ICT in transmitting knowledge) may fulfil this double requirement.

Other useful tools include policy intelligence – monitoring and evaluation of policies, innovation systems analyses, intelligent benchmarking practices, EU scoreboard, trend charts, EU policy monitoring networks, knowledge brokers (like the Finish Science and Technology Policy Council). Supportive function may play knowledge management techniques and tools such as knowledge audits, mapping, document management etc[14] (Hidalgo and Albors, 2008).

8. Stimulation of physical and knowledge infrastructure development

This condition concerns the conventional support to basic physical and knowledge infrastructure but only if it presents a systemic problem. In that sense R&D support is justifiable as one of the possible strategies. Tools that support this condition include all traditionally used fiscal facilities (taxes, subsidies, loans) as well as directives and patent laws supporting R&D, R&D schemes, funds of various sort, public research labs, etc.

The following Table 4 presents the potential of traditional policy tools to stimulate the 8 conditions. Depending on the system and its specific problems, the same tool may be used to support one or more conditions. The table therefore does not present any new way of classifying existing tools. It only shows that they could be used as building blocks of systemic instruments as individually they do not have the capacity to ensure the overall functioning and the desired direction of the systems.

{Table 4 about here}

4. Systemic instruments

In this paper we have shown that the recent innovation theory does not reject such traditional innovation policy instruments as patent law, subsidies or tax credits. Instead it (i) provides an explanation for differential effects of these tools dependent on the context of their application (Lipsey at al., 2005) and (ii) shows a possibility of achieving policy objectives without being tight to one generic instrument. The 8 conditions identified in section 3.4.1 provide a consistent

[14] For a very useful overview of strategic intelligence per phase of policy-making see Boekholt (in Smits et. al 2009).

framework for a coherent application of traditional tools for a specific system[15] and its problems. This gives a promise of a positive mutual interaction and reinforcement of individual tools and allows systemic instruments to respond to particular context dependent policy demands (Howlett et al., 2006) as well as offer a very tailor-made policy advice.

4.1 Working definition and examples

Policy instruments are techniques that one way or another involve the utilisation of state resources or their conscious limitation in order to achieve policy objectives. They are the mechanisms and techniques of government used to implement or give effect to public policies (Salomon, 2002). Over the last years a shift could have been observed in the governance of innovation policies away from a very strong role of government towards a common decision-making where other actors also participate (governance). By this the role of government changed. It is nowadays is seen as one of the actors whose job is to steer rather than to row (Peters, 2000). In that light a possible working definition of a systemic instrument could be:

Systemic instruments are methods and mechanisms used by government, political parties, business or individuals to organise, coordinate and direct innovation systems. Systemic instruments are designed for (a coherent part of) a specific innovation system and can be defined as integrated set of traditional policy instruments addressing systemic problems in an orchestrated way. Based on the review of recent innovation theory we expect that systemic instruments need to stimulate one or more of the conditions as stated in section 3.4.1. Examples of existing systemic instruments are presented in Box1, 2 and 3.

{Box 1, 2 and 3 about here}

[15] Depending on the level of analysis - it can be national or technological innovation system at a particular moment of its development. Time factor is quite important because the development stages of systems differ and may thus require different policy approaches.

4.2 Systemic instruments vs. policy mixes

Theories of policy instruments choice have gone through several generations away from analysis of individual tools to comparative studies of instruments selection and instruments choice within implementation mixes or governance strategies (Howlett et al., 2006). Current next generation of theory on policy instruments centres on the question of the optimality of instruments choice and their coherence (Howlett et al., 2006) within mixes of tools. Similar shift of attention from individual instruments and best-practice tolls towards policy mix idea is visible in the innovation policy field. The perception being that the success and failure of particular instruments is dependent on the context and governance in which it is used. In place of stand-alone policies, portfolios of policy instruments are designed, in order to enhance both the individual elements of the innovation systems as well as the system as a whole (Guy and Nauwelaers, 2003).

According to the European Policy Web Portal (2009) the 'innovation policy mix' refers to a set of policy instruments, which together aim to influence R&D investments. Incentives dominating the current national policy mixes are financial instruments (tax facilities, subsidy schemes, loans) that support production and transfer of R&D and focus on individual organisations or on the relation between organisations. Brokerage and bridging institutions (such as collaborative R&D schemes or technology transfer) as well as integrated packages are in minority or lacking (Boekholt, 2001). Table 5 presents an example of policy mix for the Netherlands.

