Policy Letter

Policy framework conditions to foster "system innovation" with some illustration from an international perspective

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Abstract. "System innovation" is a multi-actor process that entails interactions between firms, consumers, policymakers, universities, supply chain actors, societal groups, media etc. In recent years, policymakers have shown growing interest in the role of innovation for addressing 'grand challenges, such as climate change, energy security, transport and resource efficiency, food safety, obesity, environmental sustainability. This interest has given rise to a debate about 'system innovation', large-scale transitions and socio-economic transformations, due to the realization that addressing grand challenges may require shifts to new systems in energy, food, mobility, and housing. System innovation is difficult to manage and steer, for it is an open, uncertain and complex process, involving multiple social groups and co-evolution between various system elements, many of which are outside the immediate control of policymakers. Furthermore, the state is not one actor, but fragmented across different domains (e.g. public sphere, private sphere, civil organisations, government) and levels (e.g. international, national, local). Policymakers cannot bring about these processes on their own, but need to invite all the aforementioned actors to work together through strategical public-private partnerships, demonstration projects, scenario workshops, vision building, public debates, and network management. So, in early phases of system innovation, policymakers tend to act as facilitator, stimulator, and chain manager. In later phases, when there is more clarity about the best technology, market demand, and infrastructure requirements, other policy instruments (e.g. regulations, standards, taxes, subsidies, financial incentives) tend to become more important, aimed at widespread deployment and uptake. Furthermore, national innovation systems (NIS) (i.e., education and training systems, science base, intellectual property rights, university-industry knowledge exchange networks, venture capital availability) provide important generic contexts in which countries address system innovation. It would be useful if future research would develop more dynamic understandings of NIS and investigate if and how NIS need to change to facilitate system innovation (e.g. through mission-oriented R&D, changes in incentive structures for academic researchers).

Keywords. NIS (National Innovation Systems), System Innovation, Policy Framework Conditions.

1. New paradigm on the horizon: the system innovation

In the 1990s, policymakers realised the importance of innovation for competitiveness and economic dynamics. Thus, the national innovation system (NIS) approach gained much attention, which conceptualised innovation as a systemic and interactive process, focused on generation and use of knowledge, and shaped by national institutional frameworks. Lundvall (1992: 12) defined NIS as: *"the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge (…) located within or rooted inside the borders of a nation state"*.

However, the concept of "system innovation" is hard to define, because the term 'system' lends itself for multiple interpretations, especially when systems are seen as interdependent components or connected elements forming an integrated whole. In this context, the authors wish to rely on the NESTA Report's definition of systemic innovation, where it is described as *"an interconnected set of innovations, where each influences the other, with innovation both in parts of the system and in ways in which they interconnect"*. However, this can still be regarded as a rather vague and open definition that does not give any indication as to the type of systems under consideration. The further specification about components and relations between components (architecture) is useful, however, and similar to Henderson and Clark's (1990) typology of technical innovation: incremental, modular, architectural, and radical innovation.

Table 1. Typology of technical innovation. (Henderson and Clark, 1990:12)

	Components reinforced	**Components overturned**
Architecture unchanged (linkages between components)	*Incremental innovation*	*Modular innovation* (components are replaced without affecting other components or the system architecture)
Architecture changed	*Architectural innovation* (components stay the same, but linkages between them change)	*Radical innovation* (changes in both components and architecture)

Like Henderson and Clark (1990), some other scholars have taken a firm-level perspective on system innovation, emphasizing that certain innovations require multiple changes and collaborations between various actors. In the context of the discussion on open innovation, for instance, Maula et al. (2006: 2) define system innovation as "innovations that require significant adjustments in other parts of the business system they are embedded in".

Combining this understanding of systems (acknowledging both form and function) with Henderson and Clark's typology enables the following general definition of "system innovation":

> *System innovation is a radical innovation in the configuration of elements that fulfils a certain function, entailing changes in both components and architecture of the configuration.*

In a knowledge-based economy, the emphasis on bottom-up learning processes (Bunders et al., 1999) can help to avoid reification of systems as barriers to innovation. In an overlay of communications between industrial, academic, and administrative discourses, new options and synergies can be developed that can strengthen knowledge integration (Leydesdorff, 2012). The triple helix model distinguishes three basic types of organizations, namely, the universities as the organization training and spreading knowledge, the government research organizations which are organizations engaged in controlled strategic basic and applied research, and the innovative undertakings. Furthermore, it deals with the strength and intensity of the collaboration of these three types of institutions. Recently, the role of the society in creating knowledge and innovation has come to the light through the growth of the knowledge-based economy and the perfection of the knowledge-based society. The members of the society and the communities are basically related to some scientific, technical or business area, which has called the attention to a fourth sector, namely the civil sector, which is also connected to the mutual relations of the universities, the industry and the government. Thus, the further development of the Triple Helix resulted in the Quadruple Helix. Furthermore, after recognizing the impact of the (natural) environment in innovation, a third innovation model, the Quintuple Helix Model was introduced. (Carayannis et al. 2012)

