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The third sector of R&D: literature review, basic analysis, and research agenda

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ABSTRACT

The third sector of national innovation systems comprises non-academic, publicly owned R&D organizations that complement universities and private-sector firms and are normally called 'research institutes'. Scholarly attention to these organizations has been scarce, partly a consequence of the theoretical imbalance in favor of conceptualizations of innovation processes as requiring mainly universities, private-sector firms, and governmental authorities to occur and succeed. Similarly, while this third sector often makes up a significant share of national innovation systems, it receives less attention in national research and innovation policy than do, say, universities. This paper argues that the role(s) and function(s) of third sector research institutes deserve to be mapped and analyzed in greater detail in order to understand how various organizational actors interact to produce innovation. From a comprehensive literature review and basic analysis of three institute groups in three Nordic countries, the paper makes a first preliminary analysis of the topic. While this analysis yields some interesting conclusions, its main function is to point the way for future studies. In these, other actors in the system should be investigated in thorough empirical studies, armed with tools from classic sociological systems theory that enhance the conceptual strength of the innovation systems framework and enable the acknowledgement of the role(s) and function(s) of several important organizational actors, not least research institutes.

Introduction

'Research institutes' is a common name for the many non-academic, partly publicly funded R&D organizations that make up a major third performing sector of national innovation systems besides academia and private firms But there is still a remarkable shortfall of scholarly work devoted to the history, organization, and politics of research institutes compared with analyses of the role of universities and private-sector firms in innovation systems. This is also part of the reason for the lack of a common definition or understanding of what research institutes are and how they distinguish themselves in national and international innovation systems.

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This paper takes an important first step towards filling this knowledge deficit. It provides a review and analysis of some very basic features of institutes and points the way, conceptually and empirically, to future studies. First, previous scholarly work is reviewed to achieve a synthesized understanding of research institutes on a basic level, including their political rationale, their demonstrated roles and functions, and their organizational fundamentals. This includes some historical and sociological contextualization of the emergence and evolution of research institutes. Second, some very rudimentary information available in the 2015 annual reports of three institute groups in three Nordic countries is used in a basic analysis of the role(s) of institutes in national and international innovation systems. Though some conclusions are drawn from both the literature review and the data on these three institutes, the analysis is most of all used to point out the need to fill major gaps in the knowledge of the roles and functions of institutes in national innovation systems vis-à-vis universities, private-sector firms, and the expectations and demands of governments and the wider society they represent. The main conclusion of the analytical section of the paper is, not surprisingly, that more attention should be paid to the third sector of national R&D. The literature review and analysis open up the area by taking some crucial first steps, empirically and conceptually, in this direction. The concluding section points the way to such research efforts by arguing that they would benefit from an *ex ante* discarding of some popular concepts in current innovation studies, including excessive expectations of the role of universities. These concepts might be replaced by a theoretical framework inspired by systems theory and its predecessor frameworks in sociological theory, which can be of help in the study of differentiated functions and the role of actors and organizations in innovation systems.

The next section provides a literature review and gives an orientation of the topic in history, sociology, and innovation studies. This is followed by a basic analysis of three institute groups, made against the background of the literature review and with the intention of making a very rudimentary identification of the role of research institutes. They appear to respond to a range of demands from innovation systems. The paper concludes with a discussion of empirical and theoretical implications, and points the way to much needed research.

Literature review

The topic of this paper, as reflected in its title, is the 'third sector' of (national) R&D. This means a sector of organizations that undertake research and development but are not part of either the academic or the private sector. Such an indirect definition is intentional and reflects the starting point for the analysis, namely that relatively little is known about research institutes, what they are, and what they do. Crow and Bozeman (1998, p.5), who have undertaken one of the most comprehensive investigations of extra-university public R&D organizations, claim that the sector is 'among the most diverse sets of organizations one will ever find.' There are several types of technology-specific and industry-specific research institutes in many countries, and institutes with general and broad missions that span several industries and types of tasks. Some are public and funded by governments in full or in part; some are entirely private; whereas others are private and partly funded by governments. Probably most common are those institutes oriented to technology and engineering sciences, but in some countries there are also institutes that conduct research

in economics, social sciences, and the humanities. This organizational variety is, however, small compared with the apparent variety in the missions of institutes and the activities that take place within institutes. Authors have described a very wide spectrum, from basic or curiosity-driven research to consultancy work for industrial firms, via applied research, technology transfer, implementation support, tracking and adaptation of technology, various forms of technology or management problem-solving, technology demonstration and advice, testing and certification, and also education (Tether and Tajar, 2008; Nerdrum and Gulbrandsen, 2009; Gulbrandsen, 2011; Sharif and Baark, 2011).

