# Reflections on the co-evolution of innovation theory, policy and practice:

## The Emergence of the Swedish Agency for Innovation Systems

**Bo Carlsson, Lennart Elg, Staffan Jacobsson**

www.chalmers.se/tme/EN/centers/ride

RIDE/IMIT Working Paper No. 84426-010

IMIT – Institute for Management of Innovation and Technology
RIDE – R&D and Innovation' and 'Dynamics of Economies

CHALMERS

**84426-010**

January 2007

**Forthcoming in R. Smits, S. Kuhlmann & P. Shapira (eds.) Innovation policy, theory and practice. An International handbook, Elgar Publishers**

# Reflections on the co-evolution of innovation theory, policy and practice: The Emergence of the Swedish Agency for Innovation Systems

Bo Carlsson,
Weatherhead School of Management,
Case Western Reserve University, Cleveland, Ohio 44106-7235, U.S.A.
Bo.Carlsson@case.edu

Lennart Elg
VINNOVA (Swedish Agency for Innovation Systems)
SE-101 58 Stockholm, Sweden
Lennart.Elg@vinnova.se

Staffan Jacobsson
Department of Energy and Environment, Chalmers University of Technology,
412 96 Gothenburg, Sweden
Staffan.Jacobsson@chalmers.se

## *1. Introduction*

In 1987 the Swedish National Board for Technical Development (STU) invited a group of Swedish scholars in economics, engineering, management, and sociology to do a joint study of *Sweden's Technological System and Future Competitiveness* (the "STS Project"). The research group continued its work for fifteen years (on a part-time basis),[1] produced numerous publications summarized in three volumes (Carlsson 1995, 1997 and 2002)[2] and developed a framework that is 'close' to the needs (and in part practice) of VINNOVA (The Swedish Agency for Innovation Systems). During this period, the Swedish technology policy changed, as reflected in the re-organization of the technology policy agency from STU to NUTEK (The Swedish National Board for Industrial and Technical Development) and eventually VINNOVA. At the same time, the thinking and focus of the research group shifted in light of its own experience, the changing policy environment and the research findings in related areas globally.

The purpose of this paper is to trace how our academic work and policy practice co-evolved and to reflect on what has been learned. Even though the STS project was initiated and funded by VINNOVA's predecessors, the links between the project and the formation of VINNOVA are not as clear and direct as might be supposed.

The paper is structured as follows. Section two outlines the economic, intellectual and political context of the project. Section three 'tells the story' of the STS project until 2002. Much of the story refers to how the group improved its understanding of the

[1] The annual budget for the group as a whole was on the order of 1 million SEK (around $130,000).
[2] In addition, several PhD theses were written in conjunction with and with partial funding via the STS project (Tryggestad 1995; Ehrnberg 1996; Johansson 2001; Holmén 2001; Bergek, 2002; Fridh 2002).

structural components of an innovation system, how such systems are formed, and how the development processes vary between specific systems. It is also a story about improved methodological understanding and of some interactive learning between researchers and practitioners. Section 4 analyzes the formation of VINNOVA and puts the whole discussion of the impact of academic research into a wider political context. Section 5 continues the story of interactive learning post 2002. Whereas our work until then had been focused on developing concepts and methods, it now developed in a direction that was closer to the practical needs of the policy makers. Finally, section 6 reflects on the whole process and what can be learned from it.

## *2. The context of the STS project*

The term “innovation policy” was first used in official Swedish documents as late as a government bill in 1999. At the same time, as long as Sweden has existed as a nation state, policymakers have shown an active interest in improving manufacturing and trade, and Swedish trade unions early adopted a positive attitude to structural renewal (Granat Thorslund et al., 2005).

With the exception of an occasional homage to Joseph Schumpeter, the first explicit use of research on innovation in policymaking appears to have been a parliamentary review of the organization of STU, which included a review of current research on innovation[3]. Soon after that, the Royal Swedish Academy of Engineering Sciences launched a study of Sweden’s technical and industrial competence chaired by Erik Dahmén (see below in this chapter). A third case in point is a joint project between STU and the Center for Policy Alternatives at MIT, which introduced the concept of

[3] SOU 1977:64, pp 103-151

"new technology-based firms" into the Swedish discourse (Reitberger, G & Utterback, J, 1982).

The initiative for the STS project clearly came from the policy side. In 1987 Göran Friborg, division chief at STU, contacted Bo Carlsson, professor of Industrial Economics at Case Western Reserve University in Cleveland, Ohio (previously associate director of the Industrial Institute for Economic and Social Research, IUI, in Stockholm), to explore the possibility of organizing and directing a group of Swedish researchers to study "Sweden's Technological System and Future Competitiveness." The basic charge was to gain a better understanding of the role of technology in economic growth, to raise (on a permanent basis) the level of competence to analyze such questions and thereby to build a better foundation for technology policy. A comprehensive, interdisciplinary study was envisioned. Three leading Swedish research institutes were invited to participate: the IUI, the Department of Industrial Management and Economics at Chalmers University of Technology in Gothenburg, and the Research Policy Institute at the University of Lund.

The background to the initiative was the following. In the late 1970s the Royal Swedish Academy of Engineering Sciences, in collaboration with STU, had conducted a study of Sweden's technical and industrial competence. This was one of the largest research projects ever undertaken in Sweden and had broad representation of academics, practitioners (especially engineers), and policy makers. One of the working groups within the project was focused on the reasons why Sweden suddenly found itself in an economic crisis after more than 100 years of rapid growth. The group was made up of industrialists, engineers, economists, and policy makers (including Göran Friborg) and was chaired by professor Erik Dahmén. Bo Carlsson was the editor and main author of the report (Carlsson et al., 1979)

The project as a whole was regarded as a success. But while the findings were widely acclaimed, they had limited impact on economic policy. To illustrate, the 5-year forecast for the Swedish economy that was issued by the government in 1980 was similar to its predecessors in that the neoclassical macroeconomic model upon which it was based reflected little insight about the central role of technological innovation, entrepreneurship, and industrial competence in economic growth. There was no room left for policy (e.g., with respect technology and innovation) other than traditional macroeconomic policies. Technological change was still treated as an exogenous factor rather than being viewed as taking place *within* the economic system. From a theoretical perspective this meant that in order to endogenize technological change, a more dynamic, systematic approach was needed. From a technology policy perspective, there was a need to better articulate the role of technology in order to build a stronger foundation and support for policy. The question became: what are the characteristics of an environment conducive to technological innovation? This is where the notion of technological system came in.

