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The co-evolution of research institutes with universities and user needs: a historical perspective

Magnus Gulbrandsen

Centre for Technology, Innovation and Culture, University of Oslo

magnus.gulbrandsen@tik.uio.no

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Abstract

Many countries have a sector of research institutes that have been set up to promote industrial growth and help with users' problem solving. Not formally part of the higher education sector, research institutes are significantly less understood and studied than universities. This paper analyses the co-evolution of institutes and industry and the co-evolution of institutes and universities in Norway, using the framework of Whitley (2002, 2003). It is shown that there seems to be a dominant collaborative approach to developing innovative competences in Norway to which the institutes have had to adapt. Long traditions for external R&D collaboration in Norwegian industry and a structure of small low-tech firms have led to the establishment of a set of industry-specific institutes, a development reinforced by periods of isolation from industry perspectives at the universities. Alternative approaches to developing innovative competences have largely failed. Despite a low level of reputational competition in the public science system, research institutes have nevertheless contributed to increasing the level of intellectual pluralism and flexibility, creating opportunities for combinations of academic work and applied problem-solving. With weaker policy coordination and convergence in the funding criteria for all public science, there may be a risk that research in this system becomes more fragmented and isolated.

Introduction

This paper investigates the development of research institutes using examples and data from Norway. In many countries, research institutes have come under pressure, resulting in reorientations, mergers, privatisations and other changes (Larédo & Mustar 2001). I argue that the problems and challenges of the research institutes may be better understood by a historical perspective on the origins, types and growth of these organisations. Two questions are asked: what are the characteristics of the co-evolution of institutes with users and customers, and what are the characteristics of the co-evolution of institutes and higher education institutions? The main emphasis is on technological research institutes and users in industry.

Research institutes are organisations which are involved in research and development (R&D) activities. Ownership and financial structure varies between types of institutes and between countries, and the paper investigates organisations that can be defined as part of public sector research but not part of the higher education sector. Institutes may be public organisations or private non-profit, they may be oriented only at R&D or at R&D in combination with other services, they may be partly or wholly publicly funded, and they normally – at least to some extent – carry out contract R&D and services oriented at users in various parts of society like private firms and public agencies. These organisations are significantly less studied than universities. Whereas there are now hundreds, if not thousands, of scientific articles exploring various aspects of university-industry relations and changes to the universities, there are only a handful of similar investigations of research institutes (examples are Crow & Bozeman 1998; Larédo & Mustar 2001; and Beise & Stahl 1999). This paper thus aims to fill a gap in the literature on public science systems.

Public research organisations and their linkages to firms are seen as important to innovation and economic growth (e.g. Lundvall 1992; Nelson 1993; Edquist 1997). Ideas, people and artefacts are shared, exchanged and purchased in networks between different types of organisations where market demands and investments in science and technology meet (e.g. Peters et al. 1998). Most of the literature concerns aspects of university-industry relations like commercialisation, patenting and licensing, although these may not be the most important channels of interaction (see Mowery & Sampat 2005). The lack of investigation of research institutes probably has several reasons, e.g. that these organisations are less well covered in statistical databases and that public research is not an extremely important contributor to most

types of industrial innovation (see Laursen & Salter 2004; Tether & Tajar 2008). Definitions of what a “research institute” is vary between countries and between databases. Organisations that are defined as public research institutes in Norwegian national R&D statistics are, for example, defined as “private” in the OECD international statistics. In addition, the institutes and their activities may challenge simple yet widely applied dichotomies of knowledge as being either “public” (non-appropriable, result of basic research etc.) or “private” (appropriable, result of industrial R&D). Some of the popular conceptual influences on contemporary science and innovation policies like the “Triple Helix” framework (Etzkowitz & Leydesdorff 2000) and the “Mode 2 knowledge production” assertions (Gibbons et al. 1994) do not discuss research institutes at all, and they are rarely visible in various systems of innovation perspectives (see Edquist 2005).

In two articles, Whitley (2002, 2003) has set up a framework for analysing the development of public sector research. In the first, it is elaborated how public research organisations and the innovation strategies of private firms co-evolve to form different patterns in different countries. Various characteristics of public sector research influence the development of innovative strategies. Conversely, aspects of the firms like size, industrial concentration, intra-firm and intra-industry collaboration patterns etc. affect the design and organisation of public research organisations. Whitley (2002:507-508) describes four ideal types of approaches to developing innovative competences in a country: *isolated hierarchy*, *flexible teams*, *development hierarchy* and *collaborative*. Firms in the “isolated hierarchy” approach develop innovations largely internally with limited external interaction. “Flexible teams” denotes an approach with generic forms of involvement with public research organisations but with arms-length relations to suppliers, customers and competitors, typical of project-based firms in new technology-based industries. “Development hierarchy” is an approach where the firms interact a lot with each other, there is a high degree of employer-employee commitment, and there is little interaction with public sector research. Finally, “Collaborative” refers to an approach with intense co-operation with both public research organisations and other firms, particularly with relations to technologically and industry specific parts of the public science system. There is still a substantial employer-employee commitment with e.g. strong unions, collective bargaining and relatively low mobility. A key point is that particular innovation systems develop because of strong national institutions and policy decisions that are complementary and mutually reinforcing (see also Whitley 2006).