Some, but not all, of the confusion around what the third sector of R&D really comprises stems from the lack of scholarly work on the topic, as noted by several authors (Rush and Hobday, 1996; Crow and Bozeman, 1998; Modrego-Rico *et al.*, 2005; Barge-Gil and Modrego, 2011; Berger and Hofer, 2011; Gulbrandsen, 2011; Sharif and Baark, 2011). Studies of research institutes certainly exist, as the literature review in this section testifies, but they are dwarfed by the body of literature devoted to universities and firms, and their roles and functions in innovation systems. The founding fathers of the innovation systems tradition mention research institutes as potentially important actors in systemic innovation processes in contemporary society (e.g. Lundvall, 1992; Nelson, 1993; Edquist, 1997), but later key works are mostly geared to studying universities and firms, and the relationships between them (Fagerberg *et al.*, 2005; Edquist and Hommen, 2008; Lundvall *et al.*, 2009; Fagerberg *et al.*, 2013). Also, varieties of innovation systems approaches developed to identify specific actors and their functions for the system and its subsystems show a remarkable neglect of the third sector. While usually mentioning research institutes among the important actors in an innovation system, this strand of literature leaves their roles and functions largely unanalyzed (e.g. Hekkert *et al.*, 2007; Bergek *et al.*, 2008; Markard and Truffer, 2008; Bleda and del Río, 2013; Nilsson and Moodysson, 2015).

The shortfall is also reflected in the near-hegemonic role of universities and private-sector firms in innovation policy, where focus is on 'technology transfer' and the promotion of industrial clusters around universities. The popularity that conceptual frameworks such as the 'Triple Helix of university–industry–government relations' (Etzkowitz and Leydesdorff, 1997) and the 'entrepreneurial university' (Etzkowitz, 1983; Clark, 1998) have won in policy circles has likely contributed to this bias. They promote a view of R&D and innovation systems as requiring only the state, the private sector, and universities. Universities are portrayed as encompassing a very wide range of activities, including various innovation processes and strategic problem-solving for the benefit of the economy and society. The lack of practical and precise definitions and commonly accepted terms for third-sector R&D performers can partly be attributed to this scholarly and political imbalance.

But the use of the term 'third sector' R&D organizations in this paper also has a historical motivation. The first research institutes of the type relevant here were founded in Germany at the end of the nineteenth century, created more because of the limitations of German universities than because of the limitations of R&D in the private sector (Cahan, 1989; Johnson, 1990). The concept of 'market failure' beloved by economists in the mid-twentieth century (Nelson, 1959; Arrow, 1962), namely the identification of an inability of the private sector to sufficiently fund and organize the R&D it needs for long-term competitiveness, is mostly *post hoc* justification for the role of governments in organizing and funding R&D. The market failure concept was preceded in the nineteenth century by what might be called

'academic failure', although it was not so articulated and not discussed in these particular terms.

The first German institutes had heterogeneous sets of missions that can be summarized as undertaking R&D work and assisting in the R&D work of others for the benefit of industrial interests and, in broader perspective, long-term economic development (Cahan, 1989, pp. 5–6). These organizations became new players within emerging systems, with a hybrid or intermediary role. They were to bypass 'institutions moving too slowly for the times' (i.e. universities) 'without impairing the quality of the science' (Johnson, 1990, p.5). Rather, they were to improve the quality of the science by establishing a 'close connection with actual or potential technological applications' (Johnson, 1990, p.5). Their importance grew swiftly. On the eve of World War I, Germany had a domestic R&D system with three distinct sectors –universities, institutes, and industry – and significant mobility of both professionals and funding within and among them. There were joint appointments and collaborative projects and programs across the sector boundaries as well as industrial funding for university research (Hounshell, 1996, p. 20). Thirty years and two world wars later, as the Federal Republic of Germany began its process of reconstruction, institutes became a vital part of its national R&D system. The Max Planck Society and the Fraunhofer Society, oriented to basic and applied research respectively, soon grew to become international role models (Meyer-Krahmer, 1990, pp.49–53; Beise and Stahl, 1999, p. 403), and they were complemented by several 'collective research institutes', fully organized and run by consortia of industrial companies. This latter type of research institute had appeared in several other European countries in the 1930s and '40s, oriented towards R&D for specific industrial sectors, sometimes with a governmental base grant, and in close collaboration with universities and polytechnics. The differences between collective research institutes (defined by a scientific or technological area) and the increasingly common governmental institutes (oriented to such activities as testing and verification or such societal services as geological surveys, weather forecasting, and energy R&D) were not always clear; all were part of a third sector of R&D in their respective countries at this time (Gulbrandsen, 2011, p. 218).

