Paper no. 2010/11

Research councils facing new science and technology

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This is a pre-print version of a paper that has been submitted for publication to Research Policy

This version: November 2010

Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)
Lund University
P.O. Box 117, Sölvegatan 16, S-221 00 Lund, SWEDEN
http://www.circle.lu.se/publications
ISSN 1654-3149

WP 2010/11
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Frank van der Most and Barend van der Meulen

Abstract

This paper addresses the question how research councils respond to emerging fields of science. Taking nanotechnology as its case, we compare the cases of responses of research councils in Finland, the Netherlands, Norway and Switzerland during the period 1990 - 2008. The case studies are based on extensive document study and 25 in depth interviews with relevant actors. The analysis is framed by Resource Dependence Theory, which is found to overlook aspects related to long term changes and interactions between organizations and their environment. But when this dimension is added, it provides an explanation for the observed conservative response of research councils: research councils are constrained by a web of resource dependencies as it slowly develops over time and gets embedded in national research landscapes, in part as a result of research councils' own actions. We identify a four stage pattern which describes their conservative response.

Keywords: research councils; research funding; emerging science and technology; interdisciplinary research; resource dependence theory; nanotechnology

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Version: 3 November, 2010

1 Introduction

The development of science is not just an effect of the work funded by research councils, but also a source of problems. The agility necessary to address new developments does not come easy to an institution like a research council. New questions, topics and fields, big and small, emerge and have challenging implications. Research councils face at least three pressing challenges.

The first concerns the disciplinary boundaries. Most research councils are organized along disciplinary boundaries. When new research topics and fields emerge, some may fit comfortable within the existing structures of the research councils. However, in the course of more than half a century that has passed since the first research councils were established, major new areas of research have developed which spanned disciplinary boundaries. Materials research emerged in the 1950s and 1960s, biotechnology in the 1970s, computer science and information technology in the 1980s, and nanotechnology in the 1990s[i]. These interdisciplinary fields were difficult to position within the disciplinary structures of the existing research councils.

The second challenge is to foresee how a new field will develop. How should it be defined, in which directions will it develop and how influential will it become? During some time, such questions cannot be answered unambiguously and this creates uncertainty for a research council how to support the new field. Especially when the new field is hyped by actors and big promises are attached to it.

The new field may also require adaptations of research infrastructure and organization of research. Different instruments and facilities are needed, different modes of organization, and different knowledge and competences are required from researchers. This may seen as an issue of research performing organizations – universities and research institutes -, but when transition costs are high, research councils may be asked to co-invest in the new field.

In this paper, we analyze how research councils respond to emerging fields of research. The question also relates to research councils being asked for more visible signs that the basic research they support has social benefit and to the pressure to give priority to new strategic research fields. Targeted research funding directly financed by ministries or through research councils was introduced in the 1970s. New types of councils for applied research and technology development were established in the 1980s. Issues concerning intellectual property rights were put on the agenda of public research organizations. As of the late 1980s, some governments reorganized councils to address societal issues in their funding activities.

For research councils, the trend meant a shift in orientation. From their inception, they found themselves torn between government and research, each with its own reward dynamics. Initially, the councils were dominated by researchers. For decades, they selected projects through open competition. Applications were reviewed by peers of the applicants and financed as far as the councils' budgets allowed. In theory, research councils should easily be able to accommodate new emerging fields through the open competition. If enough researchers have an interest in a new field, this will change the overall funding pattern towards the new field. However, peer review is claimed to be conservative[ii], which means that early researchers have problems to get their applications recognized by their peers. In addition, when new fields make new links between disciplinary fields, researchers may find disciplinary bodies within research councils unreceptive to projects contributing to such a new field.

When pressure from governments increased, research councils introduced targeted funding modes. Targeted funding modes aim for the stimulation of particular topics or areas in research. They can have different shapes and sizes in terms of budget reservations, organizational structure, funding instruments, and application and review criteria and procedures. The new funding modes turned out not only to solve but also to shift problems and invoke new ones. By the early 1990s, the external demand for societally oriented funding had shifted and transformed into an internal problem for many research councils. Compared to open project funding, program funding requires identification of topics for prioritization, the design of a program and it induces new pressures to deliver.

To address the question how research councils respond to new fields, we study the field of nanotechnology. This is an interdisciplinary field which merges a wider range of existing disciplines than other fields have done before. It perhaps also exceeds earlier fields in terms of potential applications and societal sectors that may benefit. Especially in the earlier period we look at, the field was still under construction, and actors looked for proper definitions.[iii] Furthermore, nanotechnology experiments require high precision instruments that operate in ultra high vacuum or rooms free from dust and vibration, thus putting high demands on budgets. On all counts, the emergence of nanotechnology posed the challenges to the research councils that were listed above.

2 Research councils as resource depending organisations

During the past two decades, Principal-Agent theory has been developed and used to conceptualize and study research councils' intermediary position (Braun, 1993; Gulbrandsen, 2005; Guston, 1996; Shove, 2003; Van der Meulen, 1998). The Principal-Agent model conceptualizes the position of the research council as an agent of the government, and their relation as a contract relation, with the research community as a third party – or as a contracting agent of the council itself. Though the model explains some of the difficulties that research councils face as intermediary organizations, it is less helpful to understand the dynamics of the contract, especially not when it is unclear to the actors what the best strategy would be.

