Approaches for Developing National STI Strategies†

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Abstract

This paper reviews the most central analytical and methodological issues that arise in developing national STI strategies. First, an outline of the relationship between national innovation systems and the strategic dimension is presented. The paper shows that science, technology and innovation strategy are often used in different forms and that there is no common understanding yet of the actual meaning and coverage of these strategies. The paper develops the terminology from a discussion of different approaches towards company innovation processes analyzing their evolution in different socioeconomic environments and the role and impact of science, technology and innovation policy on company innovation processes. Based on this conceptual understanding the paper defines national science, technology, innovation, and STI strategy and explains the basic terminology. From these definitions, the strategic dimension including the impact on the stakeholders is discussed. It is shown that a major success factor for STI strategy development is the involvement of stakeholders to vary and extend their use of their portfolio of instruments. Moreover it becomes evident that stakeholders follow their own interests which aren't necessarily in the interest of the national STI strategies. The analysis shows advantages and disadvantages as well as potentials and limitations of different approaches to develop STI strategies in their ability to describe the reality of innovation processes and to allow conclusions about the relationship between innovation policy and the innovation processes implemented by companies. It is shown that knowledge of these limitations is an important factor to consider in designing consistent and coherent national STI policy which aims at supporting innovation eventually. Finally the paper concludes that the STI policy mix concept needs a more systemic development approach which is integrated in the national STI strategy development and implementation.

Keywords

national innovation system, science policy, technology policy, innovation policy, STI policy, STI strategy, STI policy mix

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1. INTRODUCTION: SCIENCE, TECHNOLOGY AND INNOVATION STRATEGY IN THE CONTEXT OF NATIONAL INNOVATION SYSTEMS

Many countries are continuously challenged with the development of the infrastructural basis of their national innovation systems (NIS). Numerous different policy measures developed in this context are commonly considered as the country's "STI (science, technology, and innovation) policy mix." Despite their best intentions, many of these measures do not pay enough attention to the social dimension of interactions of elements and actors in their innovation systems. Consequently, such measures are questionable in terms of effectiveness and efficiency, furthermore raising the issue of justification for any sort of public policy intervention.

The current major challenge in NISs is to develop the embedded elements that enable and support building capacities at different levels. Innovation systems that are turning this paradigm into sustainable measures are considered to perform better in the global STI-related competition.

Innovation is the result of the interaction between many collaborating stakeholders. In the course of generating innovation, the level of interaction, intensity, and also frequency typically vary. Moreover, any innovation is characterized by reasonable risk, which is commonly associated with a risk from the acceptance of change that is caused by any innovation. However, the change inherent in innovation often brings out resistance from those who are afraid of changing their ways. Innovations vary in not only their different types of impact or changes, but also in their different degrees and intensities of change. Hence it is necessary to understand the varied potential impact of innovations on the user and society. This needs to be taken into consideration when it comes to national innovation policy initiatives that by definition assume that innovations have a positive impact on the economy and society, justifying public support for innovation. Accordingly, an integrated national policy framework is required to create a robust innovation environment that addresses the new dynamics of global competition. An integrated innovation policy can facilitate and accelerate a market driven transition into an "innovation-based economy" that continuously nurtures and creates "new-to-the-world" products, services, and processes.

The total mix and composition of federal policies affect the overall performance of the national innovation ecosystem. Many of the critical choices lie outside the traditional focus on macroeconomic policies and R&D input such as those that influence the supply of talent, risk capital, the demand for innovation, and the vigor of regional innovation networks. A higher level of innovation performance can be realized from an integrated end-to-end (idea-to-market) policy approach. Certain general principles for STI policy and consequently for STI strategies are important to keep in mind:

- The private sector must have the lead role in transforming new knowledge and technology into products, services, processes, and other types of innovation.
- Governments can set the framework conditions to stimulate actors for engaging in knowledge generation and application, shaping the overall climate for innovation and creating an incentive to innovate as an enabler and facilitator.

- Policy measures should build on the strengths of actors and the system and expand their strong positions while minimizing weaknesses.
- STI policies measure should be balanced across all the factors that impact the innovation system. Research and technology input are necessary but insufficient for innovation success. Education, tax, regulations, competition, trade, energy, standards, procurement, and market access policies combine to influence the nation's innovation capacity and performance.

In most innovation systems, discussion at the national level assumes the central element when considering federal levels as an indicator and determinant for cultural phenomena usually attributed to nations as a territorial concept (Lundvall, Joseph, Chaminade, & Vang, 2009b). Underlying this is the assumption that regional innovation systems (or ecosystems) interact under the national umbrella in various shapes and ways while remaining in competition. It is assumed that regional innovation systems are open in the national context. Still, the question remains whether these are open in the context beyond national openness, and more importantly whether there is a need and a value-added to be expected for a regional system. In terms of national STI strategy, openness at the national level is certainly an important issue but always needs to reflect the characteristics of regional (sub-) and sectorial (sub-) systems. There are clear indications that certain regions or sectors might occupy a position along the innovation value chain at stages that are primarily serving the innovation competences of other ecosystems that are located in the same country, which are crucial for national competitive advantages and serve dedicated national interests. Thus these special characteristics are essential to know and consider in STI strategy building. International openness towards NISs and all related subsystems in the first instance narrowly includes STI-related measures and policies like science and technology research policy but are also broadly in terms of innovation such as human resources-related policies, migration and mobility policies, and tax policies. Oftentimes STI strategies are formulated with an explicit focus on developing national STI infrastructures by different means, in other words targeting science and technology basic development in the infrastructural sense but not involving complementary policy fields.