According to interviews with those involved[4], several strands of thought led to STU's initiative to set up the STS project. One was the strategic challenge to small, advanced countries formulated as the "Small country squeeze" by Kristensen and Levinsen (1983) and later Walsh (1987). The perceived challenge was that while the lower tech manufacturing base increasingly relocated to newly industrializing countries,

[4] Interviews with Göran Friborg, Staffan Håkansson, and Gunnel Dreborg, at that time senior analysts at STU´s planning department.

the growing complexity of new core technologies forced small countries to focus on limited niches, with less opportunity to hedge strategic bets.

A second motive was STU's policy need to find a platform for discussing the economic effects of investments with the Ministry of Finance. Linking up research on innovation with economic research was an attempt to accomplish this.

Finally, there was an operational need at STU to understand the impact of its considerable investments in research on manufacturing technology, in the context of its linkages to other parts of Swedish industry. According to Friborg, it was these linkages that led to the concept of a "technological system", while the work of Lundvall *et al.* was not yet appreciated.[5]

The STS project started at the same time as work was getting under way at the OECD (Organization for Economic Cooperation and Development) in Paris on what came to be known as National Innovation Systems (NIS). Christopher Freeman (professor at the Science Policy Research Unit, SPRU, at the University of Sussex in England) had presented a paper at the OECD's expert group on Science, Technology and Competitiveness in 1982 in which he mentioned the concept of 'National Innovation System.' Drawing on Friedrich List's concept of 'national systems of production' (List 1841), Freeman discussed List's advice to Germany in the mid-19$^{th}$ century regarding how to catch up with the UK. The paper was considered by the expert group to be too provocative in that it identified a role in technological innovation by factors outside the neoclassical theoretical framework (Sharif 2006, p. 751) and was not published until

---

[5] This was brought on the policy agenda mainly through OECD's "Technology – Economy – Productivity" project in the early 1990s.

2004 (Freeman 2004). But via the network of scholars connected to both the OECD and SPRU, the concept of 'national innovation system' began to catch on. Lundvall (1985) used the term 'innovation system' (but without the adjective 'national'). The first publication to actually use the term 'national innovation system' was Freeman's book *Technology and Economic Performance: Lessons from Japan* (1987). This was followed by a volume edited by Dosi, Freeman, Nelson, Silverberg, and Soete (1988) that contained four chapters on national innovation systems.[6]

Although it has not previously been articulated in the literature, Sharif (2006) shows that the concept of national innovation systems arose in the context of economic stagnation (Eurosclerosis) and concern about competitiveness in Europe combined with the rapid rise of Japan. But there are divergent views as to whether the concept came from economic theorists or from policy makers (Sharif 2006). What is clear is that the STS project started at the same time as the term 'national innovation system' was first published and that the economic contexts for the two approaches were similar.

From the point of view of the technology policy agency (STU) in Sweden, there was another strand of research that was relevant and important. In the early 1980s, STU had come in contact with the "network" school of industrial marketing, formulated by Håkan Håkansson et al. (1982, 1987, 1989) at Uppsala University. This bottom-up approach to system thinking started from the observation that relationships between suppliers and users (of industrial products) were of a long-term nature, and that marketing should focus on building such relationships rather than closing individual deals, as

[6] It is interesting to note that there was an article entitled "The Technology Innovation System in Japan" published in 1984 (MacDowall 1984) that does not appear to have been known or cited by other authors on innovation systems.

emphasized in the "standard" U.S. marketing literature.[7] They also observed that firms were involved in multiple such relationships that constituted relatively stable *networks* of firms – and other actors, such as research institutes.

This view of industrial markets fit much better than the textbook approach with the intuitive experience at STU, gained from extensive practice in influencing the formation of networks, and led to a long-term collaboration between STU (and its successor organization NUTEK) and the Uppsala group. This involved both inducing the researchers to look at new, emerging networks (e.g., by funding Anders Lundgren's PhD thesis (1991) on image analysis – which combined the network approach with a Schumpeterian perspective) as well as asking researchers from this group to evaluate STU programs in terms of how they contributed to the formation of new industrial networks.

Another foundation was Erik Dahmén's work on development blocs. His monumental study of Swedish industrial entrepreneurial activity (1950) had become influential among technology policy makers and industrial economists in Sweden. His theory emphasized the disequilibrium nature of economic development, resulting in continually changing relationships among economic agents (see Dahmén 1989), and the importance of entrepreneurial activity. This dynamic micro-based theory of economic development was a starting point for the STS project.

While STU's collaboration with the network school helped develop the internal thinking within the agency, STU perceived a need to improve its position in the policy network. It had hitherto not been effective in communicating with the (national) political

[7] Perhaps not coincidentally, Bengt-Åke Lundvall's work (1985, 1988) on national innovation systems started out with a focus on user-producer interaction.

level which allocated resources to STU/NUTEK and decided on which terms of reference would be used to evaluate performance. One reason was that it was not obvious how their micro-focus could be aggregated to assess the impact on macro-economic performance.

Some local circumstances increased the need to find new ways of communicating with the policy level. First, mainstream neoclassical economists had a stronger hold on policy makers in Sweden (and particularly on the Ministry of Finance) than in many other countries. These policy makers were prepared to discuss the need for innovation policy only in the narrow framework of market failure, and were prepared to measure policy effects only in terms of changes in the *volume* of industrial R&D, not in terms of changes in direction or organization of R&D efforts or in any other way.

Secondly (and not unrelated), the “linear model” of innovation – where increases in basic research somehow automatically lead to industrial development - was – and to some degree still is - the primary mental framework of Swedish policy makers. This has been fuelled by both self-interest from the academic lobby and mistrust of government policy by industry. One reason it has survived so long is the structure of Swedish industry, where most of R&D has been concentrated to a small number of large firms. These firms were able to internalize some of the innovation system’s translation functions between discipline-based academic knowledge and multidisciplinary industrial competence needs.