In resource dependence theory (Pfeffer & Salancik, 2003) strategies of organizations are not just framed by (contract-)relations with others, but the making of such relationships is seen as part of the strategy. Resource dependency theory (RDT) stresses that organizations are intricately and inescapably bound to their environment, which contains the resources that they need to survive. To obtain them, the focal organization depends on other actors and organizations controlling these resources. Their willingness to provide them is dependent on how effectively the focal organization lives up to their demands. So, an organization's survival depends on how well it manages external demands, either by influencing the demands or by living up to them. Because in practice, environments and the availability of resources change, there is an ongoing problem to the organization. (Pfeffer & Salancik, 2003, p. 1 - 19)

RDT stresses that the organization acts upon an image of its environment, which the organization internally creates. This so called 'enacted environment' depends not only on the organization’s environment but also on its information system, which basically refers to the organization’s internal structure. The organizational structure determines which parts of the environment are seen and it structures the enacted vision. (Pfeffer &

Salancik, 2003, p. 12 - 14, 70 - 83) Since its publication in 1978, many authors have referred to RDT, but it has scarcely been tested against empirical data or further been developed. Pfeffer (Pfeffer & Salancik, 2003, p. xvi, xxv) calls out for such tests and developments and among other things, suggests to study the consequences of organizations' efforts to manage their environments.

If we apply the two main points of RDT to research councils' responses to the emergence of nanotechnology, we need to ask which the critical resource dependence relations are and how nanotechnology is linked to these relations? Research councils are mainly dependent on two groups of actors. They depend on researchers to get grant applications, as well as peer reviews and other forms of expertise to be able to perform their funding role. Here, the councils are dependent on group support, rather than on individuals. Moreover, in many countries researchers have become rather dependent on council support or other external funding to supplement institutional funding, thus the dependency is mutual. With respect to nanotechnology, the resource relationship with researchers is alike for research councils from different countries. We may expect that in all countries researchers will address nanotechnology through applications.

The other main dependency is on funding from ministries – without which RCs cannot survive. Some ministries expect 'their' councils to support the progress of science. Others also expect them to contribute to societal and economic objectives. Nanotechnology has drawn the attention of governments as a field with high potential for innovation and economic profit. We hypothesize that research councils with a societal/economic remit are more likely to create targeted funding to support nanotechnology and secure existing resources from ministries. Councils without such a task are less likely to do so because demands from researchers can be dealt with through existing open funding instruments.

Strategies of research councils to acquire resources depend on how they perceive their environment or enact it. Research councils may, once they have signaled nanotechnology as a new area or research, decide to proactively create targeted funding for nanotechnology. According to RDT the enactment of the environment largely depends on the organization's internal structure. Thus our second main question is how research councils' internal structure relates to their perceptions of and approaches towards nanotechnology? Most research councils have divisions defined by disciplines, which implies that they will perceive their environment in terms of these disciplines. To overcome such a lock in, some councils have a functional division or unit that deals with strategic themes and/or interdisciplinary fields. Our second hypothesis is that research councils with a disciplinary structure only will respond to nanotechnology only as far it intersects with the represented disciplines, that is, as a normal disciplinary development, while councils with a functional unit will perceive nanotechnology in its interdisciplinary width as new development and respond accordingly with a dedicated instrument.

We arrive at four possible situations for research councils (Table 1), each with a hypothesized answer to the research question:
1 - Research councils with a science remit and a disciplinary structure without a strategic functional unit. We expect these to respond to nanotechnology through bottom up proposals from researchers within disciplinary boundaries, and not to create any specific programs.
2 - Research councils with a science remit, a disciplinary structure with an additional strategic functional unit. These are likely to develop interdisciplinary programs with an

emphasis on scientific quality and challenges of nanotechnology.
3 - Research councils with a scientific as well as a societal/economic task, but without additional strategic functional unit. Their response may be indeterminate in some way because societal/economic orientations often result in interdisciplinary solutions which are difficult to implement in a disciplinary settings.
4 - Research councils with a scientific as well as societal/economic task, with a disciplinary structure and an additional strategic functional unit. These councils will respond to nanotechnology with dedicated, interdisciplinary programs with a strong orientation to innovation.

3 Method

To find empirical answers and test our hypothesis we selected four research councils. (Table 1)

- Suomen Akatemia, the Academy of Finland, has responsibility for the promotion of basic research exclusively. It currently consists of four disciplinary councils, viz. Research Council for Biosciences and Environment, Research Council for Culture and Society, Research Council for Natural Sciences and Engineering, Research Council for Health. Most of its budget is allocated through open competitions organized by the disciplinary councils ("bottom up"). In addition the Academy's Board defines interdisciplinary funding programs.
- The Schweizerischen Nationalfonds (SNF -Swiss National Science Foundation) also has a basic science remit, also spends most of its budget through open competitions for project funding and personal grants and has three disciplinary divisions for social sciences, natural and exact sciences, and biology and medicine. Besides these, SNF has a division for strategic programs, which puts SNF in category 2.
- The Nederlandse organisatie voor Wetenschappelijk Onderzoek (NWO - The Netherlands Organization for Scientific Research) fits in category 3. It consists of eight disciplinary, semi-independent divisions[iv] which each have the ability to launch funding instruments. In addition to basic science, NWO's task is to address societal issues through its research support. For this, NWO's central board, through interactions with its division boards and many other actors, develops four year strategies.
- The Norges Forskningsråd (NFR - Research Council of Norway), like NWO, has a role to identify and support strategic research for the benefit of Norway. To address this role explicitly, NFR was reorganized in 2003 when its former disciplinary divisions were 'demoted' to departments in one science division and two separate divisions were added for strategic priorities and innovations, respectively.