Lundvall et al. (2009) make a distinction between the STI mode of innovation systems (the science, technology, and innovation mode) and the DUI mode of innovation systems (the doing, using, and interacting mode). While the STI mode assumes an innovation system to focus on learning and innovation, the DUI mode is about learning modes and knowledge generation in different manifestations. Hence in terms of STI strategy development, the STI mode is the primary mode utilized in NISs for its emphasis on the constitution of the system and the strategic orientation of the NIS elements and actors. The DUI mode requires a different approach in STI strategy building, with a focus on the ability of the NIS actors to use the existing NIS infrastructure (infrastructure here meaning acting in the given environment of actors and institutions) with a reasonably explicit focus on communication channels and instruments to foster interaction and communication of actors, assuming that communication is eventually converted into action in the sense of doing and using. In this regard, STI strategy is confronted with at least a partial paradigm shift from institutional views and targets functional views, considering the functions of institutions more explicitly and appreciating the human factor in the interaction and communication between actors in the NIS (Lundvall et al., 2009). However, difficulties arise in defining the relevant functions as well as in approaching

and including them in different strategy developments and assessing their eventual contribution to and their importance for innovation (Kotsemir, Abroskin, & Meissner, 2013). In the end, innovation can be understood as a lever for institutions, companies, and thus regions and nations to become and remain competitive in the global context. In this regard, innovation mainly builds on the competences and capabilities existing in a region. Innovation itself is the result of an interactive and iterative process that involves the participation of different actors with different competences to varying degrees. Regardless of the shape and type of innovation, it can be assumed that innovations always grow in specific social, economic, political, and cultural contexts (Kotsemir et. al., 2013; Muller & Zenker 2001). Since innovations are characterized by their applicability and use as well as acceptance, innovations are in any case dependent on the given context from which they originate (Kotsemir et al., 2013; Meissner, Roud, & Cervantes, 2013; Vishnevski, Karasev, & Meissner, 2014; Zaytseva, Shuvalova, & Meissner, 2013).

Business service-induced innovation provide valuable information and indication about the role and meaning of knowledge for innovation and moreover the importance of targeted activities resulting in innovation. While there is a widespread belief that with the increasing penetration of ICT-enabled tools knowledge—the basis for innovation— and innovation would arise from a more globally distributed dimension, the example of Knowledge Intensive Business Services (KIBS) shows that innovation still arises from more or less local ecosystems from which they penetrate globally (Meissner et al., 2013; Muller & Zenker, 2001). The geographical proximity of innovators engaged in dedicated innovation projects and processes remains an important condition for the integration of different actors and their respective knowledge and competences in at least the early stages of innovation generation (Meissner, 2012b). Face-to-face contact, in other words the direct interaction of individuals, is still a major factor for building the trust and confidence essential for successful innovation. One can assume that geographic proximity also involves the social and cultural proximity of actors involved, thus the use and leverage of mainly tacit knowledge is eased considerably (Carlsson, 2006; Meissner et al., 2013; Muller & Zenker, 2001; Vishnevski et al., 2014).

Given this background, one might argue that including functional dimensions in STI strategy conceptualization complicated the overall strategy building process and moreover that the functional perspective is uncertain with respect to the identification and respective involvement of the functions that have an unpredictable impact on the resulting STI strategy. The latter holds ever more true considering the different modes of knowledge creation, processing, analysis, and use in individual entities by individuals, hence institutional functions but also the exchange and transfer between people, entities, and finally locations. In this regard, the definition of NIS but also of regional innovation systems (RIS) or sectorial innovation systems (SIS) inherits the danger of being misleading if STI and DUI modes are not reflected (see also Lundvall et al., 2009b). Innovations systems, regardless of whether they are national, regional or sectorial, are increasingly becoming more global and open towards integration in the global STI sphere (Carlsson, 2006). Moreover, any innovation system is integrated in global innovation activities through the existence and participation of especially multinational organizations, either companies or research institutions, that commonly have multiple locations distributed in different national and regional but also sectorial innovation systems. Through these memberships and the intra-institutional/intra-organizational exchange of

knowledge and information, even regional actors are included in the global innovation chains although not necessarily by purpose (Carlsson, 2006).

It is common practice that multinational or international companies locate R&D and innovation facilities at places where strategically interesting and relevant knowledge bases already exist, and more importantly where companies are convinced that capacities exist to develop such knowledge. Still, through the network or innovation system membership and the inherent flow of information within large international companies, locally generated knowledge is spilling over to other regions in both intended and unintended spillovers. This is an important issue to be aware of in the course of developing STI strategies at the national level since thus far, spillovers are more known for coming from the scientific community, an open community of research and knowledge-sharing that has expanded through the increased globalization of scientific and academic education offered by higher education institutions. Mowery (1998) provided the first evidence of the internationalization of corporations and their impact on NISs in the US innovation system. He found that as early as in the 1980s, the US innovation system became more internationalized when American industrial R&D began to globally expand its operations and foreign companies increasingly established R&D activities within the United States.

Knowledge and learning are embedded, and are therefore integral elements of the innovation system. Specialized elements of knowledge are commonly localized and mainly tacit, and therefore cannot easily be transferred between places. The systems innovation approach considers innovation an outcome of activities of more or less systematic and structured processes. Still, these processes are not always explicitly structured and described or even communicated. The necessary interactions among and between actors and elements of an innovation system (or ecosystem) are commonly social processes and interactions with an inherent uncertainty of timing when they will happen and more importantly uncertainty with respect to their intensity. In this regard, interaction processes are an essential part of the overall learning process, including an increasing number of participating elements and actors with the increasing specialization of the respective knowledge/innovation field. This characteristic of the learning and interaction process is broadly known and recognized, but its measurement and assessment remains an unresolved issue. For this reason, the comparability of different NISs is still limited to a pure input-output comparison complemented by rather qualitative case study-style information (Lundvall, 2007). Close geographic proximity is a characteristic of regional clusters that has positive impact on the linkages of companies with buyers, suppliers, and other institutions. These linkages are not only important for efficiency improvements along the overall value chain, but they also moreover affect the rate of improvement and innovation. There is evident influence on productivity and productivity growth arising from these proximities (Porter, 2000).