{Table 5 about here}

That does not mean traditional instruments should be abandoned. What we criticise here is the allocation of national resources, mostly to traditional R&D (only one of the 8 conditions of systemic instruments), less for R&D cooperation and in many countries none for improving the exploitation of public knowledge or human mobility. There is further no support envisaged to other conditions such as learning or experimenting, demand articulation or strategic intelligence infrastructure development while we showed in earlier sections that these are quite critical conditions for innovation. We conclude that it is not much the individual instrument itself but the purpose for which it is used that makes the difference. This brief analysis as well as the earlier findings demonstrate that while the idea of policy mixes is very good one and theoretically well-based – in practice the current policy mixes do not meet the new demands. We expect that application of systemic instruments with their 8 conditions as broad categories for allocation of national resources gives a promise of higher rates of innovation and (more sustainable) orientation of economic development.

5. Conclusions

In this paper we have reviewed major contributions of various disciplinary strands (neoclassical economics, evolutionary, systemic and knowledge-based) to the modern innovation theory in search for their implications for the characteristics of contemporary innovation policy and instruments. Firstly, this review revealed complimentarity of the three perspectives and confirmed the need to redefine the current general philosophy of innovation policymaking including its objectives, rationale, and the theoretical model. Given that innovation takes place in systems – proper functioning and ensuring a desired direction of the innovation systems is what gives a promise of increased rates and desired direction of innovation. Concerning specific implications for the characteristics of new, systemic policy instruments we have identified 8 conditions that these mechanisms should stimulate. One of the conditions refers to the NC stimulation of knowledge and physical infrastructure development, which yet once more confirms the complimentarity of the various theoretical perspectives. We also concluded that this new, holistic approach to policy making does not dismiss traditional policy tools. Instead it treats them as building blocks for the systemic instruments to be designed by policy makers for specific innovation systems. This context-specificity of systemic instruments makes them non-transferable to other conditions and by this - also different from the popular ‘best practices’.

The changes in the philosophy of policy making as well as the ‘design activity’ poses challenges to policy makers too. There is quite a clear need for a new breed of policy makers who are able to recognise and analyse the changing policy contexts and design policy mixes, which are tailor-made to the specific institutional and locational conditions and which correspond with the selected policy objectives. It is extremely important that particular instruments function within specific political systems. For example legalistic style of administering, characteristic for most continental political systems is based on the use of tools that depend on strict legal enforcement. The Anglo-Saxon and Scandinavian styles of administering may better use tools that function through complex interactions of social and political organisations. This further emphasises the importance of public administration and management techniques to instruments success and the need to orchestrate decision-making, which often happens in different locations. As it is now, instruments selection is mostly done by the programmes that will use them, while their management is done by e.g. personnel departments or budget agencies (Peters, 2000). Peters (2000) also talks about a three-way matching: the nature of the policy problem, instruments and management technique. This is exactly what systemic instruments are about. Their increased presence may also be handy in getting rid of the so-called ‘instrumentalism’ - commitment of individuals to particular instruments (Linder and Peters, 1988) because each systemic instrument is different and may need adjustment over time.

While some of the management issues are practical about ensuring functioning of the public organisation (innovation systems); some are normative and refer to the direction in which innovation systems develop. Sustainable development is a goal chosen in a socio-political process. It is important that it is clearly stated in the form of policy objective (Kroezer and Nentjes, 2006), because it gives guidance with respect to the course of the technological development and by this it contributes to creating the selection environment for the arising alternatives. In that sense it defines the desirability of trajectories and undesirability of specific lock-ins. The heavily discussed in the literature issue of innovation governance is then about giving space for a number of (sometimes competing) innovation systems until clear, desired from the sustainability objective alternatives emerge. This suggests that (i) innovation policy should focus on new, emerging fields so that new combinations and new innovations are born and (ii) ‘contemporary’ innovation policy is by implication a sustainability-oriented innovation policy.

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Tables

Table 1. Three types of non-NC insights about innovation, based on Bach and Matt (2005).