In the second article, Whitley (2003) elaborates how different characteristics of public science and its institutional framework affect the organisation of academic science within a particular country. The key characteristics discussed are the level of intellectual pluralism and flexibility, and the intensity of reputational competition. Combining these two, the author discusses four ideal types of public science systems. In *differentiated hierarchies*, the intensity of competition and the level of intellectual pluralism and flexibility are both low. Here, incremental innovations are promoted through centrally planned programmes. With high pluralism and flexibility, the system becomes *differentiated pluralist*, where diverse programmes in different organisations are encouraged. With low level of pluralism and flexibility but high intensity of reputational competition, the system is called *competitive hierarchies*. Here, “highly coordinated contributions to disciplinary goals within established frameworks” are emphasised. Finally, with high scores on both characteristics, *competitive pluralist* systems promote intellectual risk-taking and varied approaches to common problems.

Although this framework is created to understand systems and organisations “whose employees undertake research primarily for publication” (p. 1016), it is relevant and useful to expand it to encompass research institutes as outlined above. In Norway and many other countries, research institutes have been created as complements – and to some extent competitors – to other public science organisations, even though the main motive for researchers in institutes may not be contributions to the scientific literature. The frequently close linkages to higher education institutions, the funding structure and the public or national identity of many research institutes make it appropriate to see them as part of the public science base, although the activities of some institutes may not fit easily within a simple distinction between “public” and “private” science (e.g. Dasgupta and David 1994). The existence and orientation of institutes may therefore influence both the level of intellectual pluralism and flexibility and the intensity of reputational competition in a science system, and these aspects may conversely affect whether and how institutes are created and organised. It should be added that Whitley’s institutional framework analyses a number of factors that will only be touched briefly upon in this paper, e.g. the role of strong unions and employer organisations.

Co-evolution is a term borrowed from biology which denotes how two species exert selective pressure on one another, thereby affecting each other’s evolution. Examples are host species

and parasites, host-symbiont relationships and predator-prey relationships, but also more general relations where two actors evolve together in similar environments. Research institutes is probably a case of diffuse co-evolution where several “species” evolve partly in response to a number of other “species” in addition to the environment – which may also change, albeit more slowly. Nelson (1995) has described how industries co-evolve in a relationship between technology, supporting institutions and industrial structure. In this paper, the co-evolution process is analysed with the research institutes as the focus of attention.

Norway is one of the wealthiest countries in the world, enjoying high prices for many of its key exports (oil, gas, metals, fish) and extremely high productivity in almost all industrial sectors. Some worry is expressed that the country scores poorly on many indicators of R&D and innovation, and that the industrial structure still seems strongly oriented at processing of natural resources rather than more “high technology” pursuits. In the discussion below, the industrial and innovation profile of Norway will be related to the structure and development of the public science base. Broadly defined, research institutes in Norway consist of 110 very heterogeneous organisations with the common denominator that they have all been set up to address more or less specific needs for knowledge or technology in society (Skoie 1990 and 2005). 65 institutes receive basic funding from the Research Council of Norway, and the rest are in most cases public agencies or public organisations where R&D is part of a broader set of tasks and services. The biggest group of institutes is known as “technical-industrial institutes”. These have been created to carry out contract research and to collaborate with industry by other means, and they account for more than 40 percent of the total R&D expenditures of Norwegian institutes. In total, the “sector” (as it is known in Norway) carries out one-fourth of the national R&D, only slightly less than all the universities and colleges.

Wicken (2008) has argued that the Norwegian innovation system is not one coherent system but rather a set of three layers that have been added at various points through time, without reducing the importance of the previous ones. The first layer is termed “small-scale decentralised industries”, referring to agriculture, fisheries and small firms in e.g. mechanical engineering which often have a local customer base. With very few exceptions, agriculture and fisheries have always been small businesses in Norway, often family-owned and found outside of the main cities. The second layer consists of “large-scale centralised industries”, with chemical and metal companies as an important Norwegian example. Finally, the third

layer is called “R&D-intensive networked industries”, found e.g. within electronics and ICT. This will serve as an important additional perspective in the analysis of co-evolution.

In the next section, types of research institutes are discussed, followed by an analysis of the co-evolution of institutes and users. Although the main cases are taken from Norway, a few parallel examples from other countries are referred to as well. Much of the discussion is based on historical books and reports only available in Norwegian. The subsequent section sees an analysis of the co-evolution of institutes and universities, followed by a brief discussion and conclusion. In total the paper challenges popular conceptions that institutes have mainly been created as a link in a linear model chain and/or as a result of successful big ventures like the Manhattan project and radar development during WW2. Instead, a more complex story of co-evolution is presented. There is nevertheless a constant need to review possible discrepancies between the institutes’ original missions and tasks and the present-day activities and environments that they carry out and belong to. In particular, there is a need to discuss the future of these organisations in a time when universities are increasingly asked to engage more directly with users in society – a domain where institutes have been the key organisations in many countries.

