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Public–private innovation: Mediating roles and ICT niches of industrial research institutes

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ABSTRACT

Innovation processes involve diverse sets of organizations including universities, private firms, corporate research labs and public research institutes. Collaborative forms of knowledge production and innovative activity enable actors to reduce risk, specialize, and take advantage of knowledge internal and external to the own organization. This paper discusses interactions and collaborations between public and private sector innovation. This is done through an analysis of semi-public research institutes in Sweden and their roles as arenas for R&D processes involving industry, university and government in terms of funding, research and public–private innovation. Particular attention is paid to technological niches of research institutes and utilization of research findings from collaborative R&D. The results show that institutes occupy specific niches which influence their ways of transferring knowledge. It is argued that diversity among R&D performers as well as funding opportunities is paramount for innovation systems to thrive.

Keywords: Absorptive capacity; basic science; industrial research institutes; innovation systems; intellectual property rights; knowledge transfer; technological niche

Introduction

In the Swedish institutional landscape industrial research institutes serve as an arena for collaborative research and development (R&D) activities between university and industry. The research is supported by industrial funding, competitive research funding from government agencies directed towards specific research programs in targeted areas and governmental core funding dedicated to broadly defined long-term capability development. Swedish research institutes are active in a wide array of areas such as environmental technology and management, information and communication technology (ICT), food production and processing, paper and pulp, composite materials, and other fields considered relevant for the Swedish economy and innovation potential. Their general purpose lies in stimulating knowledge transfer while simultaneously both serving industry and having public sector rele-

vance. This paper examines the issue of public sector innovation through the lens of interaction between public and private sector innovation in the context of industrial research institutes. In particular, examples of different roles and strategies of Swedish institutes active in the area of ICT are discussed along with consideration of the niches of specialization of the research institutes.

Industrial research institutes are a group of research and technology organizations (RTOs) which can be partly or totally publicly financed and 'contribute either directly or indirectly to systems of innovation' (Preissl 2006). In the terminology of innovation systems, research organizations that serve industry and public sector interests have both intentional and unintentional technological spillovers (Carlsson et al. 2002: 234). In practice, these spillovers can be inventions in terms of physical artefacts but also knowledge and skills embodied in researchers and engineers that move across organizational boundaries. This is also referred to as the human capital model of innovation, often emphasized in studies evaluating linkages and value arising from interaction between university and industry (Faulkner and Senker 1994). As important for this model as large and comprehensive research universities has been the existence of a number of big private and public firms with close relations to the state, infrastructures and other vital systems (as described in Fridlund 1999). Amongst these firms in Sweden are ABB (power and automation technologies), Ericsson (telecommunications equipment), Saab (military defense technologies), SJ (Swedish train operator), Posten (Swedish Post Office), Telia (telecommunication services) and Vattenfall (electricity and heat provider), all with extensive relations to a symmetrically organized range of public agencies, such as FMV (Swedish Defence Material Administration), and government departments for vital infrastructures such as railways, roads, telecommunications, energy and defense.

The university–industry interface for innovation has previously been analyzed and discussed in terms of implications of industrial relationships for universities (Senker and Senker 1997) and academic entrepreneurship at universities (Klofsten and Jones-Evans 2000, Shane 2004, Balconi et al. 2004, Colyvas and Powell 2007). Other studies emphasize different types of output from university–industry collaboration, arguing that while scientific publications often are the result of more basic-oriented collaborative research, applied research collaboration in contract research can facilitate interactive learning that results in new ideas and can motivate new research projects (Perkmann and Walsh 2009: 1034). This aspect of learning and acquisition of skills is also incorporated in the analysis of concepts of research and development (Godin 2006b), in particular the D in R&D. This type of analysis, concerned with tracing the definitions of basic science in organizations such as the National Science Foundation in the US and OECD (Godin 2003) can be contrasted with other studies analyzing the concept of basic science from a boundary work perspective showing how borders of the concept are discursively and rhetorically mapped out by the scientific and the policy community rather than being sharply defined (Calvert 2006).

In a classic paper by de Solla Price (1965) science and technology (S&T) is discussed in terms of a metaphor of 'geographical terrain that can be explored and traversed, [...] and conceived of as varying in terrain from difficult mountains and key passes to broad plainlands and fields' (de Solla Price 1965: 554). When we discuss technological niches in this paper we find it useful, in the spirit of the S&T landscape metaphor, to consider the character of the niches that the organizations studied are inhabiting, including the historical trajectories, IPR-regimes and affiliated member organizations that have an impact on the immediate S&T landscape in addition to considering the surrounding S&T landscape that accounts for the topography of the S&T area.