Like many private-sector firms, and most academic organizations, third-sector R&D organizations have survived the cycles of research policy and the periods of war and peace, growth and stagnation in Europe, in part because large and complex publicly funded organizations in possession of significant material and technological resources have a built-in resilience and ability to renew themselves as political and economic conditions change (Crow and Bozeman, 1998; Hallonsten and Heinze, 2012, 2016). A certain upswing was seen in the first decades after World War II, when government R&D expenditures soared because of renewed interest in science and technology as a source of social and economic (and military) development, and governments rode the wave of spectacular postwar economic growth (Smith, 1990; Tindemans, 2009). A long-term effect of this dramatic increase in public spending on R&D was, however, that companies became increasingly reluctant to invest in their own R&D, since their governments did much of this for them (Hounshell, 1996, pp. 48–9). When the economic downturn hit Europe in the 1970s and growth in public R&D spending leveled out (Hallonsten, 2016, pp. 45, 49), there was a loss of confidence in the power of basic research among industrial leaders, who realized that few or no blockbuster products had actually emerged from in-house fundamental research programs, and consequently cut down further on these (Yusuf, 2007, pp. 5–6).

In the long run, the global trend of downsizing and outsourcing corporate R&D, paired with globalization, created not only a growing potential for research institutes to play a greater role in national and international innovation systems, but also a growing market for consultancy firms and a gradual expansion of the missions of universities and the demand that they would have a provable impact and engage in directly relevant R&D activities, or even become 'entrepreneurial' (Etzkowitz, 1983; Clark, 1998). A broader redirection of research policy in (Western) Europe and North America was evident from the 1970s, with some national varieties but a number of general patterns. These included new demands for social and economic relevance, deregulation of careers and governance structures, a relative increase in competitive funding, and the introduction of more and more forms of performance appraisal and accountability (Radder, 2010; Berman, 2012). In several countries, research institutes that found themselves in the midst of these developments seem to have reacted by expanding their sets of activities, forging new strategic alliances with both industry and academia, and providing a broader range of services (Rush, 1996; Boden *et al.*, 2004; Preissl, 2006). The overall trend seems to have been an increased pressure to take part in, and drive, commercialization of research, and to internationalize (Sharif and Baark, 2011, p.2). A general trend of political reform of institutes has also been visible in the past two or three decades, whereby a series of reorganizations, mergers and privatizations has separated institutes from their original founders (and funders) and created new institute groups with broader mandates, international outreach, and – not least – a new comprehensive focus on sustainability and sustainable transitions in society (Larédo and Mustar, 2004; Loikkanen *et al.*, 2011; Cuhls *et al.*, 2012). The three institute groups analyzed in the next section (in Finland, Norway, and Sweden) have been shaped by mergers and transformations that have dramatically expanded both their roles and the scientific and technological areas they cover. In these three countries, the organizational heterogeneity of the third sector has apparently decreased by the merger of several smaller and industry-specific institutes into larger, consolidated institute groups. But the heterogeneity or complexity of the activities undertaken and services provided by these institute groups has actually increased with the growing complexity of innovation processes, the internationalization of markets, and the expanding breadth of expectations and demands on publicly funded R&D organizations (Larédo and Mustar, 2001; Loikkanen *et al.*, 2011).