Types of research institutes

An abundance of terms and acronyms have been suggested for the publicly supported research organisations outside of the higher education sector; I will continue to refer to them as “research institutes”. Large surveys like the Community Innovation Survey in Europe distinguishes between private and public research institutes (see Tether & Tajar 2008). I will concentrate on the former, but the distinction may often be fluid and unclear, not least following recent liberalisation and privatisations as well as new guidelines for basic public funding (Larédo & Mustar 2001 and 2004). Research institutes are a numerous and heterogeneous group, varying enormously in size, age, disciplinary mix, ownership and organisational structure (Crow & Bozeman 1998; Beise & Stahl 1999; Doern & Kinder 2002). There are institutes covering the whole spectrum from basic research to technical service activities, and some of them are centuries old and subject to path dependencies and certain trajectories just like other organisations and institutions in science and innovation systems.

Crow & Bozeman (1998) identified more than 16,000 “government laboratories” in the U.S. alone. Based on distinctions between three levels of government influence and three levels of market influence, the authors created a typology of public sector research with nine different archetypes. The logic behind the typology is that low market influence implies scientific activities while high market influence implies technology activities, and government influence signifies the degree of public/private character of the research institutes. The archetypes range from “private niche science” with low market and government influence, via “public science” with low market influence and high government influence and its logical opposite “private technology”, to finally “public technology” where both influences are high. In the middle are various “hybrid” organisations, for example “hybrid science and technology” with moderate influence of both types. Crow & Bozeman find “laboratories” corresponding to all these archetypes in their U.S. empirical material, indicating how complex the landscape of public sector research really is even when excluding the universities and colleges. A similar investigation of biotechnology laboratories in Europe found four different types with varying levels of orientations towards users and fundamental research and towards training activities (Senker et al. 2004; also Larédo 2003). Again, the complexity of the picture is stressed, for example that some “government laboratories” that are not universities/colleges nevertheless have a strong training element and that some “university laboratories” have a strong industrial orientation. Claims that institutes are oriented at (proprietary) “technology” and universities at (published) “science” may be too oversimplified.

However, research institutes often have different origins and policy justifications than higher education institutions. Governments still support research institutes at least for somewhat different reasons than what can be seen in the support of universities and colleges. Many research institutes have been started as alternatives or complements to universities, in some cases expressing distrust in the capabilities of HEIs, sometimes as a step in a linear model of innovation – or they have been part of government missions and policies of an age long passed. The next paragraph discusses types of research institutes in light of three different policy models: mission, cooperative and market failure (Crow & Bozeman 1998).

Many research institutes are related to specific public *missions* like exploration of the planet and space (geography, geology etc.), tasks related to nature (weather forecasting, agriculture and fishing, environmental mapping) and national interests (defence, energy etc.). In Norway, the country’s first research institute was responsible for geographical mapping – and it was

started in 1773, at about the same time as the country's first higher education institution (a mining school). It still exists as a government agency with some R&D activities although most of the tasks have changed. Later Norwegian institutes oriented at geology (1858), meteorology (1866) and marine research (1900) also prevail.

A special type of mission-oriented institutes is oriented at a particular technology like telecommunications, biotechnology and nuclear technology. Some of these post-war institutes in Europe were closely linked to industrial “national champions” – large firms appointed the task of using and commercialising results from the institutes. Although the national champions policy has largely been abandoned, the institutes often live on with a broader customer base and public support for what is seen as national “strategic areas” (Larédo & Mustar 2001 and 2004; Larédo 2003). Most of them have later reoriented themselves towards more contract research for private industry and/or merged with technological research institutes (e.g. Beise & Stahl 1999; Hofer 2007; Larédo & Mustar 2001). Thus, when the missions change, mission-oriented institutes have to change as well.

A second type of research institutes have been started with explicit goals of *industrial and economic growth*, often oriented at offering R&D services to industry and in other ways *cooperating* to achieve such goals. Germany's first public research institute (1887), the Physikalisch-Technische Reichsanstalt, as well as later institutes in Germany, were oriented at improving the international competitiveness of private companies and/or closing a perceived technological gap to other nations (Beise & Stahl 1999). General research, user-oriented R&D and linkages between firms and universities were main tasks of this type of institute.

In Germany and also e.g. Austria, Belgium, Sweden and Norway where similar organisations were started around a century ago, many different sub-types of industry-oriented institutes can be seen. Some were (and are) large institutes covering a broad range of technologies for firms in many industries, also with varying emphasis on technology push or demand-driven technological service activities. Others were smaller oriented at a single industry only, often functioning as shared laboratory for a few companies and in some cases started by industry associations and similar organisations. A few of these smaller institutes have been merged into the large ones like SINTEF (Norway), VTT (Finland), TNO (The Netherlands), Fraunhofer (Germany) and the Austrian Cooperative Research Centres.