Evolutionary aspects (general logic)	**Systemic issues (how it works)**	**Knowledge/learning related issues (basic engine)**
Endogenousness Interactivity Path dependency & cumulativeness Co-evolutionary nature Uncertain/open-ended	Collectiveness Multi-actor characteristics Importance of users Importance of institutions.	Multiple kinds & forms of knowledge Knowledge diffusion & utilisation. Learning Strategic & tailor-made information

Table 2. Summary of the policy relevance of the three types of non-NC insights about innovation.

Evolutionary aspects of innovation (general logic)	**Systemic issues (how it works)**	**Knowledge/learning related issues (basic engine)**
<u>Endogenousness</u>: - Importance of human & physical capital, esp. soft, organisational skills of actors - LM contested due to non-linearity and non determinism of innovation <u>Interactivity</u>: - Importance of communication, feedbacks, loops, networking, cooperation, knowledge sharing - MF as a rationale contested <u>Path dependency & cumulativeness</u>: - Danger of undesired, untimely lock-in, irreversibility - Importance of accumulated skills & knowledge as a source of diversity - Possibility to influence pace & direction of change along selected objectives (e.g. SD) - NC representative agents contested - EM an alternative to LM <u>(Co-) evolutionary nature:</u> - Importance of variety creation, retention & selection (EM) - Possibility of a creative destruction & dealignment of existing linkages & competencies - Importance of institutional & socio-cultural elements of a selection environment - NC def of a selection environment – too narrowly focused - EM an alternative to LM <u>Uncertainty:</u> - Importance of human capital - Importance of experimenting, trying options & learning by making various choices - Importance of looking forward,	<u>Collectiveness</u>: - Importance of good organisation of IS for influencing both the pace and the direction of innovation - Importance of actors, institutions, infrastructure & interaction within IS - IS - complementary to the LM, NC view of innovation - Systemic problems - complementary rationale to MF - Systemic policy tools - coherent & effective at the level of systems, addressing systemic problems – complimentary to market-based instruments. <u>Multi-actor character:</u> - Importance of a variety of heterogeneous actors & their capabilities - Importance of management of interfaces, coordination of information levels moderation, provision of negotiation conditions & consensus building among the growing number of heterogeneous actors - NC representative agent contested <u>Importance of users:</u> - Importance of users & their roles in innovation - NC representative agents contested - LM contested <u>Importance of institutions</u>: - Importance of (hard and soft) institutions as a selection environment - Importance of preventing too weak or too strong institutions - NC def of selection environment –	<u>Multiple kinds/forms of knowledge:</u> - Importance of scientific, non-scientific, technological, non-technological, tacit & codified forms of knowledge as engine of innovation - Importance of capacity of actors to exploit existing knowledge & to make codified knowledge meaningful - Importance of (interactive) learning for articulation of demand & vision develop. - LM – too narrow - NC def of knowledge – incomplete - Traditional tools - insufficient <u>Knowledge utilisation & diffusion:</u> - Importance of knowledge production & exploitation - Importance of actors capabilities - LM too narrow - NC approach focused on production side – insufficient - MF contested - Tools portfolio - insufficient <u>Learning:</u> - Importance of various sorts of learning & learning capabilities - NC view of learning contested - Tools - insufficient <u>Strategic & tailor made knowledge:</u> - Importance of identification & selection of useful, strategic knowledge - Importance of articulation of demand - Traditional tools - too narrow

anticipating future, long-term perspective, strategies & visions - LM, MF contested due to relevance of uncertainty as a driving force of innovation	too narrow	

LM – Linear Model; EM – Evolutionary Model, MF – Market Failure; IS- Innovation System, SD – Sustainable Development

Table 3. Summary of the policy implications of the three perspectives on innovation (evolutionary, systemic and knowledge-based) as compared to the NC approach.