Recent literature suggests there is a role (or a set of roles) for institutes to play in innovation systems. In summary, it is that institutes should provide a set of specialized services that the private sector and many organizations in the public sector need but for which they have little or no in-house capacity. Institutes can provide these services through an institutionalized understanding of the preconditions for industrial research that no other actor in the system has, an understanding with solid anchoring in longer-term research and technology development and maintenance in-house, and in the academic environments within which they collaborate intensely in both research and advanced education (Arnold *et al.*, 1998; Sharif and Baark, 2011). Institutes are supposedly capable of adapting and refocusing in response to the changing needs of both single firms and whole industries, which is different from the classic academic organization (before universities became 'entrepreneurial'), whose role is rather to remain stable and reliable repositories (and, surely, developers) of knowledge for the wider benefit of society (Rush, 1996, p.88). Institutes have a different role, an 'intermediary' role, which has been identified as increasingly important due to the

growing complexity and internationalization of innovation systems (Bessant and Rush, 1995; Modrego-Rico *et al.*, 2005; Howells, 2006; Tether and Tajar, 2008).

Although the lion's share of knowledge production in society continues to take place in an academic setting, there is a growing role for intermediaries in translating and carrying over knowledge to industry, providing firms with the knowledge and technology they need but are not capable of maintaining in-house (Beise and Stahl, 1999, p.409; Tether and Tajar, 2008, p.1092). As intermediaries, institutes can build resilient and reliable connections and collaborations with both universities and firms (Gulbrandsen *et al.*, 2015, p.365), making use of a conceivably shorter 'organizational distance' (Boschma, 2005) and 'cognitive distance' (Noteboom, 2000) to both. The intermediary role is sustained and continuously revitalized by the maintenance of an (academic) research culture, in-house or nearby. This enables institutes to build and maintain competences and tacit knowledge as well as infrastructures and other technological and intellectual resources. These they combine with a customer orientation that gives relevance to their work (Harding, 2002). Institutes remain relevant for their customers by providing in-house capacity in R&D, funded by project grants and a governmental base grant (or similar) (Rush, 1996). In other words, institutes respond to certain demands in the innovation systems that are not as clear-cut as the demands that sustain academia (research, education) or the private sector (products, services), but are instead combinations or amalgamations of different demands.

Basic analysis

Three institute groups – in Finland, Norway, and Sweden, respectively – were chosen because of their expected similarity. While national innovation systems can differ a lot in their political and institutional setups, Finland, Norway, and Sweden are neighbor countries of comparable size and with similar historical/cultural context. The three institute groups were also of comparable size in the year studied (2015) (see Tables 1 and 2) and dominated the third sectors of their respective countries. All three have emerged from various governmental agencies and institute organizations and have evolved into their present form (through governmental policy-making/reform and organizational decision-making) in the past few decades. They are umbrella organizations for a wide range of activities (including research, testing and verification, project management and coordination, SME services, and so on) and have broad mission statements that show their aims are to be important actors in their respective national innovation systems. The aims of the SP Technical Research Institute of Sweden (henceforth SP[1]) are to be an 'internationally leading innovation partner',

Table 1. Basic information on the three cases.

		Number of employees (2015)	Number of journal publications (2015)	Originally founded as
SP	Sweden	1,367	241	Government testing and verification authority (1920)
SINTEF	Norway	1,793	965	Applications-oriented branch of the Norwegian University of Science and Technology (1950)
VTT	Finland	2,470	614	Defense R&D and testing authority/institute (1942)

Source: 2015 annual reports of the three institute groups.

Table 2 Main revenue streams of three institute groups (euro '000s)

	SP	SINTEF	VTT
Governmental base grant	29,693	23,154	85,384
Competitive funding, domestic public sector	23,429	82,694	34,985
Private sector	114,169	165,388	43,732
… of which domestic	n/a	n/a	31,098
… of which international	n/a	n/a	12,634
International non-commercial funding	n/a	52,924	18,464
… of which EU	8,059	20,111	n/a
Other	1,536	6,616	1,973
Total	176,887	330,777	184,538

Note: Exchange rates used for SP and SINTEF are from 30 December 2015, retrieved from the Swedish Central Bank (www.riksbank.se): 1 euro = 9.135 SEK = 9.559 NOK.
Source: 2015 annual reports of the three institute groups.

[2] 'creating value and sustainable development for enterprise and society through contributions of competence and utility in the whole innovation process.'[3] SINTEF in Norway aims to 'develop society through mission-oriented research and innovation' and to be 'a world-leading research institute.' The VTT Technical Research Centre of Finland (henceforth VTT) 'produces research services that enhance the international competitiveness of companies, society and other customers at the most important stages of their innovation process, and thereby creates the prerequisites for growth, employment and well-being.' The analyses below concern whole-institute groups, including subsidiaries, as noted in the annual reports from which data have been retrieved.