Innovation systems, national as well as regional, are integrated in global value chains. In the course of this integration and the respective share of competences in different fields, innovation systems develop into more and more global systems that can be considered a collection and combination of different elements of regional or national innovation systems. Innovations—as technological innovations but also as service or business model innovations—are created and developed through the

interaction of elements that in the narrower sense belong to national, regional, or sectorial innovation systems. Thus, by means of cross-system interaction, the interacting corresponding elements form standalone innovation systems that are temporary in nature in intensity, producing varied flows of innovation and "are to different degrees able to keep up with state-of-the-art practices in different technological frontiers" (Oinas & Malecki, 2002).

The predominating thought among STI policymakers about innovation is to follow a linear path in which investment in science regardless of basic or applied is assumed to ultimately lead to innovation (Meissner et al., 2013; Mowery, 1998). Therefore, national STI policies often target at selected pieces of the overarching complex and iterative innovation process. This thinking is also due to increasing public pressure on policymakers towards justifying the national expenditure on STI leading to considerable large-scale investments in basic research under assumptions as to the time it would take of their conversion into applicable and useable innovations. In this course, targeted STI measures are developed and continue to be developed that again aim at selected elements of the overall innovation system. The STI policy mix concept thus far is a pure collection of the different STI policy measures that lack coordinated effort. Moreover, selected items and measures of the STI policy mix have become essential matters of negotiations for bilateral and international political treaties from as early as the 1990s (Mowery, 1998).

In the course of the evolution of innovation system thinking, a shift in the understanding of innovation activities at different levels can be observed. Although the academic literature has understood innovation as an interactive and iterative process since the mid-1970s (Table 1), economists and policymakers have only begun to fully understand the feedback and iterative dimension of the innovation process and to integrate the implications into the design of relevant policy measures (Lundvall, 2005).

Table 1: Innovation Models Evolution from a Historical Perspective

Generation	Period	Author(s)	Innovation model	Essence of the model
1	1950s – late 1960s		Technology push	Linear process
2	Late 1960s – first half of 1970s	Myers and Marquis, 1969	Market (Need) pull	R&D on customer wishes
3	Second half 1970s – end 1980s	Mowery and Rosenberg, 1979	Coupling model	Interaction of different functions
		Rothwell and Zegveld, 1985	Interactive model	Interaction with research institutions and market
4	End of 1980s – early 1990s	Kline and Rosenberg, 1986	Integrated model	Simultaneous process with feedback loops; "chain-linked" Model
5	1990s	Rothwell, 1992	Networking-model	System integration and networks (SIN)
6	2000s	Chesbrough, 2003	Open innovation	Innovation collaboration and multiple exploitation paths
7 (emerging, not formed yet)	2010		Open innovator	Focus on the individual and framework conditions under which to become innovative

Source: Kotsemir, Meissner, 2013

Consequently, science policy and technology policy were extended by the innovation dimension, resulting in the concept of innovation policy (Lundvall & Borras, 2005 for an overview). The STI

policy mix concept has emerged with increasing attention given to industry, specifically to science linkages and the strengthening of absorptive capacities of users (Lundvall, 2005).

The development and application, thus introduction, of new technology often creates new opportunities that also impose complex challenges on organizations. Technological innovation inherits the potential demand for different managerial practices that in turn may lead to organizational changes and new routines in the operations of innovation projects and the ways of innovation management. In this light, organizational and technological innovations can be seen as intertwined innovations where the adaptability of an organization is determined by its ability to create new skills and competences that correspond to technological innovations. This paradigm is apparent to companies but it can be adapted to innovation systems thinking as well. In terms of innovation strategy, both at the corporate and innovation system level, the ability of the underlying system to adjust and adapt by competence building and reshaping organizational aspects becomes an important element of strategy development.

2. DEFINING NATIONAL SCIENCE, TECHNOLOGY, AND INNOVATION AND STI STRATEGY

STI strategies are created and developed in many, if not all countries around the world. Depending on the characteristics of the NIS, such strategies are developed and communicated top-down or bottom-up, or even in mixed form. However, the implementation of STI strategies and their related STI policies remain especially challenging (Chaminade, Lundvall, Vang, & Joseph, 2009). This is mainly due to the heterogeneity of countries, but even more of regions requiring individualized STI policies due to each NIS/RIS being embedded in a distinct ecosystem or socioeconomic context (Chaminade et al., 2009; Zaytseva et al., 2013). This heterogeneity of regions and countries in the broader sense poses serious limitations on adopting STI strategies and policy measures from other countries or regions. Such strategies and measures require thorough refinement and adjustment to the respective ecosystem and their related specific characteristics.

Since the 1990s, the regional dimension was and still continues to be considered an important source of competitive advantages (Park, 2011). Scott (1995) argues that regions are the bases of the organization of the global economy. Clusters are considered being an especially important driver of innovation for companies in the long term because transaction costs for external innovation partners and detecting and absorbing knowledge are comparatively low due to the underlying trust and familiarity of cluster members and the anticipated technological and skill advantages resulting from this (Krugman, 1995; Kutsenko & Meissner, 2013; Porter, 1994). In addition to the economic advantages resulting from these intra-cluster spillovers, the social, cultural, and institutional constellations create additional sources for knowledge in different shapes and forms as well as the basis for knowledge creation (Amin & Thrift, 1995; Storper, 1996). Hence regional clusters including agglomerations have a role as stimuli for learning and knowledge generation for different actors and institutions. Such a setup naturally requires openness and a willingness to share knowledge even

though to varying degrees. Spencer (2003) found evidence that knowledge-sharing firms achieve better performance than firms that limit the sharing of knowledge.

The need for coordinated action in the form of STI strategies arises when the market is not able to allocate sufficient resources (Chaminade et al., 2009). Knowledge is considered equal to information, documented and codified, accessible and adaptable to specific conditions but this still neglects the tacit dimension of knowledge and the meaning of experience for using and applying knowledge. Although the NIS concept extends the understanding and views on innovation considerably—including a broad range of types of innovation and activities related to innovation and sources for innovation—the challenge remains to describe and explain a full system with all the elements, relations between the elements, and plausibility and causality tests.