We adopted a case study approach to be able to follow the processes through which nanotechnology came to the research councils' attention and how they developed their response. In line with RDT's emphasis on the enactment of the organization's environment, we did not define nanotechnology ourselves but followed nanotechnology as it was perceived and defined by the research councils themselves. Empirical data was gathered from documents such as policy papers, strategy plans, annual reports, program brochures, evaluation reports and web pages. In addition, 25 semi-structured in-depth interviews were held with key actors within research councils and actors closely related to the councils' nanotechnology activities, such as policy advisors, program managers, program committee members and council board members. See Van der Most (2009) for the list of interviews and more detailed and fully referenced versions of the cases.

Table 1: Four types of research councils

		Organizational structure	
		Disciplinary only	***Functional structure***
Resources dependent on ability	***to support basic science***	Academy of Finland	Swiss SNF
	to support basic science and contribute to society	Dutch NWO	Norwegian NFR

4 Case descriptions

4.1 Finland

The Academy of Finland receives about 14% of the government funding for R&D, which in 2005 equaled 218.7 M€. Its funding instrument portfolio includes open competition for research projects, Centres of Excellence, memberships of international programs and facilities, research training and career grants as well as national programs. The funding for national programs varies over time. In 2001, 21% or 39.6 M€ of the budget was spent on research programs and targeted calls. In 2005 this was reduced significantly to 8% or 17.1 M€. In 2009 it had increased to 29.3 M€ or 10% of the total budget.

A stepwise procedure leads to commencing of a research program at the Academy of Finland. In principle different types of actors can propose programs to the Board. Researchers, ministries, companies and others can turn directly to the Board with their program proposals, but this hardly ever happens. Usually programs commence with proposals to one of the Research Councils within the Academy of Finland. If the Council adopts the proposal it will then start to discuss and negotiate about it with the other Research Councils in order to gain support in the Board of the Academy of Finland. More than half of the Board members are the chairs of the Research Councils[v], so it makes sense to gain their support. In most cases, first proposals aim at a rather focused program, but discussions between the councils broaden the scope. Next, the proposal is presented to the Board, which decides upon it. The Board can also develop a program by itself and this happens in about one out of ten cases.

In 1997, the Academy of Finland launched one of the relatively early nanotechnology funding programs, together with Tekes, Finland's technology agency. Somewhat earlier, ideas for cooperation between Tekes and the Academy of Finland were discussed at both organisations. At that time, at Tekes' expert staff the topic of nanotechnology came to the fore, 'in the air' so to speak, in a mingle of events. It happened to be a personal interest of one the experts and it was a topic of an ESPRIT workshop on 'Long Term Research', which was held in Finland[vi]. The workshop further stimulated the idea of developing a nanotechnology program. At some point the people from Tekes connected to the Academy of Finland's new director J. Hattula, to J. Keinonen, member of the Research Council for Natural Sciences and Engineering, and to others from the Academy. In addition, contacts were made with Finnish researchers. This all added up to the launch of the

Nanotechnology Research Program in 1997. (Granqvist, 2007, p. 159 - 160)

The resulting 'Nanotechnology Research Program' used a comparatively open definition of nanotechnology as "the science and engineering of extremely small (~1-1000 nm) structures" (Tekes 2000, p. 3; Yu & Ziegler, 2000, p. 1). It also had no predetermined subdivision of nanotechnology as the funders wanted to invite proposals from different disciplines. One stated motivation for the program indeed was a "desire to foster new, interdisciplinary interactions leading to new, unforeseen opportunities for creativity and innovation." (Tekes 2000, p. 3) This first nanotechnology research program existed for three years, and had a shared budget of FIM 44M (approx. 7.4M€), about 0.7% per year of total funding decisions in the three years.

In 2002, the Research Council for Natural Sciences and Engineering developed an idea for another nanotechnology program through a bottom up process in which researchers and Council members participated. In December 2003, the Board allowed the research council to start negotiations about a "research program on chemical, physical and biological nanosciences" (Academy of Finland, 2004, p. 26) which was planned to start in 2006 . The list of disciplines does not mention Health, but at some point K. Väänänen[vii] contacted the group that was developing the program and suggested that a representative of the Research Council for Health was included to address the issue of potential health risks of nanotechnology. The Research Council for Natural Sciences and Engineering also involved representatives from other funding organizations from Finland and abroad, and from industry and business in developing the program. In April 2004 an exploratory workshop was held and half a year later, a program preparation group was installed, consisting of a chair and representatives of the three Research Councils for Natural Sciences and Engineering, Biosciences and Environment, and Health, a number of Finnish researchers, a program manager from the Academy of Finland and a representative of Tekes. Finally, in November 2005, the Board approved the launch of five new research programs, amongst which the Nanosciences Research Program. Shortly after, it was renamed to FinNano, as a result of coordination with Tekes' nanotechnology program. FinNano in total had a budget of 54 M€, for four years. 9 M€ came from the Academy, which is 0.8% of its total budget for research funding.

Compared to many other nanotechnology programs, the FinNano program is remarkable in the way it addresses nanotechnology's interdisciplinary character:

> "Nanoscience is targeted at studying the nanoscale, atomic or molecular level, systems and related phenomena. The phenomena and objects under investigation must be novel, which claims that merely a small size is not a sufficient parameter. The approach in this research programme must be interdisciplinary." (Academy of Finland, 2005, p. 35)

The program insisted that projects "should be focused on novel properties and functions. Traditional research on chemistry, physics and life sciences, as such, does not fulfill the characteristics of nanoscience." (Academy of Finland, 2005, p. 35) So, the program connects the aspect of new phenomena and their study to nanotechnology's interdisciplinary character.