SP was formed in 1920 and remained essentially a testing and verification authority until the 1990s, when it was transformed into a government-owned company and its functions and services were broadened. In the early 2000s, SP absorbed several industry-specific research institutes (such as the Swedish Institute for Conservation Research and the Surface Chemistry Institute), and in 2007 was renamed the SP Technical Research Institute of Sweden. The third sector of R&D has never been big in Sweden, standing in the shadow of the universities and the major industrial manufacturing companies, which, together, have always accounted for over 90% of the national spending on R&D (Granberg and Jacobsson, 2006). From the 1980s, major downscaling (in relative terms) reduced the institute sector from a small but fairly healthy position to one of uncertainty. In the 1990s, efforts were made to streamline the sector and turn industry-specific institutes into companies under a government-owned holding company. Since 2007, a restructuring process has been underway whereby several institutes have merged and the scope of SP has broadened significantly; it is now the major player in the third sector (Bienkowska *et al.*, 2010). In 2015, SP had nine divisions (Calibration and Verification; Certification; Chemistry, Materials and Surfaces; Electronics; Energy and Bioeconomy; Food and Bioscience; Measurement Technology; Sustainable Built Environment; and Safety) and 10 subsidiaries, of which one was based in Denmark and one in Norway, co-owned with SINTEF. SP had activities at several places in Sweden, with the main campus and facilities located in Borås, some 100 km east of Gothenburg.

In Norway, SINTEF was created in 1950 as a way to bring research at the Norwegian University of Science and Technology in Trondheim (*Norges Teknisk-Naturvitenskapelige Universitet*, NTNU) closer to the market (Nerdrum and Gulbrandsen, 2009, pp.77–8). The original meaning of the acronym SINTEF was *Selskapet for Industriell og Teknisk Forskning*,

meaning the Association for Industrial and Technical Research. Its status as a branch of the NTNU was abolished in a restructuration process that began in the 1980s and established the institute group as a standalone organization (a government-owned company) and let it absorb several smaller, industry-specific institutes founded in the nineteenth century. SINTEF is now the most visible and well-known institute in Norway, and a major player in Norwegian R&D (Nerdrum and Gulbrandsen, 2009). SINTEF has activities at many sites in Norway, but with some concentration in Oslo and Trondheim, where the head office is located. In its annual report for 2015, SINTEF identified five strategic areas (renewable energy; climate and environment technology; oil and gas; ocean space technology; health, welfare, and enabling technologies, including ICT, advanced materials, and biotechnology). Although it comprises a broad collection of smaller institutes and divisions, there is an articulated strategy within SINTEF that the institute group should perform as a whole and mobilize competences and capacity across the whole SINTEF organization to the benefit of customers and identified strategic areas.

In Finland, the VTT was created during World War II as a military R&D and testing/certification organization with an increasingly close relationship to the Helsinki University of Technology and joint appointment of professors and common laboratory equipment as the breadth of the VTT activities grew. By the 1980s, it had over 2,000 employees and activities in three main areas (building technology and community development; materials and process technology; electrical and atomic energy). A major restructuring process streamlined the organization in 1993, and in 2006 yet another reorganization transformed VTT into its current shape (Loikkanen *et al.*, 2011, p.84). The institute group has several locations around the country, usually in close proximity to universities, polytechnics and other research centers. It is very broad in its activities and aims, maintaining in-house knowledge and competence in order to fulfill four key functions, namely strategic research, business solutions, ventures, and expert services.

Basic data on the revenue streams of the three institute groups, gathered from their annual reports for 2015, are presented in Table 2. The three groups are of varying but comparable size, and each has three basic sources of income: a government base grant; competitive programs in the public sector, domestically and internationally; and revenue from the provision of services to private-sector firms. Interestingly, the distribution of funding in these categories varies quite a lot in the three cases. Figure 1 illustrates the three cases after the numbers in Table 1 have been grouped together in four categories.