Interventions in NIS require strong, evidence-based theoretical foundations at the basis of strategic planning efforts (Glasgow & Linnan, 2008). Designing strategy development intervention this way also allows to measure the interventions' impact at a later stage, contributing to an enhanced and improved follow-up cycle of strategy development.

Theory-based strategy development models, although conceptually well founded, need to reflect the impact of the implementation of strategies to a reasonable extent. There is a broad range of literature examining such factors in health-related research (Glasgow & Emmons, 2007; Oldenburg, French, & Sallis, 2000; Oldenburg, Sallis, French, & Owen, 1999) describing particular factors such as the diffusion, dissemination, and institutionalization of research in STI settings. STI strategies need to take these factors into account from the very earliest phases onwards. Regional STI strategy should aim at encouraging a regional innovation process that provides clearly visible advantages to the relevant stakeholders to engage in the development of a commonly agreed, bottom-up strategy (Morgan, 1997).

However, the literature does not provide reasonable definitions of the terms national science strategy, national technology strategy, national innovation strategy, or national STI strategy. They are therefore defined as follows:

2.1. National Science Strategy

The main objective of a national science strategy is to set and achieve targets in sciences by the use of scientific methods or the application of scientific knowledge with the overarching aim to contribute to society's development. Moreover, science strategy involves the retrospective evaluation of the achievement of targets set earlier and to assess the suitability of the instruments used to achieve those targets. Based on evaluations and lessons learned from past experience, science strategy must further develop existing policy measures. Science strategy aims at free basic science and targeted basic science.

2.2. National Technology Strategy

Technology strategy includes all measures by public bodies and agents that aim at directly or indirectly influencing the creation, application, and diffusion of new knowledge relevant to technologi-

cal principles. The prior mission of technology strategy was to secure the livelihood of population and safeguard economic competitiveness.

2.3. National Innovation Strategy

Innovation strategy primarily aims at creating the preconditions and framework necessary for generating the inventions that guarantee a climate that supports research and knowledge creation. The strategic dimension involves the identification of fields with outstanding prospects of conversion of inventions and the application of knowledge for new solutions for use in economic applications but also for social applications (non-profit societal applications).

2.4. National STI Strategy

Any discussion of a national STI strategy should consider a balanced assessment of the potential benefits from collective action and the risk inherent in collective actions expressed by the collective expectations raised through such strategies. While in principle the development of countries is left to the individual actors and governments are expected to set the framework conditions, in case of STI strategies a challenge arises to identify and define the meaning, objectives, goals, and reach of national STI strategies and most importantly to clearly assign the responsibilities for implementing strategic initiatives. Here implementation of strategic initiatives involves not only the practical (operational) implementation but also the financing of the strategies' implementation.

Approaches and instruments for STI strategy development can be grouped into four categories:

- Approaches to stimulate networking
- Approaches to create awareness
- Approaches to advise policymakers
- Approaches to STI policy (co-)design

Approaches to stimulate networking

These include strategy development approaches and instruments that stimulate networking, general discussions that promote relations between stakeholders, support for the development of continuous dialogue, mutual understanding, trust, and help for identifying evolving hot topics early. They may take the form of informal personal contact discussion platforms (ad hoc or regular), (thematic) networks, regular meetings, staff mobility, mutual invitations, published information, or conferences.

Approaches to create awareness

These involve creating awareness and commitment, and influencing the treatment of STI strategies and STI policy within the overall policy-making. Context information is provided as input for policy makers, including different parties' interests in STI policy issues of potential importance. Varied positions are communicated, and help to understand the stakeholders' position is provided. This approach includes awareness campaigns, position papers, foresight studies, public statements (press conferences, articles, etc.), ad hoc meetings and workshops, ad hoc studies, and lobbying.

Approaches to advise policymakers
This STI strategy development involves approaches and instruments for providing advice to policymakers ensuring that the stakeholder contribute in the desired way to the understanding of situations, possible implications, policy needs, the development of solutions, and the creation of the necessary consensus to implement policy measures. They include ad-hoc consultations, individual advisory roles, continuous consultative role advisory committees, Internet consultations, unsolicited advice, expertise, think tanks, and ad hoc advisory groups.

Approaches to STI strategy (co-)design
STI strategy (co-)design, decision-making, and implementation approaches go beyond the traditional role model where the stakeholders are limited to providing advice and opinions. In this regard, stakeholders take an active role in the instigation, formulation, and implementation of STI policies. This takes place when policymakers and stakeholders share the same objectives and combine their competencies and resources, leading to a win-win for both sides. They include impact assessment, (operative) joint decision-making, steering committees, delegated implementation, evaluations, operative support, board memberships, private sector STI funding, policy task forces, charitable foundations, and innovation (technology and STI) platforms.

The NIS's and especially science systems' characteristics—in other words, research intensity and innovation performance—provide indications for the status of strategic STI system design towards well-performing and highly dynamic systems based on knowledge- and technology-intensive economic sectors. The NIS should tend to have efficient strategy building systems in place and a large NIS that ensures a critical mass of resources and enterprises committed to STI strategy implementation. But these systems are also more likely to encounter limitations imposed by the complexity of their NIS. The NIS governance frameworks favor the development of different strategy development models and encounter different types of barriers. But neither of them seems to be superior or inferior opportunity for stakeholder involvement in the processes. The underlying NIS structure and composition also has an important influence on the nature of the strategic process. A high share of research- and technology-intensive economic sectors in the overall economy tends to foster intensive R&D collaboration and related STI-policy interaction. But if such an intensive interaction exists, it is often dominated by large enterprises. Frequently, SMEs are underrepresented in STI strategy decision processes. The strong dependency of some economies on foreign R&D investment can create further challenges.