Policy aspect	**NC perspective**	**Evolutionary view**	**Systemic perspective**	**Knowledge-based view**
Objective:	To influence <u>pace</u> of technological change.	To influence pace and <u>direction</u> of technological change.	To ensure functioning (evolution) of IS and direct IS towards selected goals, e.g. SD.	To exploit full potential of knowledge – the main resource and to create new resources within systems
Model:	Linear model (LM)	Evolutionary model (EM)	Innovation System model (IS)	Knowledge/learning-based IS
Rationale:	Market failures (MF) (externalities, info asymmetry, imperfect competition)	Problems of variety creation, retention, capabilities or selection.	Systemic problems (institutional, interaction, capabilities, infrastructure)	Problems with knowledge exploitation and demand articulation
Instruments:	Individual, fiscal, - stimulating R&D	Tools stimulating variety generation, capability and selection	Systemic instruments organising and directing IS:	Tools stimulating acquisition and exploitation of various forms of knowledge and demand articulation

LM – Linear Model; EM – Evolutionary Model, MF – Market Failure; IS- Innovation System, SD – Sustainable Development

Table 4. Potential of individual policy tools to stimulate functioning and development of innovation systems through contribution to the 8 conditions.

Conditions to be supported by systemic instruments	**Examples of traditional instruments and their potential to stimulate systemic conditions.**
1. Prevent undesired and untimely lock-in or stimulate creative destruction	Timely procurement (strategic, public, R&D-friendly); demonstration centres; SNM; political tools such as awards and honours for innovation novelties); loans/guarantees/tax incentives for innovative projects or new technological applications; prizes; CTA; technology promotion programmes; debates, discourses, venture capital; risk capital
2. Manage interfaces among actors	Cooperative research programmes; consensus development conferences; cooperative grants; bridging instruments (centres of excellence, competence centres); collaboration and mobility schemes; policy evaluation procedures; debates facilitating decision-making; science shops; technology transfer
3. Stimulate participation of relevant actors (esp. users)	Clusters; new forms of PPP, interactive stakeholder involvement techniques; network enhancing tools; public debates; scientific workshops; thematic meetings; transition arenas; venture capital; risk capital
4. Create conditions for learning and experimenting esp. for demand articulation and vision development	Articulation discourses; backcasting; foresights; road mapping; scenario development workshop, brainstorming; education and training programmes; (technology) platforms; policy labs; venture capital
5. Stimulate presence of hard and soft institutions	Awareness building measures; information and education campaigns; public debates; lobbying, voluntary labels; voluntary agreements; customs; normative values; ways of conduct
6. Prevent too stringent and too weak institutions	Regulations (public, private); limits; obligations; rights; principles; norms (product, user); agreements; patent laws; standards; taxes; non-compliance mechanisms; customs; normative values; ways of conduct
7. Provide infrastructure for strategic intelligence	Foresights; trend studies; roadmaps; intelligent benchmarking; SWOT analyses; sector and cluster studies; problem/needs/stakeholders/solution analyses; information systems (for programme management or project

	monitoring); evaluation practices and toolkits; user surveys; information databases; consultancy services; knowledge brokers; tailor-made applications of group decision support systems; knowledge management techniques and tools; TA; knowledge transfer mechanisms; policy intelligence tools (policy monitoring and evaluation tools, innovation systems analyses); scoreboards; trend charts
8. Stimulate physical and knowledge infrastructure	Classical R&D grants, taxes, loans, schemes; funds (institutional, investment, guarantee); public research labs

Box. 1. The Dutch Knowledge Network on System Innovations (BSIK KSI) – An example of a systemic instrument

General characteristics:

- Launched in 2004.
- A Dutch research programme comprising over 80 multi- and interdisciplinary researchers from universities and research institutes with specific knowledge as well as applied and practical research experience on transitions and system innovations.
- Objectives: to better understand, identify and influence transitions to a sustainable society by further developing and operationalising existing knowledge in sectors such as energy, agriculture, transport, spatial planning and health care. The interests cover on the one hand process architecture, system knowledge, learning processes and competence development of transitions, and on the other - instruments for initiating, guiding, monitoring, and evaluating transitions.
- At the core of KSI is the dynamic interaction between transition experiments and the generation and application of knowledge. Societal transition processes are believed to drive and inspire the interdisciplinary knowledge development through learning by doing. In turn, the development of new transition knowledge enables informed action of key stakeholders in societal transition processes. To realise this interaction three sub-programmes were set:
  - Fundamental Transition Programme (FTP) geared to the development of fundamental knowledge of transition and transition management along three complementary research lines: historical transitions, ongoing and future transitions, and transition management.
  - Practice-oriented research (PO) focusing on the development of competences, conditions and exchange mechanisms based on transition experiments in various sectors. Specific projects were selected and co-funded by organisations and stakeholders actively involved in ongoing transition processes. Many of them are combinations of FTP and PO.
  - Testing Ground (TG) as part of PO managed by practice organisations with participation of KSI researchers. TGs are practical transition experiments in which stakeholders work together to contribute towards solving persistent social problems in specific sectors such as at agriculture, mobility, health sector or energy.