Finally, in many countries there has been a blurred boundary between research funding agencies and research institutes. Early research councils, often with special responsibility both for funding and organising certain areas of research, have often started their own institutes which they subsequently funded. Norway's Council for Scientific and Industrial Research (NTNF) started a string of institutes after WW2, and only at the beginning of the 1980s were the institutes separated from the council, denoting a separation of the agency mission and the organisation of research institutes. Examples of agency-institutes that still exist are Italy's Consiglio Nazionale delle Ricerche (CNR, 1923), the National Research Council of Canada (NRC, 1916) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO, 1916/1926) in Australia. Some institutes may be difficult to categorise. Europe's largest research institute, CNRS in France (1951) is mission-oriented and historically incorporating an agency function, just like CSIC in Spain.

As indicated, boundaries and missions have become more blurred in recent decades. Many mission-oriented institutes have in recent years incorporated goals of industrial development and support, and many of the technological industry-oriented ones have broadened their responsibilities for more fundamental knowledge development within larger domains (see e.g. Beise & Stahl 1999; Larédo & Mustar 2001; Nerdrum & Gulbrandsen 2008). Despite changes in the framework conditions, institutes have survived and often come strengthened out of discussions about privatisation and new missions (Larédo & Mustar 2004). Many institutes, regardless of their type and historical paths, are now seen as relevant to industrial development. This might constitute a convergence in the rationales for public research institutes – implying that a fairly broad selection is needed when discussing the co-evolution of such institutes and industry.

Co-evolution of research institutes and users

Initially, industrial development in Norway was slow, which affected the build-up of a public research base oriented at industrial needs.¹ Plans for a technical university appeared early in the 19th century, but it took almost 100 years before these plans came into realisation (Hanisch & Lange 1985). In the 19th century, the country's economy was based mainly on agriculture and fisheries. The Parliament was dominated by representatives of these rural trades, and

¹ The historical examples and cases are taken from and described more fully in Gulbrandsen & Nerdrum (2008).

proposals for a technical university were turned down. It was argued that Norway's tiny manufacturing industry could not justify the costs of establishing a new university.

Instead, several research institutes were established during the 19th century. As mentioned, the first ones were oriented at national needs like geographical and geological mapping and meteorology. This can easily be tied to the centrality of agriculture and fisheries and a few other small and resource-based industries. It is furthermore noteworthy that Norway early on established academic institutions for public R&D and training in agriculture and fisheries (see Sejersted 1993:140). Thus, many of the earliest scientific organisations in Norway were set up to support the “small-scale decentralised industry” layer of the Norwegian innovation system (Wicken 2008), representing the first seeds of a “collaborative” approach as outlined by Whitley (2002) with strong sector and industry specific actors in the public science system.

The creation of applied and user-oriented research organisations reflected the weak belief in the “linear model” and the practical usefulness of basic research – most of the proponents of these perspectives were only found in the small academic community at the University of Oslo (founded 1813). Outside of the academic community, many believed that technological development should be under the control of users and the demands of production (Sejersted 1993:146). A few individuals worked unsuccessfully to start a public chemical R&D laboratory in the 1890s. Later, based on WW1 experiences and inspiration from industrial development and research institutes in Germany, the U.K. and the U.S., the Ministry of Industrial Supply proposed the establishment of six industrial research institutes in 1919 (Kvaal 1997:86; also Collett 1983:91-93). The then newly established technical university (1910) argued for a multidisciplinary “central institute” that could support all industries like the Mellon Institute in the United States (Kvaal 1997). Although plans for most institutes collapsed in the face of the economic downturn in the 1920s, they nevertheless signal the early ideological roots of the collaborative approach to Norwegian science and innovation policy, emphasising practical user orientation and industry-specific public R&D support.

The early 20th century saw the establishment of some of the major firms of the second layer of the innovation system – the large-scale centralised industry layer (see Wicken 2008). Of particular importance was Norsk Hydro, set up in 1905 based on an invention by physics professor Kristian Birkeland from the University of Oslo. Hydro and a few other firms created the first industrial R&D labs in Norway, collaborating directly with university professors in a

few cases and starting extremely ambitious projects to create new product lines based on Norwegian natural resources. Many of these projects failed, leaving a picture that large and risky ventures do not pay off, while incremental improvement in production and product lines are lucrative (Sejersted 1993; Andersen & Yttri 1997). No research institutes were set up to support the largest companies; for this layer of the innovation system, one could argue that the country followed the “development hierarchy” model (Whitley 2002). This encompasses strong linkages between the companies but relatively limited interaction with public sector research. Elkem failed to set up a joint R&D laboratory with the technical university, and the most important pre-WW2 innovation in Norway – the Söderberg electrode – was developed by Elkem engineers alone (Sejersted 1993).