Although information and knowledge in different forms are in principle transferable, the capability and competence of processing them varies between individuals and the organizations individuals are embedded in (innovation ecosystems). Furthermore, both the information and the learning dimension vary in shape, intensity, and importance for innovation between entities, organizations, regions, cultures, and individuals (Lundvall et al., 2009b; Sokolov & Meissner, 2013). In this respect, the common understanding of NISs is in many cases restricted to the STI dimension that only partially reflects the knowledge base underlying the NIS while emphasizing the learning dimension in terms of new knowledge generation and use. This requires an in-depth understanding of the institutional ecosystems and the related intra- and inter-institutional relations and exchanges in the

role, form, and meaning of the underlying basic learning and education system that is preparing the human capital and influencing the capacities of human capital in the long term. It is thus a precondition for the learning dimension of ecosystems in the long term and the capability of the NIS to generate new knowledge. The latter also varies in the degree of newness of the new knowledge generated, the potential impact and usability as well as the absorptive capacity of the ecosystems' environment. All of this can be summarized under the umbrella of the learning dimension in the STI strategy process (Gokhberg & Meissner, 2013). In addition to knowledge about actual innovation practice in corporations, there is a need for knowing the actual absorptive capacity of these actors. It is often assumed that companies possess sufficient knowledge and competence to absorb external knowledge, including the detection and processing of knowledge generated outside the corporation. This is mainly due to the manifest assumption that knowledge can be treated like products or commodities (Hoecht & Trott, 2006). However, reality shows that this kind of predominant thinking is at least questionable since recent developments show that companies increasingly assume knowledge as a tradable good, reducing the internal R&D staff or redirecting the R&D orientation of their related operations and increasing the share of outsourced activities, outweighing the internal activities and leading to a slow but steady erosion of internal core competencies. Park concludes that inter-firm networks are important determinants for collaborations and innovation of firms that are mainly active at the regional level (Park, 2001). He finds that interactions that are an important element of innovation processes are also commonly institutional routines but continue in modified, less-institutionalized routines at the regional scale. Within the firm, these interactions involve different functions within companies as well as with firms along the value chain, in other words mainly with customers and suppliers while at the wider level including the surrounding institutions.

Innovation management and innovation strategies at the corporate level commonly target at developing human capabilities in a strategic manner. In this regard, the individual is placed at the forefront of operations and the organization is understood as a place that brings different individuals and competences together. Consequently, networks in different forms are driven by individuals or teams of individuals with varying attitudes and backgrounds. The main concern for managing such networks lies in the integration of the relationship between the individuals, be it formal or informal, inside and outside of companies. Thus a management style is required creating, developing, and maintaining an adaptive and interactive organizational infrastructure that is responsive to internal and external change. In this light, the company's organization and its management need to maintain a balance between process efficiency considerations, bringing about organizational innovation and the developed and articulated corporate motivation for innovation (Hidalgo & Albors, 2008). This becomes evident in especially large corporations that integrate the corporate innovation strategy in their roadmaps. Eventually it becomes obvious that stakeholders within companies need to interact for corporate and unit strategy development.

At the national level, stakeholder involvement is equally essential. However, stakeholders' interaction with policymakers in STI strategy development takes place at two levels. First there is interaction at the formal level that stimulates and supports the interaction of all parties, defining the interaction space and providing a formalized framework for the exchange of opinions and collaborations. However, interaction situations are often complex in practice since the interaction is

influenced by more than one instrument whose combined effects create unique interaction models. Second, even the best-designed formal strategy development process will not come to life if it is not based on an equally important complementary informal level. Mutual trust and "rules of the game" evolve over time and form an underlying, country-specific interaction culture that is determined by elements of national culture and historically grown behavioral patterns. Successful examples of stakeholder involvement combine both levels: formal instruments, processes, and structures ensure an efficient and result-oriented interaction. Shared values defined by an accepted interaction culture ensure the constructive attitude of all participants.

Three important stakeholder groups shape this "interaction landscape":

- The public sector
- STI performers
- The private sector

a) Public sector
Political, administrative and intermediate institutions set the objectives and overarching framework for STI strategy. In particular, they define and implement specific STI policy measures. To involve the private sector, they apply a variety of approaches including a permanent dialogue and the soliciting of expertise and advice as input for policy-making. The degree of implementation ranges from informal interaction to sophisticated institutionalized advisory and decision structures.

b) STI performers
Academic research and higher education institutions typically enjoy a high degree of autonomy to define their own research strategies. At this level, STI strategy decisions used to be taken exclusively by their academic boards or equivalent. But in recent years, there has been a growing tendency to open these processes for complementary external knowledge, for example through external board members (including private sector representatives). Private sector STI has its own rich portfolio of links with public sector STI institutions.

c) Private sector
As a stakeholder, the private sector is represented in different levels of the STI strategy decision processes. Typically, industry associations act as private sector spokespersons, consolidating the views of their members and expressing these vis-a-vis policymakers. But individual enterprises or groups can also take the initiative to get involved in research policy, for example if they have a particular interest in public-private-partnerships. And individuals, typically high-level representatives of important companies, frequently act as advisors to research policy decision-makers as members of advisory boards. In addition, charities and foundations in some countries play an important role through their funding of research or of think tanks that issue their own research policy concepts.
Consequently the following principles for STI strategy-making apply:

- The policy domain for interaction, the purpose and objectives of the strategy process, and its desired results must be transparent and shared by all parties involved.

- A supportive formal strategy context must be ensured by appropriate instruments and by their efficient application. Complementing this, there must be a basis of mutual trust, openness, and willingness to contribute to constructive solutions.
- The dedication and commitment of both sides are indispensable. Efficient strategy development takes place in the form of live meetings. Therefore, it must be a priority for decision-makers on all sides.