In recent years, policymakers have shown growing interest in the role of innovation for addressing 'grand challenges, such as climate change, energy security, transport and resource efficiency, food safety, obesity, environmental sustainability. This interest has given rise to a debate about 'system innovation', large-scale transitions and socio-economic transformations, because of the realization that addressing grand challenges may require shifts to new systems in energy, food, mobility, and housing. The new interest in system innovation is also related to:

- demographic changes and ageing;
- urban developments (revival of city centres in developed countries and rapid urbanisation in developing countries);
- new possibilities and economic opportunities related to information and communication technologies (e.g. smart homes, smart cities, smart grids);
- concerns about food systems (e.g. food scarcity, climate change impacts, food availability and prices, obesity);
- concerns about inefficiencies, reliabilities and under-investment in critical infrastructures which are essential for the functioning of societies (electricity, gas, oil, telecommunication, water, waste, sewage, public health, roads, rail, finance);
- concerns in large firms (e.g. GE, IBM) about resources, inefficiencies, and new opportunities.

The recent interest in system innovation among policy makers can be traced to several policy challenges. The first concerns the long standing issue of the effectiveness and efficiency of national innovation policies, especially in a context of increasingly globalised R&D and production systems. In most countries, innovation policies aim to address market failures around investment in R&D in order to foster productivity and growth. But the focus is often on increasing the number of innovative firms, i.e. the 'rate' of innovation, with little regard to the direction of innovation outcomes or the distributional effects of innovation on economic growth.

The second challenge that has brought system innovation to the fore is that of sustainability, which is about safeguarding the environment and mitigating the effects of climate change and includes the protection of the earth's finite natural resources, including biodiversity.

However, current configurations of large technology and innovation systems in areas like energy, food, transport, health may not deliver the change in growth models that are needed in time to avoid the bleak scenarios. This is why "system innovation" matters – to make the systems that underpin economic and human activity more resilient, equitable and sustainable for the future.

For governments, meeting these grand challenges while achieving e.g. green growth and generating employment will require policy action to facilitate systems changes on an economy wide scale. These changes amount to no less than the transformation of distribution, production and innovation systems underpinning key economic sectors. However, effective system transformation raises formidable (tremendous?) policy challenges.

Some important strategic document related to system innovation:

- The Europe 2020 Strategy by the European Commission (2010) highlights the importance of “changing tracks” and “exploring new development paths” to generate smart, sustainable and inclusive growth. It also aims to “refocus R&D and innovation policy on the challenges facing our society, such as climate change, energy and resource efficiency, health and demographic change, and proposes transformative projects such as smart grids, a European supergrid, a major green car initiative (including electric and hybrid cars), renewable energy technologies, and strategic projects in cities, ports, and logistics
- The OECD (2010) report “Eco-innovation in Industry” highlights the importance of “system innovation”, which it defines as “innovation characterized by shifts in how society functions and how its needs are met” (p. 16). This is thought to include technological advances, organizational changes such as new business models, and broader institutional changes such as new policy frameworks and alternative modes of provision.
- Korea’s green growth strategy, “Road To Our Future” (2009) also aims to “shift the current development paradigm” by developing green technologies, promoting green industries, and changing lifestyles in industrial sectors, transportation, energy and buildings.

2. Policy framework conditions of the system innovation

The political science literature further usefully distinguishes three policy paradigms, which differ in their view on social relationships and roles of policymakers, coordination, underpinning scientific disciplines and preferred policy instruments. It is unlikely that system innovation can be brought about by a single policy instrument from one paradigm. Instead, shaping system innovation will entail a mix of policy instruments, which may differ between countries (see below).