The recession in the 1920s and early 1930s had two important structural effects (Sejersted 1993:181-182). First, the average size of Norwegian companies decreased significantly when larger firms went bankrupt and new small firms entered the scene, and second, there was a strong growth in industrial employment from last half of the 1930s. The increase in small firms, some with relatively sophisticated production methods, was an important justification for the later research institutes (see also Hanisch & Lange 1985:138). Two industries formed institutes organised as cooperative organisations: the paper industry in Oslo in 1923 and the canned food industry in Stavanger in 1931. Economic problems put other initiatives on hold until after WW2, when a string of new industry-specific R&D institutes were established in several different cities as cooperatives and public organisations. This continued and strengthened the collaborative approach to developing innovative competencies (cf. Whitley 2002) with its ideological roots in the late 19th century. Some of the cooperative industry research institutes encountered financial problems during the 1950s and were absorbed by the two large contract organisations SI and SINTEF (Gullowsen 2000, see below).

Several influential new mission-oriented institutes were established immediately after WW2, in particular the Defence Research Institute FFI and the Nuclear Research Institute IFA. FFI – described as a “small institute for large projects” and comparable to (D)ARPA in the U.S. – developed technologies and relied on private companies to produce them (Ørstavik 1994). Its first success was in sonar technology (Njølstad & Wicken 1997:69-70), where the technology benefited both the navy, the domestic fishing fleet and later other users (Sogner 1997). FFI also played a central role in the early development of Norway’s ICT industry. Its main partners, after several failed commercialisation attempts with various firms, became the two

state-owned weapon companies (Njølstad & Wicken 1997:443). By the mid-1970s, Norway had become the 7th largest exporter of military technology in the world. Wicken (1983:27) argues that the post-war development of these two companies would not have been possible without the “technological level at FFI and the organisation’s ability to transfer technological knowledge to industrial production”.

The Council for Scientific and Technical Research (1946) – a research council with strong industry representation and funding – took up the earlier idea of creating a large multidisciplinary industry-oriented research institute in Oslo, founding the Central Institute for Industrial Research (SI) in 1950. After a short period of protest, the technical university in Trondheim started its own “central institute”, SINTEF. These two institutes were oriented at industrial development but with no particular firm or industry in mind. SI was loosely based on three scientific areas, while SINTEF grew based on technology push initiatives from professors at the technical university and the need to find useful employment for engineering graduates. This may be seen as an expression of a new or renewed belief in the transformative power of science and as a desire to break with the incremental innovation strategies of the collaborative and development hierarchy models. In the new “flexible teams”-like model (cf. Whitley 2002) promoted by the post-war policy-makers, the nexus would be the institute-firm relationship, backed by public funding and linkages between institutes and academic science and incentives for firms to collaborate with one another.

The response from existing industry was not what the most “flexible teams” oriented institutes hoped for. Large firms like Norsk Hydro were supportive of the establishment of the new institutes but were reluctant to enter into close R&D collaboration (Andersen & Yttri 1997:154). Despite a few successes related e.g. to sonar development and automated ship control rooms, Norwegian industry rarely accepted the radical and cutting edge technological ideas and solutions offered by the research institutes. To some extent the firms still lacked the absorptive capacity to collaborate with public research organisations, and high technology solutions and ideas were only adopted after years of persuasion from research institute and university representatives. But the willingness to collaborate was there, and an increasing number of firms came to rely on institutes that were ever more specialised towards the day-to-day needs of single industries. The flexible teams approach adopted in the first post-war years was thus gradually abandoned as the institutes came to solve many sorts of technical problems, saving the firms the trouble of building up their own R&D units. SINTEF, based on

a combination of incremental contract research, technology push projects and the need to find employment and useful thesis problems for students became a big success, growing with almost a hundred new employees each year for a long period of time. The institute had expanded to around 2,000 employees in 1993, when it merged with its competitor SI.

Norway's public research organisations were over time able to work in a collaborative mode with all three layers of the nation's innovation system (see Wicken 2008). The small scale decentralised industries found public partners within SINTEF, the collective industry institutes, and in other organisations such as the Institute for Marine Research. Firms in the second layer – the large scale centralised industries of e.g. chemicals, metals, pulp and paper – often had their own R&D laboratories and co-operated on a small scale with the technical university and other higher education institutions directly. Increasingly, these firms found specialised partners among the groups of scientists and engineers in the research institutes, ever on the lookout for new customers and sources of funding. From the 1960s, many of the larger firms formalised their ties to public R&D organisations, increasing their financial support and consequently abandoning the development hierarchy approach based on weak linkages to public sector research.

Finally, the R&D-intensive network industries had particularly close ties to the research institutes. Many of the most important high technology firms in this third layer were started by the institutes, some of them backed by significant public R&D funding from defence and electronics programmes. The smaller high technology companies expanded their networks from the 1960s, like sonar company SIMRAD, founded on technology from the defence research institute, which found new partners in the maritime electronics R&D groups at the technical university in Trondheim and its daughter institute SINTEF (Sogner 1997:100, 173). This change can be conceptualised as a transition from a smaller flexible teams approach to a nationwide collaborative approach. For all three industrial layers, institutes and universities had to abandon their dreams of completely new industries and product lines, in return for which the firms adopted the most technologically sophisticated production processes for their existing products and activities. This may be seen as the core of the Norwegian innovation policy and strategy – a technologically advanced but highly incremental model favouring existing firms and activities.