Strategy development in large-scale systems like the National Innovations Systems needs to consider the time element as an important dimension of strategy building. Time is important since systems develop even at the moment the strategy is developed, reflecting the status of a system like a snapshot of the actors, their intentions, and strategic orientation as well as their interconnections and interrelations within the system. These configurations are subject to continuous change, hence at the point in time the strategy is implemented and communicated it can be considered as at least partially outdated (Carlsson et al., 2002). Although systems are unlikely to change in such short time horizons (except in the event of unpredictable major external shocks), there is ongoing feedback and exchange between the members of such systems that will have a minor short-term impact on the constitution of the system and also present more evident and substantial impacts in the long term. Although the importance of communication between actors within a system is undoubted and common knowledge, questions arise concerning the time required to initiate impact as well as the intensity of feedback and communication that may cause it. The challenge is to develop STI strategies that are intended to be impactful but also take into account the changing nature and composition of the underlying system (Meissner et al., 2013).

Innovation results from a learning process that used to be supported and enabled by the regional proximity of organizations that contributed to the diffusion of knowledge, information, and technologies through regional channels, alongside national and international channels (Cooke, 2001). This still holds true for the share of knowledge and information that is considered codified knowledge, and information still raises challenges for the tacit un-codified knowledge that is embedded in peoples' experiences and is usually protected, or transferred via teaching in the direct interaction of individuals. The 21st century is witnessing increasingly globalized forms of education in terms of remote as well as onsite learning. This is changing the rules of competition between countries and regions. While in the 20th century it was assumed that tacit knowledge is solely transferred between knowledge holders at the regional level, this has changed with the availability of even tacit knowledge at places that were considered remote earlier. The mobility of knowledge holders regardless of whether the changing location is permanent or fixed-term is still increasing, along with the transfer of tacit knowledge. The new strategic dimension for regional innovation systems is that they need to assure building and maintaining absorptive capacities regionally; without these capacities, spillovers from embodied knowledge are unlikely to appear and generate positive impact on the regional system.

3. ELEMENTS OF SCIENCE, TECHNOLOGY AND INNOVATION STRATEGY

An important element to consider in STI strategies is the inequality issue or the challenge of the "innovation premium" (Lundvall et al., 2009b), the justification of socializing STI-related investment (that might even include STI strategy development) when returns from STI are at least partially privatized. This dimension may impact the NIS and regional ecosystems but also the institutional ecosystem in the mid- to long-term by influencing social cohesion and generalized trust in the system. The crucial issue in STI strategy building is setting the appropriate incentives for innovation activities and balancing the investment and returns on ownerships of the different actors involved.

National STI strategies developed in most countries share common focus areas involving STI priority setting, cluster policies, technology platforms, industry-science-relationship, tax incentive schemes, STI-related subsidies, and talent measures. Core issues reflecting the development of STI strategies are the potential reach and effectiveness as well as the adoption, implementation roadmap, and implications for the maintenance of the STI strategy. It follows that strategy-building exercises should from the very beginning take the following questions into account (Glasgow & Linnan, 2008):

- Can the target actors and audience be addressed and if so, how?
- Will the target audience accept and incorporate the strategy?
- To what extent is the implementation feasible? Are stakeholders' agendas and strategies known and how do they fit in the overarching strategic intention?
- Are interfaces and stages included in the STI strategy for continuously adjusting and refining the strategy and implementing changes?

Among the essential elements of each STI strategy are respective actions and measures or at least directions for actions and measures to be taken. There is an urgent need to assess the potential impact of individual actions and measures on the NIS or respective subsystems prior to the communication and implementation of the strategy. Lundvall et al. (2002) in an illustrative example argue that "given a stable strategy mix with a too high proportion of imitators and a too low proportion of radical innovators, the legal framework could be changed to weaken the position of imitators and strengthen the position of radical innovators. Such a policy could, of course, be implemented even in a highly unstable situation, but then the outcome would often be unpredictable." Thus, strategy developers should be aware of the potential impact any strategic decision can have. Therefore, a systematic analysis of the potential impact of these on the actors and elements of the NIS and related subsystems is essential. Codification efforts to turn implicit tacit knowledge into explicit, codified knowledge are an important means to enhance the knowledge-sharing and processing capacity of systems. However, codifying knowledge requires prior knowledge of what should be codified, furthermore why and how as well as for whom this is intended (Jenson, Johnson, Lorenz, & Lundvall, 2004).

Alam (2008) in his study finds that the original assumption that the newness characteristic of innovation always refers to "new to the world" is misleading. Comparing American and Australian ser-

vice companies, he finds that “new to the world” innovations are high-risk and high-cost undertakings for companies but are clearly less popular than the low-risk and low-cost “new to the region” strategies of companies. This observation is in line with the fact that in any case most companies building a national economy are SMEs of which only a fraction is engaged in cross-border or even global activities.

Research has shown that the organizational model of firms influences the adaptive capacity of the organizations and thus their ability to innovate. Organizations that are supportive to continuous innovation are in many cases characterized by decentralized approaches that enable them to respond to changing environments in a more targeted way without having to change the overall organizational setup. This becomes even more important for organizations operating at the global scale where the local operations contribute to the overall organizations’ performance that requires near-time reaction on changing local conditions and at the same time offers the potential to gather new inspiration and accesses new knowledge and competence sources for the organizations’ innovation activities (Jarzabkowski, 2004). Eventually, the organization’s innovation performance is somewhat dependent on the levels of hierarchy and degree of processual mechanisms for cross-firm integration, permitting middle-managers to engage in external activities such as collaborations and internal activities like intra-firm knowledge networks and "intrapreneurship" as a means of maintaining and also increasing the absorptive capacity of the organization. This in turn is an important condition for the organization to engage in respective networks and communities, and eventually external relationships are selected, perceived, and understood in accordance with the existing structures of the organization (Jarzabkowski, 2004).