With the ongoing development towards internationally competitive research environments, the concept of absorptive capacity (Cohen and

Levinthal 1989) and a better understanding of firms' innovative search activities (McKelvey 2004) has gained renewed urgency for institutes motivating investments in R&D in order to also have the capacity to absorb knowledge from actors abroad and not just considering R&D investments as means to invent new technology applications and products. A related branch of innovation studies uses patent data and citations to university-based patents and publications to determine the roles of public research organizations. One example is patent data analysis of knowledge sources for patents (as a measure of innovation activity) applied to telecommunications technology (Corrocher et al. 2003). This study places Sweden, together with countries such as US and Finland, in a 'good position as knowledge creators'. In the case of Sweden and Finland, this reflects small nations with a strong innovation base from successful national companies such as Ericsson and Nokia.

Previous industrial successes in the semiconductor industry in US and Silicon Valley are now followed by analyses of 'new Silicon Valleys' in other countries (Bresnahan et al. 2005). These studies often focus on local conditions and policies (Feldman 2000, Gertler 2003), which is another aspect of public sector innovation worth mentioning also for RTOs active in the ICT field. One example of local policy is the initiative of 'Fiber Optic Valley' located in area of Hudiksvall in the north of Sweden aiming to turn Sweden 'into the world leader in the development of products and services based on fiber optics' (Fiber Optic Valley 2010). This illustrates the importance of local provision of skilled engineers as well as the international dimension of the competitive market for these types of initiatives which also involve research institutes.

Semi-public research institutes in Sweden active in the area of ICT have not been much studied, yet they provide interesting points for discussion of the importance of public sector research at universities and institutes for providing a strong engineering base for industrial research in knowledge-based economies. In both Sweden and Finland a considerable share of R&D is performed by industry; 74% in Sweden and 72% in Finland. The countries also have the top two positions for gross domestic expenditure on R&D (GERD), both exceeding three percent of GDP (OECD 2010: 19). Furthermore, the case of industrial research institutes provides an interesting aspect since these involve both industrial partners with an entrepreneurial agenda to reap the benefits of their investments, and at the same time fulfill an education function and also incorporate PhD students with a clear aim of getting their papers published in scientific journals during their doctoral education. Research examining hybrid order of scientific publication and patenting activity in the US argues that there has been a 'fundamental change in the rules governing universities' knowledge dissemination practices (Owen-Smith 2003: 1099) where publishing and commercialization have become integrated and reinforce each other. Perhaps this change can also be observed at research institutes where both patenting and publishing co-exist.

This study of industrial research institutes aims to provide insight into different forms in which public sector innovation is organized and analyze how technological niches pursued by institutes influence the ways in which knowledge production and knowledge transfer are practiced. Specifically, the following research questions are investigated in this paper:

1. How is public–private innovation organized and managed at the arenas of collaboration made up of industrial research institutes, both historically and currently?
2. What are the implications of niches of specialization for innovation practices and knowledge transfer from institutes to the wider society?

These questions are at the heart of innovation policy debates concerning which mechanisms of knowledge transfer are superior for wider society to reap the fruits of new knowledge – industrial

commercialization or open source solutions and public dissemination of results (Rhoten and Powell 2007). This makes examples from the ICT sector of particular interest by expanding the concepts of technology platforms (Corrocher et al. 2003) to ICT niches and analyzing how these influence knowledge management in organizations. By examination of the history of semi-public research institutes the aim of the study is also to contribute to earlier work on limits of public sector innovation (Potts 2009).

The paper next examines the background to the institute sector and its development in Sweden. Then two examples of ICT niches are presented, followed by a discussion that in conclusion outlines some policy implications and further areas of work.

Roles of RTOs and industrial research institutes in Sweden

In Sweden there has been a conscious policy to establish semi-public institutes since the early 1940s. Originally this policy had a strong technology push focus with institutes designated to carry out basic research in industrially relevant fields and with a large share of state funding. The underlying assumption was that industrial firms would not be able to carry out the necessary research on their own and that they would not be able to collaborate among themselves, i.e. with their own competitors, very readily on applied research which would be too close to production (Pettersson et al. 2010). The organizational form that was commonly chosen for this arrangement was to involve the state as a majority or large minority owner together with sectoral members' associations formed by industrial groups with a strong influence over the research agenda.