The program's subdivision of nanotechnology explicitly does not want to use known categories: "[T]he starting point [of developing the program and selection of proposals] was/is genuinely interdisciplinary research. Therefore, a research project should not be built on a single discipline or engineering point of view. ... As the thematic areas were chosen, care was taken in not to target at any specific discipline or research ares, but rather keep themes generic and relevant to several areas." (p. 38)

And indeed, the program identified 'Directed self-assembly', 'Functionality in nanoscience', and 'Properties of single nanoscale objects', which is rather different from the often used division of nanobio, nano-electronics and nanomaterials. In fact, as far as the program was concerned, these three could occur within all the identified areas. For example the area 'Directed self-assembly' lists 'Self-assembly with lithography and electronics', the area of Functionality in nanoscience lists 'Bionanotechnology for electronics and materials science', and the area of Properties of single nanoscale objects lists 'Nanoscale circuitry, mechanics, actuators and photoactive systems' and 'Molecular data storage and machines'. Similarly, all areas list materials related themes and two list bio related themes. (Academy of Finland, 2005, p. 38 - 39)

The FinNano program also aimed to realize interdisciplinary research by setting up the Programme Steering Group in an interdisciplinary way and by requiring that applicants organize themselves in consortia of two or more research groups.

4.2 Switzerland

In the mid 1970s, Switzerland introduced the Nationale Forschungsprogramme (NFP - National Research Programs) to address pressing societal problems. The implementation of this program instrument introduced a division of resources and labor, which is particular compared to programs at other research councils. The means were provided by the Swiss Federal Council, the ideas for programs by researchers, the political selection by the Federal Council, and the feasibility evaluation by the Swiss National Foundation (SNF). Within SNF a separate division, division IV, was established to administer the programs and their application processes.

In 1991, the Federal Council proposed a new program instrument called Schwerpunktprogramme (SPP - priority programs), which aimed for restructuring the Swiss research landscape through establishing new research centers. With the SPPs, the Federal Council wanted to make Switzerland an attractive partner for industry in particular fields such as high power electronics, optics and environmental research.

When the Federal Council abolished the SPP instrument after eight years, SNF together with the Federal Council launched a successor instrument that aimed less for technology development and economic application but continued the SPP's attempts to establish new research centers. Hence, the instrument was named National Centres of Competence in Research (NCCR). NCCR's were meant as a local centers of competence and as centers of national networks of exchange and coordination within their respective fields.[viii]

To arrive at their selection of programs, SNF and the Federal Council used a bottom up approach and kept the division of resources and labor in place that was used for the NFPs. That is, they depended on Swiss researchers to develop program proposals, involved SNF to organize scientific quality evaluation, and included the Federal Council for political selection. In 2005, SNF allocated CHF 466M, of which 17% was used for the funding of research programs and 83% for "free research".

The funding of nanotechnology programs by SNF is part of a series of programs funded by SNF and by other actors. From 1995-1999 SNF administrated the five year NFP on Nanoscience, with a SNF budget of CHF 15 M, or 1% of its budget. From 2000 to 2008, the

NCCR on nanoscale science with a total budget of CHF 137M. SNF contributed CHF 39M, again 1% of its total budget. The other two funding actors responding to nanotechnology were the ETH Board, established in 1983 as the governing board for the two ETHs in Lausanne and Zurich and related research institutes, and the technology agency KTI. The ETH Board developed its own program TOP NANO 21, which ran from 2000 to 2004 . Its total budget amounted to CHF 107M including contributions from KTI and industry. From 2004 to 2008 KTI also managed an innovation program on micro- and nanotechnology, with a total budget of CHF 217M, including CHF 116M from industry.

For our analysis we focus on the two programs funded by SNF. These are NFP 36 Nanosciences and the NCCR Nanoscale Science. In 1981, in an IBM laboratory in Zürich, H. Rohrer and G. Binnig invented the scanning tunneling microscope, the single most important tool that opened up the field of nanotechnology. Rohrer later acquired NFP funding for a program on physics and chemistry of surfaces, which ran during the first half of the 1990s. Towards the end of the program, the researchers involved in the program wanted a follow-up program. Guided by Rohrer, G. Wagnière successfully applied for an NFP on nanosciences, which was launched in 1995 and lasted until 1999.

Three reasons were mentioned to legitimize the program in academic and societal terms. The development of the STM and other similar tools allowed new research methods. This opened up a new field and the program claimed the start of a new era for some scientific disciplines. Secondly, the program predicted new industrial developments based on nanoscience. It pointed out that nanotechnology opened unexpected new perspectives on miniaturization - one of Switzerland's traditional industrial specialties. In addition, higher efficiency became possible which could also be economically interesting. Thirdly, Switzerland's head start in the field offered an opportunity for Switzerland to take a lead again after it had missed out on miniaturization in micro electronics. The application was successful, partly because Rohrer, described as a good communicator and locomotive for nanotechnology, was able to convince politicians of the importance of nanosciences.

The program aimed for an interdisciplinary approach: it targeted the physics of the nanoscale and the chemistry and biology. It used a subdivision of nanotechnology which followed the lines of existing disciplines: nano-electronics, nano-mechanics, nano-biophysics, nano-chemistry, nano-optics, and nano-tools and methods. It was felt that one cannot immediately start on a new field, and that to define it in detail one has to start from the existing disciplines. It was also felt that projects that were not based in existing fields, would run the risk of being ill defined and of producing non-reproducible results or no results at all. However, the idea behind the program was that things would not remain in the different subfields, and to prepare them for a more interdisciplinary level revolving around the use of the STMs.