Clusters in different shapes are somewhat meaningful communities with the common aim of enhancing the flow of economic activities by taking advantage of linkages and synergies among the actors. Clusters have been on the agenda of STI policy for around a decade since being recognized for their potential towards achieving competitive advantages for their member organizations. In the course of the increasing competition of organizations, regions and clusters have become under severe pressure globally to develop unique profiles and develop dedicated strengths in the race for innovation. Common measures to develop such clusters are aimed at attracting and maintaining foreign direct investment (FDI). Strategies for attracting FDI vary between clusters, regions, and also countries. The common feature of these strategies is that systems organizational designs are developed that allow seamless internal processes for relevant decision-making and the facilitation of internal and external system interactions. Such governance concepts often reflect those already applied by companies and adjusted to their specific conditions. Recently at the regional level, STI strategies are becoming a frequently used tool but there is not yet sufficient experience of the impact of these strategies that would allow a solid assessment of their achievements in terms of effectiveness and efficiency. At the national level it is found that many regional initiatives are developed exclusively with a regional focus, lacking integration in the overarching national system or a coherent policy backup (Cooke, 2001).

Being initiated by regional policymakers, the actors within the regional innovation systems are in most cases participating but have no real intrinsic motivation that lets them go beyond rather super-

ficial levels of cooperation. They need to be able to disclose their wishes, needs, and requirements at more precise and detailed levels for such strategies. One reason for this is of course the confidentiality of such information for the individual organization since competitors are usually also present in the respective regional system. Even with this taken into consideration however, insufficient interaction is still present due to the nature of the respective actors' main operations, even when regional strategy development exits.

4. BARRIERS TOWARDS INTERACTIVE STI STRATEGY DEVELOPMENT

In recent years, continuous progress has been made in the involvement of the stakeholders in STI strategy making, but significant limitations and a need for pushing the frontiers of this interaction further to maximize leverage from it remain. In the first instance, there are intrinsic conflicts that result from a "natural" mismatch in the expectations, objectives, strategies, and behavior. These stem from the fact that stakeholders, especially private actors, are primarily oriented towards their own explicit goals, financial and market goals in case of the private sector, and a balance of economic, scientific, ecological, and other societal objectives for STI policymakers. Such "intrinsic" conflicts include different objectives, incompatible decision processes, and different time horizons and ownership and confidentiality inherent in the strategy building. Second, the public sector itself encompasses a multitude of actors, opinions, and objectives rooted in the governance of the STI system. As a consequence, internal conflicts of interest between policy domains and inefficiencies can occur. Other barriers, stemming from the underlying administrative and political frameworks, add to this. The major barriers are a lack of commitment to enhance internal interdependencies, a lack of appropriate indicators, and fragmentation and complexity of feedback and administrative structures, as well as a lack of comprehensive compromise- and ownership-oriented decision processes. Stakeholders often lack awareness of an articulated interest in STI and especially in STI strategy that limits the potential for a more intense STI strategy-related interaction in some sectors. During the strategy development process, structural and cultural interaction barriers during the interaction of the parties involved arise when either side can take the lead in initiating the essential interactions, bringing it forward and providing the necessary platforms. Hence a "clash of cultures," insufficient management of the interaction interface, hidden agendas, and mismatch of expectations and attitudes as well as a lack of experience, lack of empowerment and a lack of support are likely to arise. The occurrence of these barriers depends on the individual situation of countries including the characteristics of historically grown STI governance systems and underlying overall policy frameworks, economic structures, decision processes, or sociocultural backgrounds.

The increased understanding and diffusion of knowledge about the actual iterative nature of the innovation process has resulted in the adjustment, refinement, and new development of policy measures for STI. This has led to some experimentation with new formerly untested policy measures (also referred to as policy instruments). These new STI policy instruments have lead to the STI policy mix concept that is to some extent the natural consequence of the evolution and the associated reformation of national and regional innovation systems, especially in light of the governance modes and approaches of these systems (Borras, 2009). Not all of these can be influenced directly

by STI strategies and policy instruments, indirect measures, or changes in behavioral patterns and communication culture. For an efficient and effective strategy development and the resulting implementation of well-designed processes, structures, mechanisms, and instruments, a supportive environment and the commitment of policymakers and stakeholders are necessary. A strong dedication to effective and efficient stakeholder involvement in STI strategy-making should be made an integrated part of the governance of NISs. STI policymakers should invite and solicit stakeholder interaction in their decision processes for the enhancement of quality and acceptance of policy measures. They should identify research policy areas with a need for interaction, choose and implement appropriate instruments, and ensure efficient internal decision processes and openness for stakeholder contributions. Stakeholders should develop a broad awareness of the need and benefits of being involved in research policy decision-making, identify priority STI strategy and policy areas where their involvement is crucial, and allocate a sufficiently high priority to their active interaction in related decision processes. This includes both their own initiatives and participation in public sector strategic initiatives. In the course of this interaction, all parties should set priorities on policy areas and strategy elements where interaction is of particular importance, define target level and target results of the interaction and choose approaches and instruments accordingly. This includes supportive framework conditions and—where necessary—the enhancement of a mutually supportive and trustful communication and collaboration culture. To assess their current position and improvement potentials, the stakeholders' actors should undertake a thorough review of the current level, efficiency, and achieved impact of the previous STI strategy initiatives. Depending on the outcome, they should define priorities and improvement targets for the enhancement of renewed strategy development cycles. Experience shows that strategically targeted public-related R&D interventions require evaluations on their effectiveness and efficiency with an additional impact estimate. Moreover, it is assumed that the findings from evaluating these interventions are essential inputs and used accordingly to support the decision-making process (Molas-Gallart & Andrew, 2006). This may include for example a streamlining of decision processes, the introduction of new instruments, or a cultural change of an existing communication culture. When reviewing the current status of strategy development and choosing approaches for its improvement, policymakers and stakeholders should also be sensitive to the development stage of the NIS and of its stakeholder interface. From this perspective, policymakers in the course of STI strategy-making should put a special emphasis on the enhancement of processes, structures, and instruments for involving the stakeholders. This includes a sustained and visible commitment to stakeholder involvement, ensuring “one face to the stakeholder,” applying a context-specific approach to involve the stakeholders, mobilizing a larger stakeholder base for active participation in STI strategy making, safeguarding a sane balance between different types of stakeholders’ participants in STI strategy-related interactions, building responsible, balanced, and trustful relationships with the stakeholders, and enabling seamless and transparent decision-making with anchor points for stakeholder interaction. In addition, policymakers should develop a dedicated approach for private sector involvement, stimulate enhanced interaction on the operative STI level, monitor status and progress achieved in stakeholder involvement, avoid “over-formalization” and “over-instrumentalization” of the interaction, and balance economically oriented objectives with other research policy targets. Meanwhile, stakeholders should commit to STI strategy and policy involvement, apply a context-specific approach to research policy engagement, mobilize a larger stakeholder particularly in the private sector, provide