This model changed over time, however. One feature was that the focus shifted from basic to applied research, and increasingly so as research performed at the universities gained the upper hand with major higher education and research policy reforms in the 1960s and 1970s. Another feature was that direct state funding to institutes, which was typically the majority funding, was reduced (Sörlin 2006). The sector of research institutes in Sweden was never very large but since the 1980s it suffered a major downscaling in relative terms as universities were also asked to perform more applied research. In the 1990s the institutes were turned into limited liability companies and the involvement of the state was restricted and organized as a holding company, IRECO, since 2009 renamed RI.SE used as an online acronym for Research Institutes of Sweden. In recent years, however, there has been a marked policy change driven by the longstanding debate on the European (and Swedish) paradox with high R&D expenditure and limited job creation and economic growth (for review see for example Dosi et al. 2006). In the Swedish case, this line of argument suggests that links between university-based research and firm innovation under the Swedish model are too weak and that the Swedish economy runs the risk of losing many opportunities because of too little industrial exposure to emerging technologies and new ideas. As one instrument in a counter strategy to enhance innovation there has been a conscious effort under different governments to strengthen the institutes and since 2007 there is marked growth in the sector and an effort to move into foreign markets.

Sweden is an extreme case in the European R&D landscape, with an unusually small RTO sector (Arnold et al. 2007). Most countries hold reasonably large institutes, although they differ considerably in shape, functionality, organizational model, and in their funding patterns (Sörlin 2006, Arnold et al. 2007, Fjaestad 2010). One country which is however not too distant from Sweden in this regard is Denmark. In Denmark there is also a tradition of maintaining a strong focus on university-based R&D. Denmark has however their own particular sector of institutes called the GTS institutes (Sörlin et al. 2009). GTS literally means Authorized Technological Service Institutes (GTS – Godkendte Teknologiske Serviceinstitutter) and refers to the fact that the Danish

government approves of new institutes based on applications from a firm, consortium, or organization that wishes to set up the institute.

The GTS institutes go back to about the same period as the Swedish institutes, i.e. the middle of the 20th century, and they became very numerous, albeit small, in the 1960s and 1970s; there were 46 of them at the most (Arnold et al. 2007). Later they went through a period of restructuring, fusions, and also an economic crisis that made many of them go into bankruptcy. Since around 2000 there has been a rapid growth and an emerging internationalization in the slimmed and restructured GTS sector. Today the GTS institutes are vital, profitable and regarded with high esteem among their customers. Also, in Denmark as in Sweden, there is a policy shift under way to strengthen the role of the Danish GTS institutes as focused actors in an ever more diverse and integrated research and innovation system with little resemblance of the traditional linear model (Sörlin et al. 2009).[1] One particular feature of research performance under this new 'post-linear' paradigm is that institutes cannot only be considered as mediators positioned between universities and firms. Rather they perform, on a quite independent basis, a set of targeted, often customer specific, R&D missions and activities that require broad skills from basic to applied research. This includes the traditional mediating role, but goes beyond that in a breakdown of the three-hump model (of universities–institute–industry) distribution of roles between actors in a more linear notion of the innovation process with transfer from university through institutes to industry (Sörlin et al. 2009: 30). The institutes thereby appear in the R&D marketplace both as competitive players and as alliance-seeking partners prepared to join forces with universities, firms, and other institutes, as circumstances demand. This market and operational logic is the main driver behind the policy changes going on in Denmark and, we argue, also in Sweden and other countries (Sörlin et al. 2009, Pettersson et al. 2010). This development is well aligned with parallel changes going on in research systems around the world and with the logic of globalization and may serve as a key factor in the reshaping, and possible growth, of RTOs in many parts of the world. This accounts for both industry and public sector innovation with a considerable portion of public sector customers in both the Swedish and Danish institute sectors.

The scope of activities and organizational forms in the RTO sector in Europe have undergone substantial change during recent years, triggered among other factors by institutional reforms and changing sources of funding (Preissl 2006). Different organizational options and configurations have been investigated and tried among the institutes in order to adapt to the new and changing conditions. Similar developments can also be observed among technology transfer offices (TTOs) which in some parts perform a similar function to that of RTOs, i.e. acting as an intermediary between industry and academia (European Investment Fund 2005, Tahvanainen and Hermans 2008). European TTOs vary a lot with regard to organizational forms and activities and are also undergoing change, for example regarding the scope of their activities (Conti et al. 2007). Although there are some changes that are influenced by policy and research networks at the EU level, the institutional landscape varies greatly between countries and the institutional set-up of incubators and science and technology parks is a result of local as well as regional and national science and innovation policy (Larsen 2004).