In January 1999, SNF's Division IV, launched the first call for NCCR proposals. A few proposals originated from groups involved in SPPs and this was also the case with the Nanoscale Science. The main applicant was H.J. Güntherodt of the University of Basel. Through his experience with earlier programs such as NFP 36 and MINAST[ix], he knew his way around in nano research in Switzerland, which made him a suitable coordinator. The proposal was accepted together with 13 others in December 2000.

The NCCR Nanoscale Science does not have a particular definition of nanoscale science and technology. Its website provides an explanation to the lay audience of what is meant: "Nanoscale science and nanotechnology deal literally with the small things in life. One million of the objects studied would fit onto the dot of this “i”." (SNI, s.a.). Although the website provides a description of nanoscience which remains quite close to the instruments that opened the field, the NCCR's current director, C. Schönenberger, pointed out that the leading house in Basel is specialized in the sub fields of quantum information processing, molecular sciences and molecular biology, which limits the NCCR's coverage in Switzerland. The resulting list of modules identified within the NCCR is: nanobiology, quantum computing and quantum coherence, atomic and molecular nanosystems, molecular electronics, functional materials by hierarchical self-assembly, and applied projects in nanoscience and nanotechnology. The NCCR mainly focuses on basic science, but as other NCCRs, it also pays attention to technology transfer. Industrial partners are involved in projects and by the end of 2008, the NCCR had three spin off companies.

4.3 The Netherlands

NWO, the Dutch research council, has a mission which emphasizes both scientific progress and contribution to society’s research needs, but has no specific departments for the latter task. As of 1979, successive Ministers wanted a research council that not only responded to scientific developments but also to societal developments. It took them almost 10 years of negotiations, but as of 1988, ZWO was replaced by the Nederlandse organisatie voor Wetenschappelijk Onderzoek (NWO - Netherlands Organization for Scientific Research). In order to fulfill the new mission of societal orientation, NWO introduced a new instrument, the so called priority programs. NWO also aimed to make this instrument available to Ministries that wanted to implement particular targeted research programs. In the course of time, the range of instruments expanded. NWO developed or became involved in a host of funding programs, amounting to more than 60 in 2008.

In the Netherlands, nanotechnology saw a gradual increase in interest during the second half of the 1990s. A number of foresight organizations and advisory councils noticed the field in their reports and two divisions of NWO, started financing nanotechnology programs, based on bottom-up proposal processes. In 2000, a third division made nanotechnology a priority area in its strategic plan. This triggered a response from the others and nanotechnology became a joint priority in NWO's new four year strategy plan which was published in September 2001. Although it was a priority, in terms of financial commitment it was the smallest of its priority themes and plans for nanotechnology still had to be developed. Attempts to do so initially failed and were bypassed by other actors even before the strategy plan was published.

Around 1996, three groups of researchers from Delft, Twente and Groningen, each with its own laboratory, deliberately oriented their research interests towards nanotechnology. They attempted to scale up investments through a collaborative program proposal at a joint program of the Ministry of Education, Culture and Science and NWO. Their proposal was rejected, in part because their collaboration was too young. Their collaboration however continued and they kept up their efforts to acquire funding from government.

A newly established fund from Dutch gas revenues facilitated their attempts. Since many years, revenues from gas reserves in the North East are a main source of income for the Dutch state and Dutch economy. The government invests returns of these gas fields in

Dutch infrastructure to support economic developments. In the early 1990s, the government decided to spend part of an investment fund in "research infrastructure", and since has increased the allocation to research. In two earlier rounds it spent approx € 114 M and € 211 M. In 1998, an inter-ministerial committee started preparations for a third round of € 800 M, known under acronyms BSIK or ICES/KIS 3. At the end of 2000, it identified nanotechnology as one of eight themes for funding.

Early 2001, a task force, which was set up by the inter-ministerial committee, brought the groups from Groningen, Twente and Delft around the table with other interested groups so that the contours for one common proposal could be sketched. Later that year, the researchers developed a full program proposal, titled NanoNed, which at the end of 2003, received about € 95 M funding for a five year period. A huge amount compared to the € 3 M that FOM, NWO's division for physics, spent on nanotechnology in 2002. The division for Chemical Sciences spent a smaller amount. Compared to NWOs total budget, NanoNed annual budget of € 19 M equals around 3,8% of NWOs budget in 2006, and 5% of its budget for research grants.

Thus, NanoNed caused a change in the distribution of resources and affected the research council's intermediary position. For nanotechnology, researchers could turn to government directly. FOM decided to respond. In October 2004 it published its strategy plan for the next six years in which it adopted nanotechnology as a new priority. FOM pointed out that NanoNed was an application oriented program and that there was a need for a complementary basic research program. A few months later, FOM and STW, NWO's division for technology related research, furthered their efforts by launching the Blank committee, named after the committee's chair. It developed a 'national nanoscience program', which was taken up in NWO's next strategy plan, published in May 2006.

In the course of that year, NanoNed, FOM, STW and two other NWO divisions teamed up to form the Netherlands Nano Initiative (NNI) and in the autumn, the Dutch Government published a White Paper on nanotechnology in which it encouraged the NNI to develop a national research agenda. For NanoNed, it opened an avenue for follow-up funding. For FOM and STW, it offered a venue to play a role again in Dutch research policy making for nanotechnology. NNI developed a national research agenda in the course of 2007 and 2008, based on the work of the Blank committee and extended with input from the White Paper and from workshops organized by NNI.