## *3. The STS project 1987-2002 – development of basic framework and methods*

As indicated already, the concept of technological innovation system came from the policy makers; it was the task of the research group to define more precisely what such a system is and how it can be used in innovation policy and practice. It was clear from the beginning that a comprehensive, interdisciplinary, and systematic approach was required, going far beyond the relatively simple notion of adding a “technology factor” to the aggregate production function as was being done concurrently by “new growth” theorists such as Romer (1986, 1990) and Lucas (1988), essentially by endogenizing technological change in the analysis of the economic growth process. The main policy implication of that line of research was to increase knowledge creation via support of R&D.

An important feature of the STS project was that a representative of the technology policy agency, Lennart Elg, took an active part in our discussions throughout the course of the project. Not only did this facilitate communication between the researchers and the policy makers; in retrospect it was essential, because the initial charge to the group was very loosely formulated. The more precise problem formulation was worked out collaboratively as the work progressed. This required a high degree of mutual trust. It also makes it somewhat difficult to distinguish which ideas came from the theory side and which from the policy and practice side.

One of the first questions addressed by the project group was whether or not it is appropriate to think of a single (national) innovation system, or whether it is more useful to think of a whole set of systems, each based on a different technology, generic or otherwise. We concluded that even though there are clearly national features and institutions shaping the rate and direction of innovation, the relevant actors and institutional arrangements in each area of technology are sufficiently different to justify examining each technology area separately. Thus, the English translation of the project title became Sweden's Technological Systems (plural) and Future Development Potential.[8] On this fundamental point we were influenced by the practice of STU which for long had been organized to support specific knowledge fields (e.g. semiconductor technology). This meant that in order to be relevant in the Swedish technology policy context, we needed to provide a basis for considering questions beyond the simple notion of supporting the national R&D effort. Eventually, we had to be able to deliver frameworks and tools that were valuable at the level of a single technological innovation system.

We started by picking a relatively mature area of great importance to Swedish industry, factory automation, in which we knew *a priori* that Sweden had a strong position internationally and in which we could therefore expect to find a fully developed innovation system. By studying such a system, we thought we would be in a better position to identify important characteristics (including the role of public policy and other institutional features) than if we had selected a less fully developed system. Subsequently we broadened our analysis to three additional systems, namely the Swedish technological systems for electronics and computers, powder technology, and pharmaceuticals and biotechnology. Later on, in order to better understand the role of institutions in different settings, we extended our work to international studies of the biomedical cluster. With different funding, we also analyzed renewable energy technology, microwave technology and mobile data communication. Hence, in the course of the project we focused the

[8] Actually, as already indicated, the original title referred to "konkurrenskraft" (competitiveness). This was changed to Dahmén's concept "konkurrensförmåga" (roughly translated as 'development potential') in order to avoid invoking static macroeconomic concepts and instruments such as exchange rates, interest rates, and relative wage rates, preferring instead to refer to more dynamic concepts such as innovation and entrepreneurship that influence long-term growth.

systems studied on different units of analysis: knowledge fields, products, industries and sectors.

Some difficult theoretical issues confronted us from the start. In particular, it quickly became evident that we needed a clear definition of what we meant by 'technological system' and a theoretical formulation of its nature, function, and composition. This led to the following definition:[9]

> A *technological system* may be defined as a network of agents interacting in a specific *economic/industrial area* under a particular *institutional infrastructure* or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological systems are defined in terms of knowledge/ competence flows rather than flows of ordinary goods and services. They consist of dynamic *knowledge and competence networks*. In the presence of an entrepreneur and sufficient critical mass, such networks can be transformed into *development blocs,* i.e., synergistic clusters of firms and technologies within an industry or group of industries (Carlsson and Stankiewicz, 1991, p. 111, italics in the original).

[9] The definition was based on our reading of the literature in the 1980s in industrial dynamics – the economics of innovation, new technology, and structural change in industries and firms – and in the emerging field of evolutionary economics.

With this definition it became clear that we were expanding the national innovation systems framework beyond focusing primarily on institutions at the national level into a broader micro-macro perspective: it is necessary to understand not only the institutional framework but also the micro underpinnings of macroeconomic growth. Thus, individual actors – be they entrepreneurs or established firms – and their competence and interactions (networks) need to be incorporated in the analysis.[10] There also needs to be an analysis of the economic impact of the systems, not just a description of their components.

Although there was much academic literature on networks that influenced us, we can also trace the effects from practice to theory. As indicated above, STU had a long tradition of working with network formation, often taking a ’broker’ role. For instance, this was plainly seen in an evaluation of the Swedish textile and clothing policy that one of us participated in. This tradition has, of course, continued through the reorganization and renaming of STU. A more recent case are the numerous ‘centers of excellence’ that VINNOVA funds and that have contributed to shaping university-industry networks.

These were the structural components of a system that emerged in our early discussions. They were incorporated in our first collected volume, entitled *Technological Systems and Economic Performance: The Case of Factory Automation* (Carlsson 1995). In addition to presenting the conceptual framework for the study of technological systems there were chapters on its various components: infrastructure, user-producer interaction, and analyses of sub-sectors (suppliers) of factory automation. We also attempted to formalize the analysis (through a micro-based macro model) and empirically estimated

[10] The inclusion of individual actors, especially in the form of entrepreneurs, turned out to be unique to our approach as compared to national, regional, and sector innovation system approaches.

the economic impact of economic competence and factory automation. The book concluded with a discussion of the policy implications and an international comparison.

The policy chapter was aimed at moving beyond the traditional discussion of market failure in a static context and into the realm of policy-making in a dynamic and systemic framework instead. Since this was a new arena for policy discussion without precedent (at least known to us) in the literature, and since we had only one case to draw upon, we took a cautious approach. Our recommendations were to focus on molding the system as a whole, recognizing that all the constituent parts can be subjected to the influence of policy, that policy intervention is not always necessary, that increased connectivity (networking) among the constituent parts may be beneficial, that policy intervention might be directed at weak parts of the system, and that it might be necessary to influence the visions of management of various entities. Thus, our recommendations involved the *direction* rather than the *content* of policy – away from a focus on R&D support (either generally or targeted for individual firms and projects) and towards an evolutionary systems perspective: “recognizing the difficulties of identifying future technological opportunities, the emphasis shifts from the pursuit of individual technologies or approaches to either pursuit of alternative strategies simultaneously or emphasis on early identification of important developments and on increasing the absorptive capacity of the economy” (Carlsson and Jacobsson 1995, p. 436). This represented a necessary conceptual step in a new policy direction, but it was still a long way from being practically useful.