Systemic instrument?

1. Prevent lock-in or stimulate creative destruction? YES ++
2. Manage interfaces among actors YES ++
3. Stimulate participation of relevant actors (esp. users)? YES +++
4. Create conditions for learning and experimenting? YES +++
5. Stimulate presence of hard and soft institutions? YES +
6. Prevent too stringent/too weak institutions? YES +
7. Provide infrastructure for strategic intelligence? YES +++
8. Stimulate physical and knowledge infrastructure? YES ++

Box. 2. Innovative Actions Programme (ERDF: 2000-6) – An example of a systemic instrument

General characteristics:

- European Commission programme.
- Focused on encouragement to the less-favoured regions to invest in innovation and technological development with a view to reducing the lag in their development and enhancing their competitiveness. To encourage exchanges of experience and best practice in these areas by supporting in particular the creation of inter-regional thematic networks.
- Objectives: creating and reinforcing cooperation networks between firms (SMEs) or groups of firms, research centres and universities, training organisations, financial institutions and specialist consultants; staff exchanges between research centres, universities and firms; disseminating research results and technological adaptation within SMEs; support for incubators for new enterprises which have links with universities and research centres; use of new financial instruments (venture capital) for business start-ups.

Systemic instrument?

1. Prevent lock-in or stimulate creative destruction? YES ++
2. Manage interfaces among actors? YES +++
3. Stimulate participation of relevant actors? YES ++
4. Create conditions for learning and experimenting? YES ++
5. Stimulate presence of hard and soft institutions? YES +
6. Prevent too stringent/too weak institutions? YES ++
7. Provide infrastructure for strategic intelligence? YES +
8. Stimulate physical and knowledge infrastructure? YES +

Box 3. The British Sustainable Technologies Initiative (STI) - An example of a systemic instrument?

General characteristics:

- National program of collaborative R&D sponsored by the Department of Trade and Industry (DTI), the Department for Environment, Food and Rural Affairs (Defra), the Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC).
- Focused at improving the sustainability of UK business via knowledge creation, business innovation and support to finding markets.
- Objectives: to maintain high levels of economic growth and employment while protecting the environment, making better use of natural resources and working for the good of society as a whole.
- At the core of the STI is the development and adoption of new sustainable technologies.
- STI has part-funded 68 projects.

Systemic instrument?

1. Prevent lock-in or stimulate creative destruction? YES +++
2. Manage interfaces among actors? YES ++
3. Stimulate participation of relevant actors? YES +
4. Create conditions for learning and experimenting? YES +
5. Stimulate presence of hard and soft institutions? YES +
6. Prevent too stringent/too weak institutions? YES +
7. Provide infrastructure for strategic intelligence? YES +
8. Stimulate physical and knowledge infrastructure? YES +

Table 5. An example of a Dutch policy mix, 2000, source Boekholt (2001).

	Support of R&D	Measures addressing the mismatches in (risk) capital markets	Improving absorptive capacity	R&D co-operation	Knowledge diffusion	Framework conditions for high-tech starters	Human Mobility	Improving exploitation of public knowledge	Total per delivery mechanism
Tax facilities	54 (1)								54
Subsidy Schemes				18 (2)	1 (1)			2 (1)	22
Credit & Loans		10 (1)							10
Brokerage and bridging institutions			5 (1)	5 (1)	1 (1)				10
Integrated packages						3 (2)			3
Total per policy objective	54	10	5	23	2	3		2	100

The numbers represent the share of the type of instrument in the entire innovation policy budget. Number of instruments is included in the brackets.

Figures

Type of learning	Source of learning
By doing	in-house production experience
By using	user experience and competence
From advances in S&T	monitoring and forecasting S&T developments
From spillovers	involuntary leakage or voluntary exchange of useful knowledge
Formalised inquiry	R&D
From interaction	cooperative relationships

Figure 1: Network learning opportunities (source: Rycroft and Kash, 1999)

Annex 1. New innovation insights that appeared in selected literature positions attempting to link recent innovation theory and practice with policy.