Table 2. The main features of the three different policy paradigms (De Bruijn et al., 1993: 22)

	Classic steering (top - down)	**Market model (bottom – up)**	**Interactive network governance**
Characterization of relationships	Hierarchical, command –and – control (government sets goals or tells actors what to do)	Autonomous (government creates incentives and ´rules of the game´, which create context for autonomous actors).	Mutually dependent interactions
Characterization of coordination processes	Government coordinates through regulations, goals, targets	Incentives and price signals coordinate self-organizing actors	Coordination through social interactions and exchange of information and resources
Foundation scientific disciplines	Classic political science	Neo-classical economy	Sociology, innovation studies, neo-institutional political science

Governance instruments	Formal rules, regulations and laws	Financial incentives (subsidies, taxes)	Learning processes, demonstration projects and experiments, network management, vision building through scenario workshops, strategic conferences, and public debates

The role of the general context for system innovation and transitions with regime actors and some policy-makers using this context to emphasise the costs of transitions, and expressing a willingness to slow things down. In many cases, innovation policies have an important role in facilitating system innovation.

System innovation can help for policy makers re-think their innovation policies in broader context. In this section, we will give a comprehensive overview about the main factors which have impact on system innovation.

- A central tenant of system innovation is that governance of the transition does not lie solely in the marketplace but in niches and regimes where institutions, regulations, consumers, and governments interact. Governance mechanisms (i.e. co-ordinated decision making, risk-sharing and co-financing among stakeholders, self-assessment and independent evaluation etc.) as a whole play an extremely important role in the success of system innovation.
- Large-scale, high-tech resources and infrastructure are great assets, which can be used for accelerating technological innovation through public-private partnerships. It provides common platform to efficiently stimulate collaborative activities with interested actors from industry, academia, and public research institutes; allowing them to save costs, time and generating synergies.
- Private investment expands an economy's productive capacity, drives job creation and income growth, and in the case of international investment, is a conduit for the local diffusion of technological and enterprise expertise and spurs domestic investment, including through the creation of local supplier linkages. Such benefits can act as a powerful force for development and poverty eradication. The benefits of investment do not necessarily accrue automatically or evenly across countries, sectors and local communities. Countries' continuous efforts to strengthen national policies and public institutions, and international co-operation, to create sound investment environments matter most.
- The education system plays a major role in system innovation. How quickly education and training systems respond to the needs of emerging niches – e.g. catering to new disciplines by founding new university departments and by standardising education - seems an important determinant of swift transitions. Human resource development has multiple dimensions, covering educational attainment, workforce skills, population health and the set of employment policies that connect people to business enterprises with appropriate skills and the ability to adapt quickly to new challenges.
- Intellectual property rights give businesses an incentive to invest in research and development, and ultimately lead to the creation of innovative products and processes. They also give the holders of such rights the confidence to share new technologies, such as in the context of joint ventures. Successful

innovations are in time diffused within and across economies, bringing higher productivity and growth. Investment is thus, both a pre-condition for the creation and diffusion of innovation activity. The intellectual property right protection instruments used by governments to encourage investment in research and development include patent and copyright laws, which give the owner, for a pre-determined period of time exclusive right to exploit the innovation. The intellectual property rights regime is not only a matter of concern to large firms and multinational enterprises with significant research and development programmes, but also to small- and medium-sized enterprises (SME). SMEs are a driving force behind innovation, yet their potential to invest in innovation activities are not always fully exploited. SMEs tend to under-utilise the intellectual property system, partly due to their lack of awareness and associated costs.

- Intellectual property including foreground and background IP can be managed flexibly according to the strategic nature of a partnership. IP policy can be limited, or open to outsiders for the exploitation and dissemination of IP, or encouraged to be shared jointly with participants. P/PPs could us specialist groups to provide professional advice on IP management issues in the form of IP working party or IP committee under the P/PP governance structure.
- Research funding reform has focused on efficiency and economic impact. Less attention has been paid to the 'branching' of scientific disciplines that is sometimes necessary to facilitate transitions. Funding opportunities for communities of researchers interested in emerging topics may be hard to come by. Social processes, such as reputation dynamics (e.g. older journals have higher citation ranks but may be conservative) may act as barriers to branching. For the branching of technology too, the formation of viable voluntary associations can be crucial to standardisation.
- The branching of science is sometimes triggered by technological developments. The history of technology is replete with examples of technological inventions that were poorly understood by the science of their time. In some cases, breakthroughs were only possible after science had 'caught up' and adequately explained the behaviour observed in new technology. Despite progress in linking science and technology, most scientific research is governed and driven by its internal dynamics.
- Corporate political strategy suggests that firms can act as political entities and use various strategies to shape policy-making processes:

  Information and framing strategy. Industries can:

  a) setup research institutes or sponsor favourable research,
  b) use this expertise to contest scientific findings and draw attention to uncertainties,
  c) report research results to influence policy debates or demonstrate the(in)feasibility of certain solutions, testify as expert witnesses in policy hearings.