At the end of this first phase of the project we had described and analyzed a fully developed innovation system in a particular domain of technology.[11] But it was still only a single case, and it was not clear that the findings could be generalized at all. For that reason we turned in the second phase (summarized in Carlsson 1997) to a study of three additional systems (electronics and computers, pharmaceuticals, and powder technology), at different stages of development, all at an earlier stage than factory automation. The powder technology case was a system still in its infancy, centered on two knowledge fields (involving the production of extremely hard metallic and ceramic compounds under high pressure). The pharmaceuticals case was originally intended to be a study of biotechnology, but we soon found that there was not sufficient activity in Sweden in the early 1990s to justify such a narrowly focused study. Instead, we focused on the development of beta blockers (a product-centered system) and the transition from chemistry to biology/biochemistry as a basis for the pharmaceutical industry (changes in the knowledge base of a system centered on an industry). We also tried to gain a better understanding of general purpose technologies and their impact on economic growth. In addition, we simulated the economic effects of knowledge spillovers.

We found many similarities among the systems - especially, the importance of interaction among actors and organizations in the system, the characteristics of knowledge and spillover mechanisms, the absorptive capacity of actors within the system, and the mechanisms that create variety. We found that path dependence plays a major role in every system. We also found important differences, especially with respect to where strength lies in each system – partly as a result of different historical

---

[11] The notion of technology was applied quite broadly here. Others may have labeled our approach at this time a sectoral innovation system.

background. As a result, it became obvious that public policy must be adjusted to each specific innovation system, that policy should focus on the weakest links in each system and that absorptive capacity is an important constraint.

The policy discussion that resulted from our analysis distinguished between strengthening or preserving existing systems and creating new systems. In a dynamic perspective, the latter is far more important but also more difficult. We found three roles of public policy to be particularly important: to improve the receiver competence or absorptive capacity within the system – and here the prime movers in the form of existing firms or entrepreneurs play a role, along with the academic sector, in creating the necessary knowledge and skills; to promote connectivity among the various actors in the system; and to create variety. Again, we were quite influenced by practice. We have already referred to the 'broker' role of STU (promote connectivity). Additionally, by sharing the experience of a 'policy entrepreneur' in the area microelectronics, Sven-Ingmar Ragnarsson, we came to understand the need for a proactive science and educational policy that forms the competence base (including receiver competence) required to break path dependence.[12]

Thus, the policy discussion in the second phase of the project became both more dynamic and somewhat more concrete than in the prior phase. But it was still at a general and conceptual level. With hindsight, much of the discussion aimed at identifying generic system weaknesses, defined in terms of the nature of the structural components of an emerging technological system. Of course, from the perspective of a policy maker

[12] Government funding of academic research in Sweden includes both block grants to Universities (around 45% of total funding in 2005) and competitive funding at both the program and project level, involving both peer-reviewed "basic" research, and strategic or mission-oriented research. It is in the latter category that STU/Nutek/VINNOVA plays a role.

responsible for intervention in a specific system, a general discussion of this nature can only act as a source of inspiration, at best. Translation into specific policies and from there into practice was still a long way and many difficult steps away.

In the third phase of the project (see Carlsson 2002) we focused on technological change in the rapidly evolving bio industries (loosely defined). In order to address issues involving path dependence and institutional differences in settings other than in Sweden, we wanted to make an in-depth international comparison. We chose Ohio. The choice of geographic focus reflected both practical considerations (part of the research team was located in Ohio, part in Sweden; given the nature and volume of the necessary data collection, physical presence in each location was required) and certain similarities in demographic size, industry composition,[13] and economic history.[14]

The broad nature of the system under study forced us to confront a number of difficult conceptual and methodological problems:

- How should an emergent technological system be delimited?
- What should be the main sublevels and subunits of such an analysis? Should they be products, technologies, firms, or industries?
- How should we reconcile the longitudinal and synchronous aspects of the analysis – the fact that different (parts of) systems are at different stages of development?
- What yardsticks should be used to measure the performance of systems that are immature and rapidly evolving?

[13] Both Ohio and Sweden have a large share of output and employment in manufacturing, especially transportation equipment and industrial machinery and equipment.
[14] Both Ohio and Sweden performed well in international comparison in terms of economic growth until the mid-1970s but have since suffered a relative decline.

- How should a comparative analysis in such a heterogeneous field be done?

Questions such as these posed both analytical and methodological challenges. Analytically, we needed an even more dynamic approach, focusing not only on the technology generation and the organizational/institutional arrangements conducive to diffusion and utilization of technology (the supply side) but also on conversion of technical possibilities into business opportunities that are successfully exploited via entrepreneurial activity in the market (the demand side). This led to a clearer articulation of the three dimensions of technological innovation systems: the cognitive dimension (design space), the organizational and institutional dimension (actor networks), and the economic dimension (competence bloc).

Whereas in other approaches to innovation system analysis the object of study is given (a nation, a region, or a sector), the delimitation of a technological innovation system is itself a matter of careful deliberation and raises interesting methodological issues. In each dimension, where are the boundaries, and what techniques can be used to determine them? In terms of evaluating system performance we had to develop our own tools, as the existing literature provided little guidance.

Before we proceed to discuss the innovation policy environment and the interaction between innovation theory and policy we summarize below the theoretical, methodological, and policy contributions of the project through the publication of our 2002 volume.

**Theoretical Contributions**

The main theoretical contributions of our study can be summarized as follows.

1. Technological systems emerge and evolve; the composition of actors and their roles vary over time as the magnitude and direction of the underlying driving forces shift; these changes do not necessarily follow any particular pattern or trajectory, linear or otherwise. Therefore, we need to move beyond static analyses.
2. There are several dimensions of innovation systems: cognitive (i.e., technology), organizational, and economic.
3. In order to understand the dynamics and evaluate the *economic* performance of an innovation system, it is necessary to view the innovation process from two angles simultaneously: the cognitive or technology side, and the product or market side, respectively. A technological innovation system is defined primarily from the input (technology) side and focuses on the knowledge base of the system. Innovations are generated, diffused, and utilized within the system. The market-demand side is represented by the notion of development and/or competence blocs, which are defined primarily from the product or user side. A development bloc is a synergistic cluster of firms and technologies that together constitute an industry or set of industries.