The Dutch government meanwhile developed plans for a fourth ICES/KIS round. The change in resource distributions that was felt by FOM for nanotechnology, was also felt by NWO and Dutch researchers in relation to the entire third round of ICES/KIS. NWO had publicly opted to take on the priority setting role. Its new chair, J.J. Engelen, suggested that the funds would be given to NWO to distribute. NWO did receive a role in the fourth round in that NWO staff participated in the organization and expertise of NWO staff could be invoked in the organization of the scientific peer review (Commissie van Wijzen ICES/KIS, 2009, p. 2 - 3)[x].

4.4 Norway

During the past decade and a half, two major reorganizations transformed the Norwegian research councils and agencies into the Norges Forskningsråd (NFR) as it is known today. The first comprised a merger in 1993 of five research funding bodies, funded through multiple ministries, into one council with six divisions under primary responsibility of the

Ministry of Education, Research and Church Affairs. The second reorganization took place a decade later when after an evaluation of NFR's functioning[xi], its internal structure was changed from disciplinary into functional. The primary division differed fundamentally from the previous one and from those used by many other research councils, in that it was not based on a disciplinary or theme wise compartmentalization of research, but on NFR's main tasks of science promotion, policy advice and stimulation of innovation[xii] through the Division for Science, the Division for Strategic Priorities and the Division of Innovation respectively. Divisions for basic scientific research had become departments within the Division for Science. The Division for Strategic Priorities became responsible for Large Scale Programs, a newly introduced funding instrument covering research activities from basic research to innovation in strategic areas, like genomics and nanotechnology.

Almost at the time of the evaluation of NFR, the University of Oslo decided to prioritize the field of materials research, which had recently changed or was in the process of changing from structural materials research into functional materials research. It organized a national consortium called FUNMAT and developed a research agenda which also addressed nanotechnology. After an unsuccessful attempt to acquire funding at NFR, FUNMAT turned to the Ministry of Science and Education and convinced it of the need for funding. This was the start of a multi-step development of the NANOMAT program and its successor, NANOMAT phase 2, at NFR. These steps involved a shaping and reshaping of the program for materials research and nanotechnology.

One part of the shaping of the first NANOMAT program was the merging of the Ministry's labeled budget for materials research and a nanotechnology program which two NFR divisions had been developing. As a consequence, nanotechnology was defined in service of materials research:

> "Nanotechnology includes nanoscience, and may be defined as:
> new techniques for synthesis and processing, including manipulation and assembly using nature's own building blocks (atoms, molecules or macromolecules), for the intelligent design of functional materials, components and systems with attractive qualities and functions, and where dimensions and tolerances from 0.1 to 100 nanometres (nm) play a decisive role." (NFR, 2003, p. 2)

This description does not address nanotechnology's interdisciplinary character and elsewhere in the program brochure it is acknowledged implicitly or as self-explaining. The list of program's thematic priorities shows an emphasis on materials research and a familiar subdivision of nanotechnology along existing disciplinary lines:

> "Nanotechnology and functional materials in:
> - o Energy and the environment
> - o Electronics, optics and communications
>
> Nanomaterials
> Other functional materials
> Bionanotechnology
> Design, theory and modelling
> Infrastructure and nanotools
> Ethics, the environment and society." (NFR, 2003, p. 6)

The shape of the program was also influenced by the 2003 reorganization of the research council. Just after the reorganization six Large Scale Programs were launched, one of which was NANOMAT. To fit to the design of the newly funding instrument NANOMAT covered both basic and applied research, though around 80% of the budget went to basic research. NANOMAT started in 2002 and ran till 2006. Its total budget was NOK 337M, about 1.3% of NFR its budget over these years.

A few years after the launch of NANOMAT, in the course of regular policy making processes, the Ministry of Science and Education presented its new multi-annual White Paper. It listed materials research and nanotechnology as one of seven national priority areas. In response, NFR launched an expert panel to develop a National Strategy for Nanoscience and Nanotechnology. In view of nanotechnology's interdisciplinary character and its wide range of applications, the expert panel proposed to completely re-organize the position of nanotechnology in relation to both the White Paper's priority categories as well as NFR's Large Scale Program and other instruments. Basically, it proposed to give nanotechnology a new status through a 'New Nano Program'. The program would be a new type of funding program in basic research and infrastructure, in materials research and an integration of nanotechnology in other areas. In addition, the expert panel pled for a separate national council that would coordinate all nanotechnology research in Norway.

Neither the Ministry, nor NFR followed these proposals. NFR did launch a follow-up of the NANOMAT program, called NANOMAT phase 2 and incorporated elements from the panel report. This included the subdivision of the program in the areas 'Energy and the environment', 'ICT inclusive microsystems', Health and biotechnology' and 'Ocean and food'. It also included the suggestions for funding of equipment and facilities which in turn were a further development of such instruments in the first NANOMAT program.

Other changes introduced with NANOMAT phase 2 was a 50-50 division of budget over projects for basic and applied research respectively and a decrease of attention to materials research. NANOMAT Phase 2 thus replaced the definition of nanotechnology in terms of materials research by a more common definition of the field. "Nanoscience and nanotechnology (nanoST) is about deliberate control of materials and processes on the molecular and atomic levels" (NFR, 2007, p. 3)

5 Discussion and conclusions

Based on resource dependence theory we hypothesized that councils who fund research to contribute to societal goals are more likely to create research programs to support nanotechnology. Moreover research councils with a functional structure will signal earlier nanotechnology as an area for program funding. Translated to our cases, we expected that the Norwegian Research Council would have been the most active of the four councils in funding, while the Academy of Finland would probably limit itself to funding through open competition. NWO’s mission would require them to fund, but whether they were able to see nanotechnologies importance was uncertain, as a functional unit for strategy making is lacking. SNF on the other hand has a functional unit for programmatic research, but the response is not of main importance in terms of its mission.