In Sweden there is currently a rich flora of different industrial research institutes, each shaped by its own unique circumstances. Three main types of institutes can be identified (Sörlin 2006). The first group consists of institutes dedicated towards particular scientific fields, for example

[1] For further discussion of the historical construct of the concept of the linear model, see for example studies by Godin (2006a) or Edgerton (2004).

surface chemistry or computer science. The second type includes institutes that focus on specific industry sectors with a strong presence and tradition in Sweden, like paper and pulp industry or manufacturing industry. Thirdly, there are institutes that specialize in providing particular functions directed towards all industrial sectors, for example technical evaluation and testing or consulting services in areas such as quality and continuous improvement; SP Technical Research Institute of Sweden being the prime example and dominating this category.

The two examples of research institutes we discuss in the following belong to the first and second category of institutes (outlined above) and are used to provide a richer account of contemporary institutional underpinnings of collaborative innovation activities.[2] Another related approach to study these aspects has a stronger historical focus examining the background to current industrial research institutes analyzing early Governmental Bills and historical archives to get a thorough understanding of roles formulated for industrial research institutes in Sweden in different time periods, starting in the 1940s (Pettersson et al. 2010).

ICT NICHES AND INNOVATION PRACTICES: TWO EXAMPLES

In the following section two examples of institutes are discussed with regard to their relations with the private sector and their practices concerning innovation and commercialization of research results. The two institutes studied are both part of the Swedish ICT innovation system, although they have very different focus areas. Case 1 is focused on research concerning software development while case 2 is predominantly occupied with R&D in hardware, e.g. microelectronics, sensors and optical components.

Case 1: Software development under incentives and constraints shaped by industrial collaboration

The first studied institute, case 1, has a general principle that the institute owns the results of its research. Nonetheless, the firms in the members' association that partially owns case 1 enjoy free rights to use the results of case 1's research as they find appropriate.[3] Only large firms, mostly Swedish, with considerable bargaining power are members of that association. This means that tensions can arise if the institute and the member firms have differing opinions on the use of results, and the ways to transfer knowledge or commercialize R&D output. The member firms also have an influence on the choice of institute's collaboration partners.

The results of this institute's research are mostly presented in scientific publications and/or used by the member firms. Examples of research areas where the institute is active include wireless sensor networks and distributed systems. A few of the results of case 1's research have been patented; the patents can later be sold, licensed or used for creating spin-off firms. In comparison with the hardware-focused case 2 patenting is more difficult for case 1, it is for example considered nearly impossible to patent production processes in the software field.[4] Another obstacle to patenting and consequently patent-based spin-offs is the fact that the firms in the members' association have to give up their universal rights to free use of results before a patent can be sought by case 1. This can lead to discussions based on divergent views on the most appropriate means to put results to use so that they are beneficial to the Swedish society at large.

Some results are also released by case 1 as open source software that can be used freely by anyone. However, it is not unusual that the member firms

[2] In addition to the public–private collaborations that we study here there are other types of innovative activities that institutes are involved in, for example through the collaborations between institutes and actors such as public sector agencies, public enterprises, regional or local governments. However, these are beyond the scope of this paper.

[3] Interview with CEO of case 1, 8th of April, 2008.

[4] Interview with CEO of case 1, 8th of April, 2008.

are reluctant to releasing results as open source; they can therefore sometimes block such knowledge transfer.[5]

Case 2: Focus on hardware and in-house commercial know-how

This institute employs an active IP strategy in order to detect patentable innovative steps early on in the research process so that they can assure proper protection for research results with commercial potential.[6] Since scientific publication is an obstacle to getting a patent, at least under the European patent law, it is vital for case 2 that technology is protected before it is revealed to outsiders and published. Patenting is in most cases chosen over early publishing, due to a strong commercial focus of the institute. Competence has been developed internally to manage legal aspects of agreements and IPRs, but the institute also relies on external resources in the form of a law firm and a patent consultancy. The protected technology can then be licensed or sold. The institute has also produced a large number of spin-off companies based on protected technologies developed at case 2.