The market selection of technologies and products is intertwined and dynamic; it is not a linear process. Not all technical possibilities are converted into business opportunities, and not all business opportunities are successfully exploited in the market. Sometimes the impetus for change comes from the product side, sometimes from the technology side. Their confrontation in the market is what generates industrial dynamics in the form of economic transformation and growth. Thus, combining the two approaches allows us to examine why a particular system is or is not successful in converting technical possibilities into business opportunities that create economic growth. To our knowledge, ours is the only innovation system approach to integrate entrepreneurial activity into the analysis.

**Methodological Contributions**

In the area of methodology, our findings are the following:

1. A multidisciplinary approach to the analysis of innovation systems is often necessary. For solid empirical work in multifaceted fields, one needs people who understand each of the dimensions of innovation systems and who can also communicate with each other sufficiently to have a common understanding.
2. The content of each innovation system needs to be operationalized in each dimension (cognitive, organizational, and economic).
3. Identification of the actors and delimitation of the system are important research issues.
4. It is important to evaluate system performance and identify appropriate measures.

**Policy contribution**

In the policy arena, the main insight had to do with the unique, dynamic, and multidimensional nature of each system. No policy can possibly fit all cases, nor any specific case over time. It is necessary to identify and address the weaknesses in each system, from each period to the next. But not all weaknesses need to be addressed through public policy. Sometimes systems emerge spontaneously and actors within them take appropriate action to avoid or overcome hurdles. In other cases, policy intervention such as building networks and infrastructure (perhaps in the form of absorptive capacity and legitimacy) or providing incentives and resources is necessary.

Our research showed that policy-making requires high competence, a large measure of adaptability, and continuous learning. We realized that as academic researchers we could only provide a conceptual framework – more precise and fully developed at the end of our project than at the beginning, to be sure – but still leaving the translation into specific policies and conversion into practice to policy-makers who have the necessary political influence and to practitioners with sufficient specific competence. We identified, however, a set of 'generic' policy challenges (Carlsson and Jacobsson, 1997); connected to these is a wide range of systemic policy instruments that may be deployed. These include science policy measures, organizing platforms or meeting places and forming early markets via e.g. procurement policies (see the chapter by Smits et al. on the toolkit of policy makers pursuing systemic policies).

## *4. The formation of VINNOVA*

During the 1990's, many Swedish flagship industries became foreign-controlled through mergers or acquisitions: Asea became part of ABB, Volvo Cars – the automobile part of Volvo – was bought by Ford, Saab Automobile was acquired by General Motors, Astra became part of Astra Zeneca, and Pharmacia merged with Upjohn. The task of policy could no longer be seen as supplying a small number of national flagship firms with "good enough" R&D competence covering all their needs. Instead, Sweden had to compete globally for each new R&D (and production) investment, which involves the need to be world class in at least some areas. Can that be achieved without both stronger focusing of R&D efforts, and the capability to refocus rapidly as priorities change?

Even if Sweden succeeded in retaining many successful large firms, their future growth will not necessarily result in new jobs, since many are operating in relatively mature sectors where relentless rationalization is a key means to profitability, and new production is located close to emerging markets.

For this reason, a second policy challenge is to build the foundations for new, high value-added businesses. This requires a much broader, systemic innovation policy approach. Perhaps in response to these challenges, there has been a gradual shift of focus at the Ministry of Industry from “growth policy” towards “innovation policy” and towards a more systemic view, starting around 1995.

Around 1996 - 97 attempts were made to formulate a ”Coordinated growth policy” (not yet innovation policy), inspired by OECD’s “Technology – Economy – Productivity” project, which would also have involved the ministries for labour and for finance. In the end, however, the attempt was abandoned.

At the same time, regional policy was being reshaped. The basic idea was that regional policies should be adapted to local needs (and local perception of needs). Regional actors were encouraged to formulate regional development agreements which set out how available resources should be prioritized. The first round of such agreements was reached in 1997-98.

In 1998, the ministries of industry, of labour market, and of communications were merged into one large “ministry of growth”. At the time it was described as a growth policy measure, but it is also consistent with a more long-term process to break down barriers between different policy areas. At about the same time as the new regional policy came into place, there was an increased interest in the role of the entrepreneur (not just "small firms"), inspired by research on entrepreneurship[15]. More attention was also being focused on innovation issues - but these were still largely understood in a narrow sense as dealing with inventors.

In Sweden, research policy has oscillated between calls for relevance and defence of academic independence, but, as was noted above, the "linear model of innovation" has retained a strong hold on policymakers. This was again demonstrated in 1998 when a high-profile committee on research funding, appointed by the Ministry for Education and Research, recommended that all government research funding should be based on academic excellence alone, and awarded on the sole basis of academic peer review. This provoked strong reactions from industry and the Ministry for Industry, who saw funding for industrially relevant research threatened. To engage in this battle, a credible alternative policy rationale was needed.

The innovation systems paradigm had already been adopted by several other countries, and filled two important requirements:

1) It gave a rationale for other kinds of policy intervention than research funding based on academic excellence
2) OECD´s extensive work on National Innovation Systems legitimized this perspective as a valid policy rationale.

A new committee set up by the Ministry for Industry recommended the creation of a funding agency for industrially relevant research, based on the innovation systems concept. This became VINNOVA, the Swedish Agency for Innovation Systems.

---

[15] In particular the work done by Per Davidsson at the Jönköping International Business School.

The process which led to VINNOVA was, thus, initiated by a political crisis which had little to do with advances in the theory of innovation systems: Decision-makers looked for a way to legitimize a reorganization, and the innovation systems concept "was in the air." The fact that the innovation systems concept had been legitimized by OECD was crucial to its acceptance: "For every academic theory there is always a counter-theory, but this was state-of-the-art according to OECD." It also helped that the concept fitted well with the personal experience of some of the actors involved in the process.

The creation of VINNOVA can perhaps best be described in terms of Cohen, March & Olsen´s (1972) "Garbage can theory", formulated to give a more realistic description of organizational decision-making. In this theory, problems and solutions are to a large extent formulated independently of each other, and collected in a “garbage can” of possibilities. When a problem demands the attention of a decision-maker, he looks into the garbage can for a solution which reasonably fits his interpretation of the problem. Note that this theory has a lot of elements in common with evolutionary theory: history matters, limited rationality, local search, satisficing behaviour, etc. Hence, the impact of theory on policy came through this type of indirect and non-linear process.