Our findings partially support our hypotheses. Looking at the size of the response we indeed find that RCN had the largest nanotechnology program. Its first Nanomat program lasted for five years and had an annual budget of about 1.3% of RCN its total budget. The second program is scheduled for the period 2007-2016 and its budget claims towards the government are at least similar. The SNF had two programs, a five year program and a seven years program, both with a size of 1% of SNF its total budget. The Academy of

Finland had a response, but a small one. Its two research program took just three and four years, and had a budget of less than 1% of the total budget for research funding. (See Table 2) NWO deviates from the pattern predicted by RDT. Its response was only by flagging nanotechnology as a priority, but without providing substantial extra funding. The first proposal for a program was not rewarded, and in the years after NWO was by-passed: researchers got their money directly from the government through the gas revenues.

There is another remarkable deviation from our hypothesis. Though the Academy of Finland and SNF do not have an explicit strategic task to meet societal demands for research, they launched programs in the second half of the 1990s. In the other two countries, there were some initiatives and signals from foresight exercises around that time, but it took much more time before they were translated in a strategy. Both in the Netherlands and in Norway the research councils failed to acknowledge the importance of the first program proposal and in both countries researchers got their funding through government support. In Norway a nanotechnology program was launched in the course of a reorganization of the council. In the Netherlands, the research council simply was put off side for a couple of years. Through collaboration with the government funded research program it managed to be involved in agenda setting.

Table 2: overview of nanotechnology program's budget sizes

Research council	**1st response** (years)	**Size** (% of total budget)	**2nd response** (years)	**Size** (% of total budget)
Academy of Finland	1997-1999	0.7%	2006-2009	0.8%
SNF-Switzerland	1995-1999	1%	2001-2008	1%
NWO – Netherlands	2001-2004	--	2007	--
RCN Norway	2002-2006	1,3%	2007-2016	unknown

Our second hypothesis states also that research councils with a strategic functional unit will develop dedicated programs, whereas the disciplinary organized councils will fraction support along disciplinary lines. The results show little support for this hypothesis. NANOMAT Phase 2, developed when RCN had a clear functional unit for strategic investments in research, has a clear interdisciplinary character, other programs deviates from the hypothesis. The strategic response of NWO's divisions support the complementary statement that without functional unit responses will be organized along disciplinary boundaries.

On the other hand, the Academy of Finland shows that its disciplinary structure is no hindrance to it developing funding programs that have either no division of nanotechnology or a non-disciplinary division, say, a 'native' division of nanotechnology. Moreover, the programs of SNF and RCNs first NANOMAT program, all three from research councils with functional units, show a different pattern in terms of their definition of nanotechnology. These programs are more or less following upon earlier initiatives in material sciences and their position within the emerging field of nanotechnology. While RDT suggests that functional units for strategy development enables research councils to make more independent strategic choices, we find for these programs a strong dependency on researchers input.

When RDT was proposed, it was an explicit divergence from then mainstream organization studies which focused mostly on internal structures and functioning of organizations. We took up RDT for research councils because of its focus on changes in the organization's environment. Other studies had looked to more stable contract-like relationships with the government. Nanotechnology, although a major development in S&T, did not constitute large enough external pressure on RCs to adapt their internal organizational structures. The theory deals with changes and responses to changes as short term, one-of cases. This overlooks at least two important points.

First, research councils do not only respond to developments in their environment, but in the course of time, through their actions also contribute to the shaping of their environment. This includes routines for external actors to respond to emerging science and technology. Research councils distribute resources, and through their selection mechanisms they shape research landscapes. The more researchers are dependent on external funding, the bigger the influence of the research councils can be. This has consequences for later changes and responses. One of the challenges to research councils identified in the introduction concerned the difficulty of knowing how a new field should be defined or outlined. The Swiss SNF's nanotechnology programs were divided along disciplinary lines, even though they were created outside SNF's disciplinary divisions. Researchers developing these programs apparently were inclined to use existing disciplinary divisions to structure the programs. Similarly, NANOMAT had an orientation to materials research because of existing research groups in materials research. So, subdivisions made by research councils as well as researchers are a result of structures of existing national research landscapes, which in turn and in part are the result of earlier resource distributions. Thus, organizations in the course of time shape a web of resource distributions, which they do not control as a spider controls its web, but which limits and shapes its possibilities for maneuver. Changing such a web is possible, but takes time.

The second point RDT overlooks, is that environmental changes and responses to it take time. The field of nanotechnology did not grow overnight but took about 15 to 20 years to reach its shape and size. Equally important, responses by research councils were not developed overnight. The Finnish case shows that discussing proposals and balancing or aligning internal interests can take years. The Dutch NWO divisions spent around four years on regaining a place in Dutch national agenda building for nanotechnology. All four cases show that responding to a field may include multiple funding programs, sometimes direct successors and sometimes with five years in between.

Taking our findings vis-à-vis our hypotheses into account, the cases add up to a pattern of different stages of reluctant adaptation to change. In a first stage a new field like nano is around, but just as an interest of a limited number of researchers who apply for project funding. The emergence of nanotechnology becomes visible to research councils through the use of the 'nano'-label by researchers, in titles and texts of their applications. No special response from the councils is required. They can accommodate the emerging field through their open project funding instrument and funding programs that happen to accept nano-proposals. Nanotechnology's interdisciplinary character and wide range of possible applications allows proposals to go to a variety of programs. At this stage, research councils do not enact nanotechnology as a new and promising field that they have to do something about. When the use of the label continues and expands, this may change.