Naturally, a few radical innovations developed in the decades after WW2, and the most famous case is probably the GSM mobile phone system, an international project where Norwegian research played a key role. This was the result of a Norwegian project organised in close collaboration between the central laboratory of the national telephone company and the electronics laboratory at SINTEF. Ambitious engineers, a wealthy telephone company under political pressure and special challenges in the topography and geography of Norway helped create a new technology which soon became the international standard in telecommunications (see Collett & Lossius 1993 and Gullowsen 2000:160-217). Despite the technological success, the industrial effects in Norway were small compared to the impressive growth of firms like Ericson and Nokia in neighbouring Sweden and Finland. One may see this example as the final failure of the Norwegian model of research institute inventions commercialised through local firms, a strategy that became ever more difficult to uphold in an era of globalisation and the rise of multinational companies. The GSM case could also be seen as an example of how an alternative approach to developing innovative strategies in a system dominated by another way of thinking, may have problems in succeeding. Firms within electronics, computers, engineering and other high technology industries never became important industries of their own in the Norwegian system, but rather suppliers to companies from the older layers of the innovation system. Even the expanding oil and gas industry may be seen as a continuation of the early layers of the Norwegian innovation system with its maritime and exploitation of natural resources components.

International oil and gas companies were attracted to Norway with policy mechanisms which required national R&D collaboration in exchange for North Sea drilling rights. These “technology agreements” and “goodwill agreements” were thus founded in the long-standing collaborative approach of developing innovative competences in Norway. Before the large-scale development of offshore oil and gas, Norway’s public research organisations in fields such as geology, marine technology, materials and electronics laid an important intellectual foundation for the industry, creating a small pool of knowledge that could be expanded when the need arose in the early 1970s. Most of the research institutes moved into new areas of R&D to meet the needs of the national and foreign oil companies. For example, IFE (nuclear research) used expertise accumulated through nuclear R&D to enter electronics, computing and petroleum technology. The institute’s work in areas like reservoir modelling, process automation and corrosion problems is estimated to have saved the oil companies of “hundreds of millions” in reduced material and maintenance costs (Njølstad 1999:398). Njølstad (p. 522-

523) argues that IFE's build-up of scientific competencies in the 1950s and 1960s was necessary for these advances, and suggests that the decision to spend 5 million NOK in 1947 on the first reactor project may have been the best public R&D investment ever in Norway. The example shows the unplanned and serendipitous directions applied research can take, and that the public science base is sometimes able to expand in new directions in a fairly short period of time with seemingly significant synergies between different scientific and technological areas.

The growth of a very profitable oil and gas industry transformed the R&D demand side in Norway. Suddenly almost all the main customers for many of the largest research institutes were oil companies, and the institutes went through a decade of strong growth until the mid-1980s when they carried out more than 30 per cent of the total national R&D effort (see also Gullowsen 2000 p. 76). This may not have threatened the collaborative approach to developing innovations in Norway, but the changes made the institutes increasingly dependent upon a few large customers. SINTEF and others became more vulnerable to changes in the funding and organisation of R&D in a few companies, and the smaller companies – which still constituted a political justification – became a lot less visible in the work and the annual reports of the R&D institutes.

Co-evolution of research institutes and universities

Many important themes of co-evolution of institutes and universities have already been touched upon in the previous section. The establishment of research institutes has most likely contributed to increasing the level of intellectual pluralism and flexibility. With a large number of R&D-performing organisations compared to the country size, scientists have been able to pursue many different goals and utilise different approaches. Whitley (2003:1019) has argued that this type of system may be more likely to encourage research that both seeks to improve fundamental understanding and to solve practical problems (“Pasteur’s Quadrant”, see Stokes 1997). As shown above and in Gulbrandsen and Nerdrum (2008), this seems to be a strong feature of the Norwegian public science system. However, the intensity of reputational competition has probably remained low for most of the 20th century. Salaries at the universities and many of the research institutes have followed national standards and regulations. Although there has been high mobility between universities and research institutes and many joint positions, this has mainly been oriented at finding a fruitful division

of labour and a means for individuals to follow different motives for doing research – not an indication of a strong competition for the most qualified people. Professors at the universities have traditionally been hired to fill demands for teaching particular subjects, and promotion criteria have not had a very strong element of international scholarly reputation.

In sum this means that Norway's public science system can be characterised as “differentiated pluralist” (Whitley 2003, esp. p. 1020). The strength of such a system is that it may be able to create a large amount of variety, but the main weakness is that scientific contributions can become “fragmented and incomprehensible to others, depending on the organisation of employment units”. This may have been the case in several of the failures in ambitious technology push projects of the research institutes and some university professors in the first post-WW2 decades in Norway. Later successes in e.g. GSM technology and oil and gas exploration and processing may be due to the ability of some of the actors to play a coordinating role and avoid fragmentation despite R&D being spread out on a large number of organisations. In many cases the coordination role has been played by research institutes like the Defence Research Institute and SINTEF.