What does it then mean to base innovation policy on a systems perspective? At the simplest level, it could mean doing “business as usual”, only cloaked in a new rhetoric. A higher level of ambition might involve retaining the policy goal of producing industrially relevant research results, but making this process more effective by adopting a systemic view. However, we believe that in order to achieve the true potential of the systems perspective, policy objectives should be formulated in terms of more effective innovation systems.

As suggested by the STS project, a policy aimed at leveraging system performance needs to identify weak parts of each innovation system, in order to strengthen these, and enhance connections between the constituents of each system. Policy results should be measured in terms of impact on system performance. Since each innovation system is unique, and subject to genuine uncertainty, there is no hope of designing an "optimal" policy. Instead policy *learning* becomes important. This learning can come from various sources: Past experience (sometimes formalized as evaluation), policy analysis, foresight and intelligent benchmarking.

At VINNOVA, all programs involve cooperation between industry, academia and other actors, and must be supported by an analysis of the specific innovation system involved, its strengths and weaknesses. Funding is allocated along two dimensions: A Division for Competence Areas designs programs for specific technology fields and sectors.[16] A second Division for Actors designs programs aimed at supporting the connections between various groups of actors in the system. To support strategy development VINNOVA was set up with a strong policy analysis and evaluation capacity. This has been enhanced though long-term funding of four competence centers for "Innovation system research on R&D and growth."

With this background, it is necessary to discuss the relationship between theory and policy on two different levels: a) theory as a basis for policy rationale and b) theory as a basis for policy practice. As we have argued above, the innovation systems concept used to motivate the creation of VINNOVA was very much of the NIS flavour, as interpreted by the OECD. On the other hand, when the new organization tried to interpret

[16] This also accommodates legacy programs from predecessor organizations, which were mainly structured along this dimension.

its mandate, the experiences from the STS project were very important, not least in emphasizing that the innovation system looks different in different fields of technology or industries. STS showed that not only differences in national institutions were important (a result of the work on NIS) but that technological systems had different characteristics, and as a result that policy design had to be based on an understanding of the specific conditions of each unique system. As described above, part of this understanding was based on a mutual development between theory and policy practice, which long predates the creation of VINNOVA.

It has taken more than 20 years from "industrial networks" to an Agency for Innovation Systems and the government's innovation strategy. For a number of years, it is fair to say that policy practice started to develop ahead of a policy rationale which was still founded (at best) on a market failure argument. Academic research learned a great deal from practice but also added to it.[17] However, with the creation of VINNOVA, it appears as if theory has run ahead of practice: VINNOVA has a mission framed in innovation systems terms but is still struggling with what that means in practice. We will now turn to the next stage in interactive learning, one in which policy makers can learn more from academics in applying a system perspective.

## *5. The co-evolution of policy, practice, theory & methods 1987-2002 – the development of functional analysis*

At the establishment of VINNOVA in 2001, some of its activities were organized, as mentioned above, into a number of competence areas, each representing a system,

[17] An example is the adoption of the "network" concept of Håkansson et al. Indeed, Hans Weinberger gave his history of STU the title "The network entrepreneur" (Weinberger, H. Nätverksentreprenören (The network entrepreneur) Stockholm Papers in the History and Pholosophy of Technology, 1997)

although these were delineated in different ways (some broad sectors, e.g. telecommunications, and others applications of a generic technology (e.g. IT in home care). This led immediately to the question of how to operationalize the notion of innovation system for public policy purposes.

Meanwhile, some members of the STS team (Johnson 1998; Jacobsson & Johnson 2000; Johnson & Jacobsson 2001, subsequently developed in Jacobsson & Bergek 2004, Jacobson *et. al.*, 2004 and Bergek *et al.*, 2006) had applied system analysis to the energy field. The starting point of that work was our 1997 policy discussion on blocking mechanisms in system formation (Carlsson and Jacobsson, 1997).

Initiated by a Ph.D. student (Anna Bergek, formerly Johnson), we developed a "functional analysis of innovation systems." With this framework, we go beyond analyzing technological systems at the structural level only and added a second level: functions in innovation systems[18]. These functions capture what is being achieved by the system (and what is not achieved). System weaknesses can then be described not only in structural but also in functional terms. Seven such functions were eventually identified (Bergek et al., 2006): (1) knowledge development and diffusion; (2) guiding the direction of search; (3) entrepreneurial experimentation; (4) market formation; (5) legitimation; (6) resource mobilization (financial and human capital in particular); and (7) development of positive externalities.[19]

With funding from STEM (Swedish Energy Agency), we tentatively applied an early version of this framework to the evolution of wind and solar power in Germany (and the Netherlands) but only as a way to analyze the historical evolution of these

[18] See for a more elaborate discussion of the functions approach the chapter of Bergek et al.
[19] The functional analysis was developed further in collaboration with researchers in Utrecht.

systems [Bergek and Jacobsson, 2003; Jacobson et al., 2004)]. In 2003, there was chance meeting with a senior official of VINNOVA, S.G. Edlund. Edlund, with a background in control engineering, asked one of us if the notion of "function" could be useful in innovation systems analysis and he was shown our early attempts to apply such a framework to renewable energy technology. This led to a small experiment whereby one of us applied our framework to a case already developed at VINNOVA: wood manufacturing. The response was enthusiastic and the case study was presented to most analysts at VINNOVA – legitimizing the approach. This positive experience led to a further project involving the application of this framework to three more case studies. Also these were presented to most analysts at VINNOVA.

In these experimental cases, we went from arranging the empirical material in functional terms to specifying the policy problem in such terms. The objectives of policy were formulated in terms of 'process goals' that were specified as functions that need to be fulfilled, rather than in structural terms or in final outcomes such as the diffusion of a particular technology in a particular application. Current functional patterns can be explained by linking functions to the structural components of a system (actors, institutions, networks), identifying, in particular, mechanisms that 'block' the development of powerful functions. A functional analysis can then act as a 'filter' for policy makers in finding the precise points where an intervention may help the system to move in the desired direction. Of course, for a policy maker who has the responsibility to design policies for a specific innovation system, a framework like this may prove to be quite valuable.