Conceptually speaking, these three revenue streams correspond to different missions or different parts of the missions of the institutes, as identified against the background of the literature review presented earlier. Research institutes, just like universities and firms, exist and fill certain roles in innovation systems because there is a demand for them. First, the direct procurement of services from the institutes by firms indicates the *industrial relevance* of the activities of the institutes, which corresponds to their ability to compensate for what was called 'academic failure' in a previous section, namely the inability of university R&D to respond to the needs of industry. Put differently, if firms did not value the services provided by the institutes, and were not prepared to pay for them, this revenue stream would not exist. The attraction of grants, in the category 'Competitive funding, public sector', signals *scientific and/or strategic relevance* since such competitive funding is normally allocated through case-by-case evaluation of scientific quality, feasibility, and competence of the applicant(s), and/or evaluation of capability to respond to specific demands of a call. In this

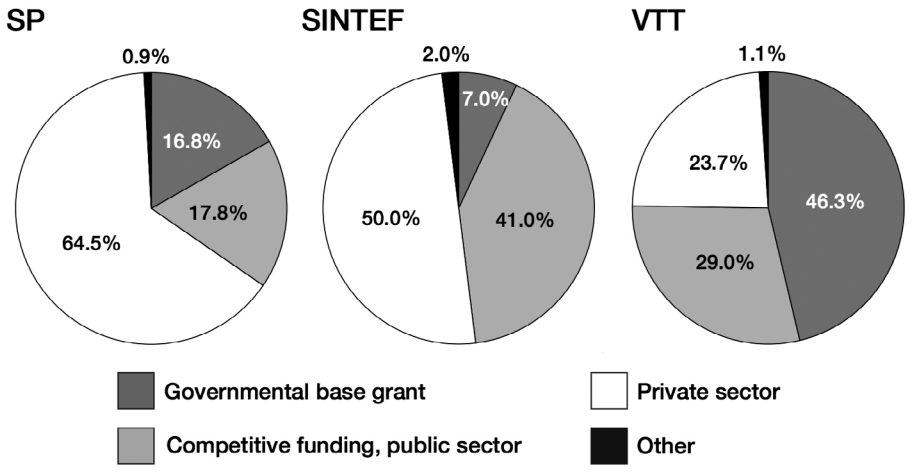

Figure 1. Graphical illustration of the distribution of revenue.
Note: The dark grey slice, the white slice, and the black slice, representing the categories 'Governmental base grant', 'Private sector', and 'Other', are identical to the first, third, and eighth rows of Table 2. The light grey slice, representing the category 'Competitive funding, public sector', is a merger of the second, sixth and seventh rows of Table 2, which means that it also contains EU funding and other 'International non-commercial funding'.

category, institutes compete directly with university research groups for funding. Finally, the base grant from the government signals *political relevance*. In part, this corresponds to market failure in that the government has taken responsibility for R&D activities deemed necessary for the longer-term competitiveness of the economy, but which the private sector has no capacity to fund and organize itself.

All three cases stand out in their own way. SP has a very high share of funding from the private sector (from selling its services in the market). One explanation for this can be found in the history of the institutes now under the SP umbrella. These have received insufficient government funding and have been neglected in government research policy for a long time. This has made them less competitive than universities in acquiring public sector funding (Benner, 2001; Pettersson, 2012). SP's comparably low share of base grant and competitive public sector funding should, logically, correlate with lower scientific performance than, say, VTT, whose base grant is significantly larger. The number of publications (see Table 1), confirms this: SP published a mere 0.17 publications per employee in 2015, compared with SINTEF's 0.54 and VTT's 0.25. Confirming a high share of revenue from the private sector is SP's boasts that it had over 10,000 customers in 2015 (no exact figure is given), dramatically more than the 3,792 customers of SINTEF and 1,490 customers of VTT in the same year.

What stands out in the case of SINTEF is its very large share of competitive public-sector funding. The possible historical explanations for this include the fact that SINTEF has an academic (or semi-academic) background as a branch division of the Norwegian University of Science and Technology (NTNU) and that close collaboration is still maintained between the institute and the university. The number of publications (journal papers, peer reviewed) from SINTEF is double that of VTT when adjusted for size, which is yet another sign of the scientific strength of SINTEF, which correlates with the high share of competitive public-sector funding. VTT is distinguished by its very large government base grant – in real terms, almost three times that of SP and over three times that of SINTEF – comprising close

to half of VTT income in 2015. This can be explained by VTT having a stronger position in Finnish research and innovation policy than SP and SINTEF have in their national systems. But it may also be a sign that VTT is in greater need of state support because of its problems attracting grants and selling services to the private sector. These inferences are, of course, highly speculative, but a deeper study of the role of VTT in the Finnish innovation system could make use of such observations as natural starting points for formulating research questions. The analysis here is limited in its scope but provides some keys to conducting deeper and broader studies on the topic.