Case 2 is partially owned by a members' association of firms and organizations. However, case 2 does not consider the association as influential over its activities as case 1. Since case 2 was created as a merger of different institutes its members' association has had a limited influence on case 2 over the years.[7] Still, case 2 is interested in having active partner firms and has decided to form groups of actors with interest in particular fields of technology that can focus their efforts on these fields. This move has been somewhat upsetting to members of the owners' association since firms in these focus groups do not have to be paying members of the association.

Case 2 states that the ownership of results from its research and development projects depends very much on the financing of specific projects.[8] Normally, for a totally privately sponsored project, the firm financing it owns the results, for example in the form of a pre-defined product, but the background knowledge and general know-how are properties of the institute. In partially privately sponsored projects, firms contributing to the financing can have the right to free use of results, which are nonetheless owned by case 2. In practice however, it is not uncommon for collaboration partners, especially large firms, to try and claim ownership of all results in specific areas although they only partially finance research at the institute. When that happens, usually a round of negotiations follows where a mutual agreement can be reached.[9] In this way the tension between the private, commercial sphere and the public sphere is expressed at this particular institute.

Conclusions and discussion

Interaction between public and private sector innovation has been examined in this paper through a study of industrial research institutes as arenas for collaborative R&D. The results bring attention to different roles and strategies of Swedish institutes active in the area of ICT also considering the niche of specialization of the institutes. The two examples of institute practices presented above suggest two main conclusions.

Firstly, the relationship to and balance of power with the owners' association seems to be important for implementing knowledge management strategies and making decisions on means of transferring knowledge to other firms and the society at large. Case 1 seems to be influenced by its owners' association in a much more profound way than case 2, which has effects on how activities are organized and research results used.

Secondly, it seems as though the cases examined here either lean towards the commercial side, devel-

5 Interview with CEO of Case 1, 8th of April, 2008.
6 Interview with Manager of Sales, Administrative Support & Quality at Case 2, 14th of October, 2008.
7 Interview with Managing Director of Case 2, 26th of March, 2008.
8 Interview with Managing Director of Case 2, 26th of March, 2008.
9 Interview with Manager of Sales, Administrative Support & Quality at Case 2, 14th of October, 2008.

oping the organization in accordance with commercial principles of protecting intellectual property created at the institute or towards the academic side, focusing on academic publishing and publicly available results through open source, thus not yet achieving a hybrid order where private and public uses of research results clearly reinforce each other. The trade-off between costs and benefits with a public knowledge regime of scientific publications, as compared to private proprietary knowledge management targeting commercialization, also illustrates different prerequisites for IPR in software development and ICT hardware technology. The respective niches that these institutes have specialized in force them to develop certain ways and organizational practices to manage utilization of research findings so the findings can benefit both the owners' associations and Swedish society at large. One area that warrants further examination is international comparative studies of different historical trajectories and research niches that public- or semi-public RTOs occupy, which influence their strategies with regard to knowledge transfer.

The experiences from the examples presented above corroborate a general tendency towards actor complexity and funding diversity in innovation systems. In Sweden this is an important finding. For about three decades, since the early 1980's, Swedish innovation policy has been strongly aligned with national policy for science and higher education. This has meant, in reality, that a large responsibility for innovative capacity has been placed on universities, partly as research performers but even more so as providers of research-based training of undergraduates and advanced level students, what is commonly called the 'human capital model'.

This nationalistic innovation system model with provision of great numbers of university trained students to a limited number of large R&D performing Swedish owned companies has been largely successful but has run into serious problems in recent years. This has been associated with globalization and emerging markets, as well as an increasing complexity entering the innovation process where large numbers of small players with innovative technologies have increasing possibilities of performing vital innovative functions by means of cheap and small scale operations. Customer-oriented, complex innovation in order to serve emerging and often unforeseeable niches in the market is not well taken care of by the traditional Swedish model. That is the basic explanation behind a return to a more multi-facetted innovation agenda marked more by actor pluralism and strategic diversity.

This also explains the renewed interest in RTOs. Universities will undoubtedly continue serving a fundamental role in the innovation systems of most countries, and certainly in Sweden, by providing highly trained specialists to industry and public sector and by performing path breaking research, sometimes in collaboration with industry. However, it is impossible even for a diverse and large university system to cater to all kinds of needs that dynamic and ever changing innovation systems will have. That explains the need for small, flexible, and customer oriented R&D performers with a pronounced market and needs-based orientation.