Although VINNOVA only wanted us to solve some methodological problems in connection with the experimental applications, we decided jointly that the best way to do this was to write a policy ‘manual’ that would synthesize and make available our findings and that could also serve as a teaching tool. In this manual we included not only “functional analysis” but much of what we had learned in the course of the whole STS project, including methodological issues (Bergek *et al.*, 2005). The manual was then seen by a member of the Swedish Environmental Protection Agency who requested another experimental application – organic milk. Again, the framework seems to meet the needs of policy makers.

## 6. Some reflections on the past and future

Although the STS project was set up with a loosely formulated charge, it was expected to contribute to an improved understanding of technology in economic growth and, therefore, build a better foundation for technology policy as well as to raise competence. The former does not mean that researchers should provide specific policy suggestions, although many of us always try to do that. Policy making is a ‘political’ process where the political context needs to be understood, and where knowledge is needed of which policy suggestions have been put forward previously, and been rejected, and which therefore are not sensible to put forward. Policy makers are keener to see new perspectives, or “glasses” through which they may interpret the world. In that connection, it is a strength that researchers from different disciplines come to similar conclusions - in our case the similarities between the Uppsala school of industrial networks and our approach which both end up at a “meso” level of some kind. Our work was, therefore, only one of several that used a system perspective applied to a meso level.

Yet, it was not any of these that most influenced the formation of VINNOVA (at least the choice of its name) but it was the National Systems of Innovation concept which, although less suitable to an organization like VINNOVA, due to its main focus on policies for specific technological systems, was legitimized by the OECD and used in a political struggle over the nature of science and technology policy. In that respect, the OECD was much more influential than the STS project. Nor was the STS project successful in finding means for VINNOVA and its predecessors to communicate to the politicians at the national level, but it is fair to say that the politicians have taken notice of the combined efforts of research using different system approaches. A case in point is the current vogue to design cluster policies.

Yet, we have probably been successful, although future will tell, in developing an analytical framework and methods for analyzing systems centred on a particular knowledge field/technology or product. We got a head start here as we quickly left the NIS approach. There are also some attempts to apply the “functions in innovation systems” approach at VINNOVA although it is much too early to say whether or not it will be widely implemented ( there is also an international interest in the approach, see e.g. Hekkert et al., 2006)

We were, however, only partly successful in developing competence. In addition to senior researchers, only two PhDs graduated within the STS project, although several others worked with the same framework using additional funding from other sources. The emphasis on senior researchers means that there is now a clear shortage of younger researchers who can undertake analyses using our approach. It is an old lesson that needs to be re-learned: research and doctoral training should go hand in hand.

Over the whole period, there was an interplay between “needs-driven” or directed research and “curiosity driven” academic work. Both VINNOVA and STEM fund directed research but both do it with much space for free thinking by the academics. Indeed, the early formulations of the “functional approach” were entirely the result of “curiosity driven” research although, as underlined above, it rested on earlier work done in the STS project. These efforts proved to be highly complementary. Yet, it would have been impossible to assess the utility of the STS project beforehand. In particular, it was impossible to even imagine what would come out of it 15 years after its inception. As with much other knowledge development, the time frame is long and uncertainties profound. Funding of directed research therefore need not only to allow much space for “curiosity driven” work but also to be patient.

Yet, the process of developing and applying new knowledge could have been more effective. A number of lessons can be drawn for future work. First, although the research was followed by one or two members of STU and Nutek, more, and more direct, interaction with policy makers would have been useful. A better mutual understanding of the policy issues between the research team on the one hand and the decision makers within STU/Nutek/VINNOVA as well as the policy makers at the ministry level on the other might have led to better communication and therefore both better theory (greater relevance of the research) and better policy formulation. Second, the conversion of policy into practice could also have been more effective. As it was, there was almost no communication between the researchers and those responsible (“practitioners”) at STU and Nutek for implementation of policies in specific domains. A more intense interaction could have been a channel from academic research to the policy making community and instrumental in developing the receiver competence among policy makers. Perhaps collaborative research efforts would have been part of the solution in the form of doctoral level courses by academic researchers for policy makers. Third, although we developed a manual for policy makers, more synthesis work is required in order to make science useful – efforts are required to “translate” the ever growing academic literature to useful methods and tools. It is in the interest of both policy makers and academics to organize this “translation” and it is the responsibility of both parties to act upon this opportunity to use science as a tool to shape a useful policy.

**BIBLIOGRAPHY**

Bergek, Anna, 2002. Shaping and Exploiting Technological Opportunities: The Case of Renewable Energy Technology in Sweden. Ph.D dissertation, Department of Industrial Dynamics, Chalmers University of Technology, Gothenburg.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., and Rickne, A. (2005): Analyzing the dynamics and functionality of sectoral innovation systems – a manual for policy makers, report delivered to VINNOVA.

Carlsson, Bo (ed.) 1995. *Technological Systems and Economic Performance: The Case of Factory Automation*. Boston: Kluwer Academic Publishers.

Carlsson, Bo (ed.), 1997. *Technological Systems and Industrial Dynamics.* Boston: Kluwer Academic Publishers.

Carlsson, Bo (ed.), 2002. *Technological Systems in the Bio Industries: An International Study*. Boston: Kluwer Academic Publishers.

Carlsson, Bo and Staffan Jacobsson, 1995. "Factory Automation and Government Policy," ch. 14 in Carlsson (ed.), *op. cit.*, 417-440.

Carlsson, Bo and Staffan Jacobsson, 1997, In search of a useful technology policy - general lessons and key issues for policy makers, in Carlsson, B, ed, Technological Systems and Industrial Dynamics, Boston: Kluwer Academic Publishers, 299-315.

Carlsson, Bo and Rikard Stankiewicz, 1991. On the Nature, Function, and Composition of Technological Systems, *Journal of Evolutionary Economics*, 1 (2), 93-118.

Carlsson, B., E. Dahmén, A. Grufman, M. Josefsson and J. Örtengren, 1979. *Teknik och industristruktur - 70-talets ekonomiska kris i historisk belysning* (Technology and Industry Structure – The Economic Crisis of the 70s in Historical Perspective). Stockholm: IUI.

Cohen, M. D., March, J. G., and Olsen, J. P., 1972. A Garbage Can Model of Organizational Choice. *Administrative Science Quarterly*, 17(1), 1-25.

Dahmén, Erik, 1950. *Svensk industriell företagarverksamhet* (Entepreneurial Activity in Swedish Industry, 1919-39). Stockholm: IUI. Also published in 1970 by the American Economic Association Translation Series under the title "Entrepreneurial Activity and the Development of Swedish Industry, 1919-1939". Vol. 1 and 2. Stockholm: IUI.