  Financial incentives strategy. To influence policy makers, industries can:

  a) make contributions to politicians or political parties,
  b) pay fees for speaking at conferences,
  c) offer politicians lucrative jobs at the end of their career.

  Organised pressure strategy. Industries can mobilize networks to create pressure through:

  a) mobilization of employees, suppliers, customers, etc. who send letters and pressure their representatives,

b) creating fake grassroots organisations ('astroturf') that claim to speak on behalf of public interests, but are funded and managed by industries, or
c) create industry associations that speak for the industry.

Direct lobbying strategy. Industries can:

a) hire lobbyists or
b) directly mobilise company executives to engage governments.

Confrontational strategies. Industries can:

a) oppose laws through litigation,
b) threaten policymakers with plant closures, layoffs, or relocation,
c) refuse to implement policies, or
d) comply only partially with policies.

Existing divisions of policy portfolios emphasise the role of national and increasingly regional levels of governance for innovation, while the city level has traditionally received little attention. However, innovation needs and complementary investments during transitions can be highly localised requiring the mobilisation of policy makers from the national, regional and, especially, the city level of governance.

There are different rationales for innovation policy, linked to different topics and disciplines. The rationales for system innovation relate to some of the specificities of system innovation, discussed above:

- *Directionality*. System innovation is about purposive transitions, oriented at solving social problems and meeting political goals. It is important to develop visions, perhaps through foresight tools or expert committees.
- *Demand articulation*. System innovation includes changes on the demand side; demand for new innovations is not waiting 'out there', but needs to be articulated; markets needs to be actively created (Sarasvathy and Dew, 2005), often in co-evolution with new technologies through a 'probe and learn' process (Lynn et al., 1996).
- *Policy coordination*: because system innovation takes place in concrete sectors or domains, (system) innovation policy needs be (horizontally) coordinated with and sectoral policies (transport, energy, agriculture). Because system innovations entail large consequential changes, support from high political levels may be needed to enhance the legitimacy and visibility of transition initiatives (e.g. embedding within and reinforcement by broader national environmental policy strategies).
- *Reflexivity*. System innovations are open-ended and uncertain processes. Evaluation and regular monitoring of public policies serve to ensure feed-back into policy design.

3. Some international example for the system innovation

Governments in different countries practise different policy styles. They are therefore likely to manage specific system innovation challenges in different ways.

Korea: green innovation (Lee, 2014)

The green innovation-based system transition has the objective to mitigate the degree of climate change and to create new growth engines for the future. Korea has the ambition to become a leader in the global market of green innovation. The Korean government is committed to using a holistic strategy to connect enterprises, local governments, local innovation actors and towns. Increasingly, civil society actors are also integrated. Ongoing initiatives include energy plans, green towns and a smart grit roadmap. Low energy prices, hidden costs of transition programs, few market opportunities and weak consensus building with local communities pose challenges to system transition. Enabling technologies are expected to play an increasingly important role in Korean system innovation, since many of them are in the early stage of diffusion. One problem seems to be the confusing boundaries of what is green innovation.

Netherlands: biobased economy (Besseling, 2014)

The goal is to largely replace fossil oil by biomass, with a focus on chemistry and agriculture. Some materials can in fact only be produced with biofuels, e.g. policy lactic acid. The government´s main function is that of a network partner between science, chemistry, energy, agro-food, horticulture and water processing industries, while the role of society is central to the success of system innovation. Open questions concern the sustainability and ethics of biomass production. Most sectors involved in biofuel are supported through public-private partnership initiatives. Progress has been made in the development of indicators, which were analyzed in various studies. As one example, the number of network linkages of the biorefinery technology has increased significantly from 2010 until 2013.

United Kingdom: system innovation in long-term care (Mace, 2014)

In the UK, the elderly care system is shifting from residential care, based on nursing homes, to a new model which emphasizes the care of the elderly in their own homes. Both an ageing population and financial pressures force governments to re-think their approaches to elderly care. Assisted-living technology can help enable elder citizens to stay independent longer than is currently possible. The goal is to use new technology to monitor people at home and transfer the data to health and care facilities. The shift is expected to take decades, hence the project is still in an early phase. There are two main lessons learned: barriers to system change can be closely interconnected (technical, procurement, cultural values, fragmented policies), which is why policy needs to respond to this interconnectedness. Secondly, uncertainty is particularly important in this case and needs close attention to deliver successful elderly care. This makes a holistic approach necessary, as one particular political actor will not be able to overcome all challenges at once. Uncertainties, also with respect to business models, are addressed through the economic and business models of ALIP.