Taking up the historical perspective, the perceived need for a user-oriented and applied sector may be related to university policies and developments. Although the University of Oslo was started with clear expectations of practical benefits, it gradually became more oriented at ideas of “pure science” and “education as personal enlightenment”. Despite a few entrepreneurial professors, the university let practical degrees like training for the mining industry decline during the last half of the 19th century. The technical university in Trondheim started out in 1910 with professors involved in industrial relations and consultancy. But after the university imposed greater restrictions on faculty consultancy activities in 1921, most of the remaining professors went into basic research with little or no industrial collaboration. This period of isolation contributed to increasing scientific competence which later found industrial relevance (Hanisch & Lange 1985). But it also served to increase the sense of a gap between academia and the needs of industry and may have paved the ground for the creation of industry-specific institutes.

Despite some world-class scientists, the first Norwegian universities were weak institutions with limited funding and political support. For decades, leading scientists survived on funding for public missions like geological surveys and coastal mapping. Many of these activities

were organised through research institutes, which then served also to support the most entrepreneurial of the academic scientists. This is an example of mutual influence between universities and institutes.

It is obvious that the universities in many cases affected the research institutes. The clearest case is SINTEF, one of the largest R&D organisations in Europe which was started as an outreach tool and contract research mechanism for the technical university. SINTEF's scientific orientation and practical organisation was largely decided upon by the professors. A more indirect influence was the study programmes at Norwegian universities. For example, in the spirit of technology push after WW2, the technical university set up a study programme in "physical electronics" (Hanisch & Lange 1985). This was the first engineering degree programme that did not have a particular national industry in mind, and the candidates often found work within the newly established research institutes. Also the interests of many of the scientists in the astrophysics department at the University of Oslo in computers provided the research institutes with personnel with early and in-deep knowledge in this area. Even though there were obvious tensions between the two types of organisations e.g. related to the struggle for resources and recognition, most of the institutes were supportive of and to some degree interested in linkages to basic science. Over time there has been a build-up of shared facilities and equipment in many cities.

Institutes also affected universities, and again the clearest example is SINTEF's influence on the technical university – the Norwegian Institute of Technology, which generally has been seen as "entrepreneurial and proactive" since the early 1950s (Hanisch & Lange 1985:213). SINTEF handed large numbers of industrial contacts and influenced the content and direction of both research and teaching at the university (*ibid.* p. 246). With funding through the SINTEF system, the university became less dependent upon ministerial routines and budgeting processes. For example, it could create positions for talented researchers without asking the Ministry to create new professorships. Another historical example is how representatives of the defence and energy research institutes wrote a memo to the leadership of the technical university in the early 1950s, encouraging it to move from a German-type "technische hochschule" to an American-type Institute of Technology, with MIT as the ideal. Many of the suggestions were followed. Finally, the institutes influenced universities by coordinating large-scale national and international projects through which university scientists came in touch with practical perspectives. The largest example is the Penguin Missile project,

probably the biggest R&D project ever in Norway, coordinated by the Defence Research Institute and involving firms, universities, institutes, defence and public agencies.

The institutes have often depicted themselves as a bridge between universities and industry, but their existence may also have created barriers. With increasing basic funding, the universities' incentives and opportunities for industrial collaboration – apart from at the technical university – were minimal during the first three decades after WW2. Firms with problems which had scientific solutions had many specialised organisations to go to. Nevertheless, professors interested in practical applications could work through mission-oriented institutes and institutes more directly tied to industrial needs such as SINTEF and SI, and they could find funding through the industry-influenced research council for technology and natural science.

Many contract activities in the research institutes were not very sophisticated and probably not in the R&D categories at all. But government-supported projects in the institutes often required high scientific and technological competence, and the mission-oriented organisations benefited from substantial and long-term financial and political support after WW2. Many of the scientifically important findings in electronics and reactor technology came from Norway's research institutes, not the universities (Ørstavik 1996). Boundaries were blurred with e.g. SINTEF becoming involved in teaching at the technical university and institute researchers finding work as full professors. Some institute groups were ambitious and strived for “excellence” in a few select areas, whereas universities more often had to build up broad departments to cover teaching needs. As mentioned, this contributed to a high degree of intellectual pluralism and flexibility, but with low reputational competition.

A turn in the development can be seen from the late 1970s with increased tension between universities and institutes. The higher education institutions moved more into contract research and the scientific ambitions of some research institutes made them stronger competitors to universities for basic research council funding. Institutes like SINTEF grew dissatisfied with professorial control of its activities and wanted an arms-length relationship to the technical university (Gullowsen 2000:68). For their part, some professors expressed displeasure with the way SINTEF dominated the contract research market. First and foremost this reorganisation probably served to increase the level of reputational competition as all parts of the public science system were subject to decreases in core funding and more peer

review-based external funding. With a new funding system emphasising academic criteria also for the institutes' core funding, this competition has been recently strengthened. However, Norwegian universities have also exercised greater control over the research institutes in their vicinity, and a new wave of mergers can be seen. Increased university ownership of institutes could be taken as a strategy to reduce competition by creating a locally coordinated division of labour. This may reinforce the picture of "differentiated pluralism" (Whitley 2003). But with weaker national coordinating mechanisms than previously, fragmentation may become a bigger challenge.