Smith (1994)	**Lundvall & Borrás (1997)**	**Smith (2000)**	**Mytelka & Smith (2002)**	**Kuhlmann (2004)**	**Chaminade & Edquist (2006a)**	**Metcalfe (2005a)**	**Klein-Woolthuis (2005)**	**Smits et al, 2009**	**SUMMARY**
Non-linear, continuous rather than intermittent with complex interactions between firms and their external environments	Nonlinear, complex		Non-linear, complex	Uni-linear	Complex	Outcome of human decision making	Nonlinear, complex of reciprocical nature	Endogenous	**Endogenous and therefore non linear and complex and interactive**
Interactive, social process, continuous feedbacks,	Interactive of social nature, complex	Complex interactions between a firm and its environment and among the firms at various levels	Interactive	Iterative, complex with intense communication and interaction	Interactive at various levels (within the firm and beyond)	Matter of business experimentatio n, the economic trial of ideas	Interactive with feedback mechanisms, interaction central to cooperation	Interactive search	**Interactive**
	Cumulative	Path-dependent	Path dependent	Embedded in historically rooted, long standing socio-economic structures	Path dependent over time			Path dependent and accumulative	**Path dependent and cumulative**
Integrates market opportunities with design, development, financial and engineering capabilities of		Evolutionary processes play role	Co-evolving	Co-evolutionary	Evolutionary process, outcome of evolutionary processes within the systems. Never	Matter of interdependenc e between market and non market and public and private spheres	Evolutionary processes play important role	Evolutionary, result of co-evolution of technology and society	**Co-evolutionary**

firms, socio-technical process					achieving equilibrium				
	Uncertain, open ended.	Uncertain	Uncertain		With uncertain outcomes, unclear which path will be taken	Discovery process, With uncertain unpredictable outcomes, not a matter of calculable risks		Takes place in uncertainty	**Uncertain**
	Collective	Systems conditions have decisive impact on innovation decisions and modes	Occurring in systemic environments	Systemic	Within the systems, not performed in isolation, collective	Systemic	Not taking place in isolation	Systemic process rather than product of individuals	**Collective/systemic**
	Image of lonely scientist in a lab – no longer realistic	Multi-actor		Act of a variety of heterogeneous actors	Multi-actor		Heterogeneous actors	Variety of actors contribute	**Multi-actor**
	Role of competent users	User-producer interactions important		Importance of actors other than scientists				Special importance of users	**Users**
	Formal and informal institutions play role	Importance of institutions	Occurring in specific locational and institutional contexts that shape systemic environs	Importance of various kinds of institutions, inter-institutional networks and locational context, cultures etc	Role of institutions		Institutions crucial to economic performance and behaviour	Institutions and policy making matters	**Institutions**
Increasingly linked to science activity, but not only research based	Comprising not only scientific research	Knowledge creation central to innovation capability, different	No longer seen as a process of discovery only	Importance of soft side of innovation, non technical factors such as HR mangt	Not narrowed down to research and invention	Knowledge based, needing multiple kinds of information	Info asymmetry important	Increasingly linked directly to scientific knowledge, demanding knowledge and	**Multiple kinds and forms of knowledge**

		forms of knowledge important: tacit, codified, public, private disclosed and restricted		Increasingly linked to science				understanding of soft factors of innovation	
	Comprising not only scientific research but also different steps in the process incl. organisational aspects until a new product or production process has been launched.	Knowledge distribution within innovation systems determining their performance.						In addition to knowledge creation – knowledge diffusion and demand driven knowledge utilisation	**Knowledge diffusion and utilisation**
	Knowledge/learning based, learning – ability to acquire new knowledge	Interactive learning	Process of interactive learning in which social science field and a policy arena have been jointly shaped	Ability to learn critical	Interactive learning process		Interactive learning	Learning and learning environments are crucial	**Learning**
Tacit knowledge plays role	Importance of tacit and codified knowledge	Relevant economic knowledge	Economically useful knowledge, importance of tacit knowledge		Based on knowledge both codified and tacit	Tacit, lying outside of firm, need of valuable knowledge			**Strategic and tailor made knowledge**