a base for active participation in STI strategy-making, safeguard a balanced representation of the stakeholders in STI strategy-related interaction, extend private sector involvement to less research-intensive and service sectors, speak with one voice, and build committed and trustful relationships with the public sector as well as take the initiative and come up with their own creative ideas in important areas.

In a broader context, international organizations can support the exchange of experiences and joint learning among the countries in order to contribute to the development of the national public and stakeholder interfaces by promoting the concept of stakeholder interaction and encouraging the exchange of experiences and joint learning, establish an inventory of good practices and where appropriate quantitative and qualitative indicators and benchmarks, and work towards guiding principles for countries combined with possible pathways for improving stakeholder interaction, periodic monitoring, evaluation, and peer review as a mutual learning process.

5. CONCLUSIONS

The design and implementation of national STI strategies requires the recognition and consideration of a broad range of stakeholders' interests and their own strategies. Increasingly, the private and the public sectors are engaged in the development of these national STI strategies. We are witnessing a growing engagement of private actors in basic research, in service-related research in national STI infrastructure, and in educational and human resource-related issues that are commonly considered essential elements of national innovation strategies. Efficient stakeholder participation requires dedication and a structured approach since such effective interaction does not happen naturally. It must be instigated, shaped, and maintained in a conscious effort on both sides. Stakeholders must be aware of the benefits of being engaged in research and research policy and undertake a dedicated effort to express their perceptions, needs, and proposals in STI strategy making processes. Public sector policymakers must understand the other stakeholders' perceptions and needs, solicit and integrate its opinions and proposals, and be open for feedback.

A broad range of approaches and instruments can be used for this purpose and are currently applied. But there is no single instrument or a one-size-fits-all approach that guarantees successful interaction, and moreover each country and therefore NIS must develop its own specific approach to involve the stakeholders in STI strategy making, giving due consideration to its overall and STI policy objectives, its STI governance framework, and its economic environment. STI strategy development is not a purely rational process. Different views on how issues should be addressed compete for supremacy, and different actors seek recognition of their strategy proposals. Therefore, trustful relations, cooperative behavior, and a communication culture are indispensable. Therein, stakeholders have a double role. On the one hand, they provide useful support as a neutral advisor. But at the same time, they are also stakeholders with their own interests. Accordingly, both sides should strive for a transparent and constructive interaction at an optimum level of intensity. More stakeholder involvement does not necessarily mean better strategies. Policymakers must make a conscious choice as to what extent they want to base their policy decisions on the expressed

stakeholders' needs and/or strategy proposals. This includes the maintenance of a sound balance between STI for commercial use, the general advancement of knowledge, and the provision of solutions for societal issues such as in the health and environmental areas. A multitude of influencing factors and actors shape the national interaction landscapes. Current systems of stakeholder interaction have grown organically and vary considerably among countries. Their intensity of interaction, applied approaches, and instruments as well as the way in which these are applied in practice are determined by the overall NIS and its related governance frameworks, the structures of national science and innovation systems, and underlying communication cultures. Interaction varies also by scientific disciplines (with a preference for natural, engineering, and medical sciences of economic relevance), type of research, different time horizons and policy levels, the type of policies and instruments used, and the primary target group for stakeholder interaction.

STI strategy initiatives need to take into account the basic facts underlying innovation, in other words the fact that the generation of innovation is commonly considered the responsibility of companies, that the major origins of innovation are quite well known—users or science (pull or push)—and that the sources for innovation-related competences vary stemming from the science base, research base, or commercial entities. Challenges remain in that each innovation is unique and innovation varies not only in shape (product, process, service, and business model) but also in underlying competence (application/technology). Innovation in this context mainly serves the purpose of becoming or remaining globally competitive. Countries aim at innovativeness at the national level where competition appears in a different dimension within the global industrial competition, where searching for the best solution for the best price that meets the users' requirements as well as competition for output, talent, and research environments happen on a transnational scale. Countries are also in a global competition for the best innovation-related framework conditions in the vying between global communities vs. national ecosystems and regional vs. national ecosystems. STI priority-setting is commonly done using technology foresight studies, which frequently have to narrow their focus and neglect societal developments, considering limited policy and strategy dimensions. In summary, national STI strategies are challenged by the following:

- There are always winners and losers in a NIS;
- Political establishments play an important role;
- Federal and regional institutions might not be in line;
- Competition between federal (national) entities (ministries, councils etc.) limit coherent strategy development.

Implementation is challenged by top-level political initiatives creating a certain momentum for some time, but also raising expectations that might run the danger of falling short. It is common sense that the implementation of policy measures via subordinated agencies is the key bottleneck of STI strategies; in other words, the more agencies, the less stringent the implementation. National STI strategies per se do not allocate resources or assign responsibilities and success indicators. Eventually it seems reasonable to look at corporate innovation strategies and learn from success factors at the corporate level.

The paper showed that there is an urgent need to raise the awareness of political decision makers that the STI policy mix itself needs more systemic attention. The shift from the sole NIS consideration towards a more profound systemic thinking includes the thorough analysis of the interdependency of different policy measures within the STI policy mix. Moreover consistent and coherent STI policy requires STI strategies are complemented by respective implementation and monitoring activities. This requires the development of new instruments like integrated STI roadmaps at different levels within the NIS.

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