In the second stage the new field is recognized as a promising field for additional investments. The new field gets a label, in this case nanotechnology, and as such comes to the research councils' attention. Sometimes also ministries or government agencies acknowledge the field as of strategic value to the national interest. Government and researchers expect research councils to address the field and enact upon the new field as a new field requiring extra funds. Basically, a research council has two options: to yield to the pressure, or maintain its own course. If they do not take any action they may legitimate that by pointing out how much is done already through business-as-usual. For example, they can look for the occurrence of the nano label in their funding portfolios and identify projects and programs that fully or partly address issues that fall within a particular definition of nanotechnology. This starts as a continuation of Stage 1 response, but an account has to be offered, and this can lead to further questions and thus further pressures.

Ongoing events may move to a third stage of institutional change, especially when actors insist on special treatment for the new field. These may be researchers who find that existing funding opportunities do not meet their needs to further develop the field. These may also be actors within research councils, as the history of the US NNI shows. Governments or ministries may benchmark national against foreign developments and conclude that novel measures are necessary. Not all these actors have discretionary power to release substantial additional resources. Ministries and government agencies have such a position, and sometimes research councils themselves. For research councils, the important point of this stage is not the institutional change per se, but that the response to the new field gets linked to other, political developments and deviate from existing routines of the council. As a result the council might be bypassed or the new field may be used as leverage by external actors to enforce internal changes.

This may add up to a fourth stage of organizational changes. With reference to our cases this is still a speculative one, but both in Norway and the Netherlands there were some indications. In both countries panels preparing next programs for nanotechnology, advised strongly to create separate divisions or funding bodies for nanotechnology, arguing that nanotechnology was more than just a new field, but a major change in science and technology requiring its own "disciplinary" organization.

Our findings have important implications for the role of research councils in research systems and especially expectations one can have of these councils to respond to emerging fields. Research councils are dealing with many changes related to their resource dependencies. Besides developments in research, these include changes in demands from government, overall budget cuts due to economic crisis, occasional budget spikes, pressure from industry and other non-governmental actors. An emerging new field such as nanotechnology is thus just one element in an evolving web of resource dependencies in which research councils operate. As a result of their intermediary position in a web of resource dependencies, research councils are relatively conservative organizations.

For quick responses to new fields of science and technology, there currently seems to be an gap in funding instruments between stages one and two. Research councils better address that by creating priority setting and funding routines facilitating initiatives from researchers to respond to emerging fields. "Bottom up" as research councils like to label such initiatives. Such programs will be of limited size and duration and may have follow up programs. Or they may not: resource demands from researchers are not unified as a council deals with many different disciplines and sub-disciplines to whom nanotechnology, or any other new field, is not equally interesting. This means that when substantial demand for funding of nanotechnology occurs, councils still need to balance that against other demands from other researchers.

Furthermore, the development of larger programs requires involvement of more researchers and maybe funding actors, and thus requires more time. For more substantive responses and programs, bottom-up processes are not enough. If one expects research councils to have a key role in creating such substantive programs, separate units and budgets are required that enable steering actors to enforce essential characteristics like interdisciplinarity, the linkage of science and technology or the involvement of industry and other actors.

Acknowledgements

This article is based on research performed at the Department of Science, Technology, and Policy Studies (STePS) at the University of Twente. It received additional support from the Institute for Innovation and Governance Studies (IGS) of the same university. Writing of the article was performed at the Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE) of Lund University and the Rathenau Institute in Den Haag. We would like to thank all interviewees for their cooperation.

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[i] The periods indicate when a particular field developed into a major category in research institutions. In each case, earlier developments can be identified.

[ii] Chubin & Hackett (1990, p. 66) report that 61% of respondents to a survey agreed that "Reviewers are reluctant to support unorthodox or high-risk research.", 21 % was neutral and 18% disagreed.

[iii] We use nanotechnology as the generic term. In our research we have come across actors using nanoscience, and nanophysics, nanomedicine, sometimes pointing on what they see as essential differences.

[iv] These are the divisions for earth and life sciences; chemical sciences; physical sciences; humanities; social sciences; medical sciences; physics; technical sciences

[v] The Board consists of a chair, the chairs of the Research Councils, a representative from research organizations and a representative from industry.

[vi] ESPRIT is the European Strategic Program for R&D in Information Technologies, launched in the early 1980s. It was incorporated in the European Union's first Framework Program and had follow ups until and including the fourth Framework Program which ended in 1999. (Guzzetti, 1995, p. 76 - 82; Rogers, 1997)

[vii] Väänänen became Chair of the Research Council for Health in 2004.

[viii] See (Braun & Benninghoff, 2003) for a history of the development of the NCCR instrument.

[ix] MINAST was an SPP on micro and nanotechnology which was administered by the ETH Board and ran parallel to NFP 36

[x] This limited role was publicly contested by a number of scientific organizations, including NWO, through a letter to Parliament. The organizations argued that scientific evaluation of proposals should be delegated altogether to NWO. (Dijkgraaf, Engelen et al., 2009)

[xi] See (Arnold, Kuhlmann et al., 2001) and the accompanying background reports.

[xii] Another important difference between many research councils/agencies and NFR is that within NFR science support, technology development support and innovation is combined in one funding council.

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