Dahmén, Erik, 1989. Development Blocs in Industrial Economics, in B. Carlsson (ed.), *Industrial Dynamics: Technological, Organizational, and Structural Changes in Industries and Firms*. Boston: Kluwer Academic Publishers.

Dosi, G., C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds.), 1988. *Technical Change and Economic Theory*. London: Pinter.

Ehrnberg, Ellinor, 1996. Technological Discontinuities and Industrial Dynamics. Ph.D. dissertation, Department of Industrial Management and Economics, Chalmers University of Technology, Gothenburg.

Freeman, Christopher, 1987. *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Freeman, Christopher, 2004. Technological Infrastructure and International Competitiveness. *Industrial and Corporate Change,* 13(3), 541-569.

Fridh, Ann-Charlotte, 2000. Dynamics and Growth: The Health Care Industry. Ph.D. dissertation, Department of Industrial Economics and Management, Royal Institute of Technology, Stockholm.

Granat Thorslund, Jennie, et al,, 2005. ”The End of An Era? Governance of Swedish Innovation Policy”, in OECD: Governance of Innovation Systems, Vol 2, Case Studies in Innovation Policy, Paris: OECD, 245 – 282.

Hekkert, M. P.; Suurs, R. A. A.; Negro, S. O.; Kuhlmann, S. and Smits, R. E. H. M. (2006): Functions of Innovation Systems: A new approach for analysing technological change, forthcoming in *Technological Forecasting and Social Change.*

Håkansson, Håkan (ed.), 1982. *International Marketing and Purchasing of Industrial Goods. An Interaction Approach.* Chichester: John Wiley.

Håkansson, Håkan (ed.), 1987. *Industrial Technological Development. A Network Approach*. London: Croom Helm.

Håkansson, Håkan (ed.), 1989. *Corporate Technological Behavior. Cooperation and Networks*. London: Routledge.

Jacobsson, S., Sandén, B. and Bångens, L., 2004. “Transforming the energy system - the evolution of the German technological system for solar cells”. *Technology Analysis and Strategic Management*, 16 (1), 3-30.

Jacobsson, S. and Bergek, A., 2003. The development of a growth industry – the wind turbine industry in Germany, Holland and Sweden, in Metcalfe, S. & Cantner, U., eds, (2003): *Change, Transformation and Development*, Physica-Verlag, Heidelberg.

Jacobsson, S. and Bergek, A., 2004. Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology. *Industrial and Corporate Change*, 13 (5), 815-849.

Jacobsson, S. and Johnson, A., 2000. The diffusion of renewable energy technology: an analytical framework and issues for research. *Energy Policy*, 28, 625-640.

Jacobsson, S. and Lauber, 2006. The politics and policy of energy system transformation – explaining the German diffusion of renewable energy technology, *Energy Policy* 34 (3), 256-276.

Jacobsson, S., Sjöberg, C. and Wahlström, M., 2001. Alternative specifications of the institutional constraint to economic growth - or why is there a shortage of computer and electronic engineers and scientist in Sweden? *Technology Analysis and Strategic Management*, Vol. 13, Number 2, June, 179-193.

Johansson, Dan, 2001. The Dynamics of Firm and Industry Growth: The Swedish Computing and Communications Industry. Ph.D. dissertation, Department of Industrial Economics and Management, Royal Institute of Technology, Stockholm.

Johnson, A., 1998. *Functions in Innovation System Approaches*. Mimeo, Department of Industrial Dynamics, Chalmers University of Technology, Sweden.

Johnson, A. and Jacobsson, S., 2001. Inducement and blocking mechanisms in the development of a new industry: The case of renewable energy technology in Sweden. In: Coombs, R., Green, K., Richards, A. and Walsh, W. eds: *Technology and the Market, Demand, Users and Innovation*. Cheltenham: Edward Elgar.

Kristensen, P.H. and J. Levinsen, 1983. *The Small Country Squeeze.* Roskilde: Førlaget før Samfundsøkonomi.

List, Friedrich, 1841. *Das Nationale System Der Politischen Ökonomie.* Basel: Kyklos (translated and published under the title "The National System of Political Economy" by Longmans, Green and Co., London 1841).

Lucas, Robert E., Jr, 1988. On the Mechanics of Economic Development, *Journal of Monetary Economics*, 22, 1, 3-41.

Lundgren, Anders, 1991. *Technological Innovation and Industrial Evolution – The Emergence of Industrial Networks.* Stockholm, EFI.

Lundvall, Bengt-Åke, 1985. *Product Innovation and User-Producer Interaction*. Aalborg: Aalborg University Press.

Lundvall, Bengt-Åke, 1988. Innovation as an Interactive Process: From User-Producer Interaction to National Innovation Systems, in Dosi *et al.* (eds.), *op. cit.*, 349-369.

MacDowall, Joseph, 1984. The Technology Innovation System in Japan. *Journal of Product Innovation and Management*, 1(3), 165-172.

Reitberger, G., Utterback, J. Technology and Industrial Innovation in Sweden. A Study of new technology-based firms. Center for Policy Alternatives, MIT, 1982.

Rickne, Annika, 2000. New Technology-Based Firms and Industrial Dynamics: Evidence from the Technological System of Biomaterials in Sweden, Ohio and Massachucetts. Ph.D. dissertation, Department of Industrial Dynamics, Chalmers University of Technology, Gothenburg.

Romer, Paul M., 1986. Increasing Returns and Long-Run Growth, *Journal of Political Economy*, 94 (5), 1002-1037.

Romer, Paul M., 1990. Endogenous Technological Change, *Journal of Political Economy*, 98 (5, part 2), 71-102.

Sharif, Naubahar, 2006. Emergence and Development of the National Innovation Systems Concept. *Research Policy*, 35(4), 745-766.

Tryggestad, Kjell, 1995. Teknologistrategier og postmoderne Kapitalisme: introduksjon av computerbasert produksjonsteknikk. Ph.D. dissertation, Lund University, Lund.

Walsh, Vivien, 1987. "Technology, Competitiveness and the Special Problems of Small Countries. A Survey of the Literature." IKE Workshop on Technological Change and the Competitiveness of Small Countries, Denmark