It is, we suggest, in the light of this general development that we should understand recent policy trends in a range of European countries, including most EU member states. In many of those countries research institutes have been a strong component of the research and innovation system and despite the predicted decline of RTOs that has been voiced since the 1980's, there is now a growing support for the institutes. Universities tend to increase their share of national R&D budgets, but only marginally, and in countries with solid and longstanding industrial research institute sectors, like Germany, the Netherlands, Finland, Norway, and Spain, institutes show no signs of weakening. On the contrary they reaffirm their positions in the diversified landscape of R&D performers taking on more comprehensive roles and increasing their budgets and activities, leaving the three-hump model behind. At the same time, in countries with smaller institute sectors (and larger university sec-

tors) there is a visible change of policy going on in adjustment to the new demands; RTOs are being entrusted with growing roles in the innovation systems, according to the logic just described.

Sweden and Denmark are perhaps the most pronounced cases in point. With a targeted approach and niche-based development this pluralistic post-nationalist innovation strategy can be performed with a quite limited risk in terms of public finances since the R&D support provided in institutes can be flexible and market oriented, depending somewhat on the institute structure. Even in this respect Denmark and Sweden provide interesting examples with comparatively small and diverse institute sectors but nevertheless with a wide coverage of large sectors of the economy and with a capacity to support both small and large firms and the public sector. Further it is interesting to note that, somewhat contrary to common understanding, it is the public universities (funded with more than 90% from public sources) that cater to the needs of the largest private companies whereas the research institutes in relative terms cater more for the small and medium sized firms, and, indirectly, sustain public sector innovation in interesting ways.

What are the main policy conclusions that one can draw from this analysis? Apart from the obvious – the need for the state to secure diversity among the R&D performers – the most important conclusion might be to uphold diversity also among funding opportunities. In most European countries public R&D expenditure is divided between university and institute sectors according to some historically given formula that usually changes only slowly. In some cases, like Germany, the division in public funding between institutes in the Max Planck (basic-oriented research), the Fraunhofer (applied research in close ties with industry), the Helmholtz (research with a holistic approach within fields such as environment, energy and health) and the Leibniz (research in cooperation with universities within humanities, social sciences, life sciences, etc.) Societies on the one hand, and the Universitäten/Hochshulen on the other, is almost equal with additional funding coming from research funding agencies (Bundesministerium für Bildung und Forschung 2008). In China universities receive only a fraction of public R&D spending, while a considerable share is directed to the large number of more or less sectoral and strictly mission-oriented public research institutes (Liu and White 2001). China in this respect has repeated a structure that has been common in Eastern European countries and the Soviet Union, with more research being performed in academies and institutes and less in universities (Chang and Shih 2004). In other countries the share of public funding directed to universities is much larger, in the extreme Swedish case it is a mere 3-4% of public R&D funding that is devoted to industrial institutes. In the US roughly one third of federal funding is directed towards university research and about the same share goes to federal laboratories and special institutes. Direct funding to firms that perform R&D is also a major feature of the US system and has been since WWII. However, the large share of private funding in the US system (Eliasson 2004) and the sheer size of the system, make comparisons with other countries difficult. Some useful comparisons are however made at the sector level (Owen-Smith et al. 2002) and for technology transfer offices (TTOs) in Europe and the US (Gaulé and Conti 2009).

Obviously there are many ways to organize innovation in a national system and each system has advantages and drawbacks. Evaluating innovation systems in a comparative fashion is difficult, innovation is not an easily quantifiable category and it is affected by many more factors than R&D. However, a common trend among policies in this field can be observed, namely a shift towards greater diversity, flexibility and multiple functions in R&D and innovation with multiple performer categories and multiple funding sources at the core. We identify this as a key aspect to study as we go further, with important questions concerning for example the roles, collaborations and interdependencies between various types of actors in innovation systems.

The cases discussed in the paper also bring attention to the longstanding discussion among policymakers and scholars of science, technology and innovation about knowledge transfer and innovation coined in terms of appropriability of public knowledge. This is another key task for future studies of public innovation: to further analyze mechanisms of knowledge transfer in public–private collaborative R&D, facing both increased international collaboration and more entangled relations between research performers in public and private spheres of innovation. Another future challenge lies in further studying technological niches and the extent of hybrid modes of operandi for public science performed at institutes and universities characterized by appropriability of science in some areas but not in others.

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