The share of international private- and public-sector funding in the total revenue of research institutes could be taken as an indicator of how well an institute has opened up to international markets and adapted to globalization. Secondary sources suggest that few institutes have much international funding at all, and hence limited presence outside the borders of their home country (Berger and Hofer, 2011). National government subsidies and focusing activities on home markets are blamed (Loikkanen *et al.*, 2011, p.79) and EU funding programs have been identified as a possible vehicle for the internationalization of institute activities (Sharif and Baark, 2011, p.3). SP does not distinguish between domestic and foreign customers in its annual report, thus how much is international capital of almost two-thirds of the total revenue of the SP group is unknown. EU funding was a mere 4.5% of total revenue in 2015, although SP partook in 121 EU-funded projects in 2015 (14 as coordinator). SINTEF has a similar share of EU funding (6%), but another 10% of its revenue comes from international assignments that are not EU projects. Although, like SP, not distinguishing between domestic and foreign customers in reporting revenue from the private sector, SINTEF has customers in 54 countries, which says something about the degree of internationalization of its activities. VTT, for its part, is clear in its annual report that 28.9% of its revenue from the private sector comes from abroad (which means 6.8% of total revenue), and that another 10% comes from international, non-commercial, sources. The significance of such statistics depends largely on context and perspective. Investigation in deeper studies with more detail is required.

But the key message of the numbers in Table 2 and their graphical representation in Figure 1 is another one, namely that there is a clear *demand* – or, rather, *different demands* – for a third sector of R&D in all three countries. To reiterate, the 'private sector' revenue stream means that there is a demand in the private sector for the services that these institutes provide (industrial relevance); the 'competitive funding, public sector' revenue stream means that the institutes are competitive in attracting third-party funding for R&D projects (scientific/strategic relevance); and the 'governmental base grant' means that the state sees a certain value in these activities and is willing to support them with substantial funding (political relevance). There may, of course, be an element of historical lock-in with the state unwilling to discontinue funding for an activity and an organization with over 2,000 employees. Most important, however, is the conclusion that all three institute groups apparently satisfy all three demands simultaneously (albeit with significant variations, as seen in the data). This means that there is an overall demand in innovation systems for organizations that combine activities that are industrially, scientifically/strategically, and politically relevant. This is as close as the analysis in this section comes to identifying and conceptualizing a role for research institutes in innovation systems. Further research efforts are needed, but these must be appropriately equipped with theoretical insights and conceptual tools.

Research agenda

While the analysis in the last section contributes only very rudimentarily to a better understanding of the role of the third sector of R&D in innovation systems, it points the way to studies that can contribute substantially to such an understanding. The proven similarities and dissimilarities between the three institute groups analyzed can be used as a blueprint for future studies. A natural starting point for the study of institutes is asking why these three show such different features. Qualitative research and detailed quantitative analyses are needed to investigate the differences and how big they really are in practice.

A set of activities typically takes place in institute settings: R&D and engineering projects, partly in collaboration with private-sector firms and/or academic researchers; gathering of business and technology intelligence; technology and management problem-solving; technology demonstration and advice; and testing and certification. But role(s) and function(s) are defined in relation to other actors and their roles, and in relation to other functions and how several different functions together form a system with an overall function. In addition, institutes are supposed to respond to market failure and academic failure; a base grant allows competence building, and a continuous orientation to the needs of the private sector. As intermediary organizations, institutes supposedly provide stable but dynamic links between academia and industry by maintaining close organizational and cognitive distances to both. These features are fairly straightforward to study, illustrate, and evaluate in empirical research, but, for them to be understood as roles and functions in an innovation system, they need to be understood theoretically. In other words, the obstacles to a better, deeper, and more nuanced understanding of the role(s) and function(s) of the organizational actors in the third sector of R&D lie not on the side of what is empirically possible, useful, or warranted. Instead, the challenges are on the theoretical level.