Hungary: system innovation in knowledge based economic transition

The National Smart Specialization Strategy (S3) is intended to provide a point of origin and a framework for the design processes and implementation related to the research and development and innovation activities. The strategy aims to transform the economy into a knowledge-based economy by development earlier innovation activities, which requires the adjustment of the governance structure. It also strengthens the specific regional conditions in order to develop a specialised RDI system which is competitive internationally and, through its resource absorption ability and resource utilisation efficiency, contributes to building an economy which is competitive in the European context. In this context, the successful implementation of S3 can be regarded as a system innovation.

The figure 1 below summarises briefly the Hungarian smart specialisations and the national priorities, which can be derived on these bases.

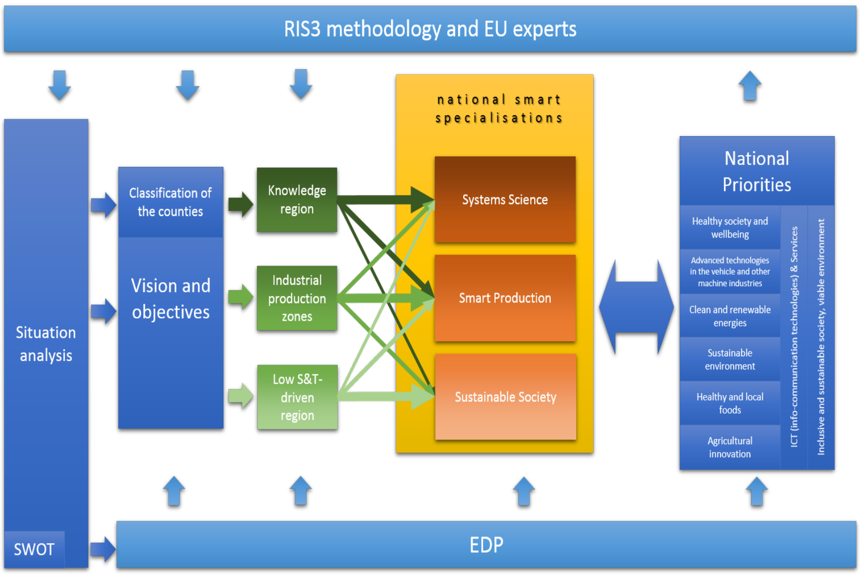

Fig 1. The Hungarian smart specializations and national priorities

Table 3. Summary of the systems science, smart production and sustainable society

Systems Science:	Emphasis is put on the systematic approaches implemented in researches. New scientific results are achieved at the border areas of disciplines, by use of world-class scientific results achieved by similar disciplines, thereby renewing the research area. Directly stemming from or based on these results, such applications will be possible to be used that are of importance to the economy or society.
Smart Production	Its focus is on product development. It is able to manufacture its own products or improve an already existing product through technological renewal in the innovation value chain, which provides a competitive advantage, in particular with the support of smart technologies and/or advanced materials.
Sustainable Society	Innovative answers are given to societal challenges. The sectors are put at an advantage by instruments of follow-up innovation, by use of the newest research results, modern technologies, devices and materials; thereby making the environment fit for life and enhancing the preserving force of the region through social innovation.

4. Conclusion

To sum up, system innovation is characterized by: 1) fundamentally different knowledge base and technical capabilities that either disrupt existing competencies and technologies or complement them leading to 'new combinations', 2) changes in consumer practices and markets, 3) changes in infrastructure and other elements (e.g. policy, cultural meaning).

The development of new knowledge and capabilities, for instance, is also crucial for system innovation. Furthermore, national innovation systems (education and training systems, science base, intellectual property rights, university-industry knowledge exchange networks, venture capital availability) provide important generic contexts in which countries address system innovation. A drawback, however, of much of the NIS-literature is its static and comparative character. It would be useful if future research would develop more dynamic understandings of NIS and investigate if and how NIS need to change to facilitate system innovation (e.g. through mission-oriented R&D, changes in incentive structures for academic researchers).

Effective management of the system innovation will require intensified coordination between policy areas (innovation, education, tax, regulation etc.), between levels of governance (national, regional, cities), between stakeholders (public, private and voluntary organisations). Effective policy design will hinge on improved understanding of the process of transition, of barriers and facilitators. It will likely require new ways to link research to system innovation, the deployment of dedicated policy instruments and new approaches to governance (e.g. public-private partnerships, performance contracts).

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