Conclusion

This paper has sought to utilise the framework of Whitley (2002, 2003) to analyse the origins and historical development of research institutes in Norway, with two important modifications. First, research institutes are seen as part of public sector research despite the applied and possible proprietary nature of at least some of the institutes or their activities. Second, instead of looking at the innovation system as a more or less coherent whole, the framework of Wicken (2008) has been used to discuss aspects of different industrial layers of the Norwegian innovation system. It has been shown that many research institutes are as old as universities and have evolved together with both user needs and higher education organisations. Many of the institutes have furthermore not been started primarily as a link between universities and industry in a linear perception of innovation, but on the contrary as an expression of a lack of faith in this view of innovation.

Most of the first public institutes and higher education institutions in Norway were established to cater for the needs of the first layer of the innovation system, the small-scale decentralised industries in agriculture, fisheries, simple mechanical production/services and more. This denotes a "collaborative" approach to developing innovation competences (Whitley 2002) with strong linkages between firms and between firms and specialised public research organisations. In addition, Norway has been characterised by strong unions, strong employer federations and other aspects of the collaborative approach that have been outside of the scope of the discussion in this paper. But the long-standing close relationship between unions and employer federations may have set certain boundaries for the type of innovative strategies that could develop. The paper has shown that the ideological foundations of the collaborative approach go back at least to the second half of the 19th century. Many of the industry-specific

institutes were, however, not established until after WW2 when a new research council with strong industrial representation was set up. Practical and industry-friendly perspectives were, on the other hand, also prevalent in the earlier mission-oriented institutes.

For the other two layers of the Norwegian innovation system, attempts were made to develop new approaches to innovation strategies and policies. The second layer of the innovation system, the large-scale centralised industries of chemicals, metals and paper, initially set off on an isolated hierarchy approach with strong inter-firm linkages and fairly weak ties to public sector research. Over time, however, these firms strengthened their collaboration with research institutes and universities, not least following the establishment of public research units with competences tailored for specific industries. The third layer firms – in the high technology networked industries (Wicken 2008) – never became as dominant as the policy-makers had hoped for. The attempts may be characterised as a “flexible teams” approach that wanted to sever the ties to the incremental innovation strategies of the pre-WW2 period. But instead of becoming a separate vibrant sector like in the other neighbouring countries, the Norwegian high technology firms’ main customers have become the strong firms of the natural resource-based industries of layers one and two, not least the oil and gas industry which itself was attracted and founded on policy mechanisms highly collaborative in nature.

The paper has argued that in a country with a very strong emphasis on one approach to developing innovative competences, industries founded on other approaches may find it problematic to grow. Radical new initiatives like the research institute projects in the first post-WW2 decades often failed, and a shift to incremental innovation was carried out. This process contributed to reinforcing the structure and the collaborative and incremental innovation approach of Norwegian industry. The survival to the present day of many of Norway’s traditional industrial companies, often with low internal R&D expenditures, may be seen as evidence of the success of this approach. As has been argued by other authors, the success of an incremental innovation strategy may also be due to other factors like a high degree of authority sharing which gives the firms strong incentives to invest in competence building for a broad set of employees (e.g. Lorenz & Lundvall 2006; Whitley 2006).

Thus, different types of Norwegian public research organisations have been established to cater for the needs of the three different layers of the innovation system. But the research institutes and at least some of the higher education institutions now provide meeting places

for institutions and actors from all three layers. The existence of such places for discussion and collaboration is partly due to the long-time dominance of SINTEF and the Norwegian Institute of Technology in engineering R&D and training. In addition, the emergence of the oil and gas industry created strong incentives for applied research groups to focus their attention on the needs of these firms. With the growing technological sophistication of the “low-tech” industries and the ever stronger linkages between large firms and public research, the Norwegian innovation system as a whole seems to have converged on the collaborative model which, it has been argued, also has the oldest roots in the Norwegian system.

Critical questions may nevertheless be posed to recent developments where universities are entering what used to be the domain of the research institutes and increasingly taking control and ownership of institutes in their vicinity. There could be a danger that this decreases the level of intellectual pluralism and flexibility in the science system or that it reduces the opportunities for a certain degree of national co-ordination of research agendas and perspectives. Some would argue, not least research institute representatives, that what is needed is a revitalisation of the institutes with some increases in basic funding and an improved independent situation. Others will call for mergers between institutes and universities. The present-day situation can be seen as a middle solution between these extremes, a solution that follows historical trajectories but may lack a clear vision for tomorrow’s science system.

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