The systems approach to innovation, since its launch in the 1980s and journey through the academic disciplines of economics, geography, political science, and sociology, has not been sufficiently equipped with conceptual frames and tools to be useful as a theory. The innovation systems paradigm has become an instrument of ideology (Eklund, 2007; Sharif, 2010; Widmalm, 2012). Despite its original formulation of innovation as involving a multitude of actors, organizations, institutions, and processes that develop, diffuse, and use innovations in dynamic constellations (Lundvall, 1992; Nelson, 1993; Edquist, 1997), the systems approach has often been combined with one-sided perspectives on innovation that downplay actors other than universities and private-sector firms, and neglect processes other than technology transfer and commercialization. The skew has arisen by default rather than design, although some authors actively promote one-sided views. The concepts of the entrepreneurial university (Etzkowitz, 1983; Clark, 1998) and the Triple Helix of university–industry–government interactions (Etzkowitz and Leydesdorff, 1997) both perpetuate a view of universities as the only natural producers and diffusers of knowledge and technology, at least in the public sector, and advocate that the mission of universities be expanded far beyond providing high-quality education and conducting basic research. There is much to suggest that such an expansion of the role and mission of universities severely compromises and damages the academic culture and (self-)organization of universities. This is to educate skilled labor, and to maintain and develop the intellectual base vital for democracy (Garnsey, 2007, pp.228–36; Münch 2014, pp.38*ff*.). If universities were to become fully entrepreneurial, there would be no need for institutes. A variety of actors,

fulfilling different roles and functions, is necessary for the innovation system to function. This needs to be acknowledged with the help of empirical studies that are guided by theory which does not perpetuate bias.

A possible remedy for the neglect of institutes in innovation studies, one that can also make a theoretical contribution, is to use the systems approach to innovation to identify actors, organizations, and activities that are functionally differentiated and specialized. This would mean highlighting the third sector of R&D by studying the role(s) and function(s) of its organizations in relation to other organizations and their role(s) and function(s), including (but not limited to) the academic and private sectors. Thus the systems approach can be put to work in studies that take into account the various elements of systems and how these interact in various processes that produce innovation. The study of society and its various parts with a systems view has a long tradition in social science going back to early notions of division of labor as essential for efficient resource utilization and productivity (e.g. Smith, 1776/2012; Durkheim, 1893/1997). Systems theorists in sociology have pointed to specialization and differentiation of different functions as crucial for society's organization and development (Parsons and Smelser, 1956/2010; Luhmann, 1995). Innovation systems scholars have neglected this rich conceptual toolbox and the possibilities it offers for identifying and analyzing different roles and functions in innovation systems.

Previous investigations have contributed many important insights into the activities that takes place in the third sector, but none has provided a comprehensive view, theoretically and empirically well informed, of how these relate to other important actors (universities, private-sector firms, funding agencies, state authorities, and such supranational bodies as the European Union); of how they contribute specifically to innovation in certain contexts, sectors, and industries; and of how institutes are organized and work in order to fulfill these roles and functions. There is a clear role for research institutes, namely to provide services to industry. This is clear from their long-term competence building, but mostly from what industry requests. But little more than this is clear. In demonstrating the shortcomings of quantitative (and shallow) source material, this paper's analysis emphasizes the need for further empirical studies.

The concept of functional specialization and differentiation is key to an understanding of innovation systems that go beyond ideology and the quick-fix solution of expanding the role of universities. The concept highlights the importance of other actors with other functions and roles that stem from other institutional and organizational bases and capacities. Empirical studies should be directed at processes that involve several actors, including research institutes, private-sector firms, and academic research environments, in order to investigate how their interactions are shaped and what their respective contributions to innovation processes are.

The analysis in this paper reveals that institutes are relevant and competitive as providers of services to customers, for which customers are willing to pay; as R&D performers that can answer the calls of funding agencies for strategically important research; and as part of a government-organized and government-funded R&D system. In other words, the question is not whether the institutes of the third sector of national R&D systems have a role to play in innovation systems. They do. The question is what this role is and how it differs from the role of other actors. The task that lies ahead is to investigate this matter by careful inquiry into how institutes interact with their customers, with their partners, with their funders, and with the government.

Notes

1. SP ceased to be its acronym in 2007, but remained in the name for purposes of recognition, and originally stood for *Statens Provningsanstalt* (Swedish Government Testing and Certification Institute).
2. Institutional quotes are from the respective organizations' annual reports for 2015.
3. Since our analysis, SP has merged with two other Swedish institute groups, Innventia and Swedish ICT, to form RISE (Research Institutes of Sweden), whose stated aims are similar.

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