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Scandinavia

Inertia and change in Scandinavian public-sector research systems: the case of biotechnology

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This article reviews and analyses recent reforms of research funding in Denmark, Norway and Sweden where research councils traditionally have been the dominant funding mechanism. It analyses how the research council system is affected by changes in the political, economic and cognitive environments of public-sector research (PSR) and how the councils try to adapt to the changing conditions. Inspired by institutional theory the article starts with a discussion of path-dependency in PSR systems. A survey of the development of research councils in the Scandinavian countries traces the changing organisation and orientation of research councils in relation to political, economic and technological processes, and in particular how they have adapted to the emergence of a new research area, biotechnology, where the boundaries between science and technology, academic research and commercial application, are blurred.

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DIFFERENT MODELS FOR FUNDING public-sector research (PSR) have emerged in the post-war period (Senker *et al,* 1999). One, developed in countries such as Germany and Italy, is to a large extent based on 'general university funds'. Funding from central government, sometimes in combination with funding from regional governments, is distributed at the university level.

Other countries, such as the UK and Sweden, have developed a dual system. 'General university funding' or 'floor funding' to the universities is in the form of a general government grant that covers equipment and parts of researchers' wages while the rest is allocated through research councils using response-mode operations with a competitive peer-reviewed selection process. Funding from mission-oriented agencies has grown as an alternative route in most countries. That type of support has most often been the responsibility of the existing research councils, but in several countries separate mission-oriented agencies have been established.

The following analysis will concentrate on the function of the research councils in the PSR. Our hypothesis, generated from neo-institutional theories of political and organisational change, is that reform of organisational routines and missions is difficult to achieve, although it is possible depending on the flexibility and what kind of institutionalised support and established routines there are in the system.

The research council system was established as an organisational model adapted to specific conditions prevailing at that time. When new demands and conditions for knowledge production and academic

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research have emerged, this has put the research councils under severe stress and difficulty in adapting to the dynamics of new areas, new political demands and economic conditions.

With the emergence of new research patterns, especially new interdisciplinary areas, as well as intensified demands on the PSR to contribute to economic and technological renewal including corporate competitiveness, systems of PSR funding have come under great strain. A hypothesis is that, in countries dominated by research councils, the councils will either be reformed or their traditional structure will be reproduced, but at the cost of an increasing financial and organisational marginalisation in the PSR system. The outcome of the selection process is not given once and for all. On the basis of our study, we will contribute to the understanding of the functions of the research councils in contemporary PSR organisations and knowledge production, as well as shedding some light on the theoretical debate on the process of organisational continuity and change.

Path-dependency and organisational reform

We use the concept of 'research governance' to denote an ideal-typical model of research support, organisation and reward. We identify three such governance models: response-mode; 'block-grant'; and interventionist.

As an ideal-typical construct, research councils are steered by academics and support high-quality research, as defined in a peer-reviewed process. Collegial procedures are therefore closely connected to the response-mode model. The councils themselves tend to have small central offices and are governed mainly by the boards and committees evaluating the project proposals. Expertise is normally recruited for certain periods of time, often three to six years.

The response-mode model is an institutionalisation of a particular mode of academic research based on disciplinary boundaries, academic self-regulation and project organisation. Hence, researchers in PSR systems governed by research councils organise their work in a relatively autonomous and decentralised fashion (Sandström, 1997).

In some countries, 'floor funding' or block grants have become the primary model of research governance. Here, research management is concentrated at the departmental level, where senior researchers organise and structure the performance and evaluation of research. This governance model is therefore accompanied by a more hierarchical organisation of academic research where the profile of local laboratory management is central to the development of PSR.

A third model of research governance could be labelled 'interventionist'. It shares some of the characteristics of both the first and the second model. It is decentralised and project-oriented, but is also based on a greater amount of steering of the daily practice of the researchers. The mission-oriented agencies, which are at the centre of this governance model, can also be expected to direct the efforts of supported researchers into desired paths.

Table 1 explains this interpretation of the different governance models.

Our argument is that the evolution of a PSR system is path-dependent. The future development of PSR is locked-in because of choices of institutional design that imply long-term consequences for routines and roles within the system (Arthur *et al*, 1987; Pierson, 1994). The formation of a funding structure based on the research councils around World War II is, we argue, an example of such a "formative moment" (Rothstein, 1998). It laid the basis of a particular structure and organisation of PSR, including a specific form of research organisation around projects rather than departments or laboratories, steering being based on initiatives taken by individual researchers and a research ideal based on progress along disciplinary lines and collegial recognition.

The choice of maintaining the 'block-grant' model in other PSR systems also can be seen as formative, however in a different direction. The political ambitions in many countries during the 1960s and 1970s to steer research into targeted areas of social and economic importance represented an attempt to develop a new governance model for research (Rothschild, 1971; OECD, 1971).

The impact of formative moments can be broken

Table 1. Ideal-typical PSR governance models

Funding model	Research organisation	Steering	Ideal
Response-mode	Project	Expert/peer	Discipline
Block grant	Group	Local management	Discipline
Interventionist	Group	Political	Relevance

under certain circumstances such as economic or political changes, or reforms of research policy. Some of these changes may be of a more cyclical character, such as economic downturns, while others are of a more fundamental character such as the emergence of new technologies, or a reconstruction of the international economy. An important element in the understanding of changes in PSR is therefore the political preconditions for organisational reform and retrenchment.

Key actors in the process include policy-makers, representatives of the research councils, academics and industrialists. Pierson (1994), in a study of reforms in social policy, has emphasised the role of policy constituencies and policy feedback in reforms of the public sector. A policy constituency consists of the interest groups influenced by public policy. Policy feedback refers to the consequences on these groups of policies pursued:

> "… previous policies matter because they help shape the distribution of political resources (including information) and provide the raw material from which retrenchment advocates must try to design successful strategies." (Pierson, 1994, page 50)

The argument is therefore that earlier policy choices create a policy constituency and provide it with certain resources. This in its turn makes it difficult to enact major changes in that policy area in the face of opposition from those groups. For PSR systems dominated by research councils, a 'scientific community' based in the university system seems to be the most important interest group, in contrast to the 'block-grant' model which instead creates a policy constituency of department leaders and laboratory managers.

The interventionist governance model, on the other hand, is based on networks of political, social and economic agents attempting to re-focus academic research. If radical reforms of PSR are to be successful, they must be able to break the strength of these interest groups, or their interests have to be redefined. Furthermore, new coalitions of actors have to be established around the new targets (Hall, 1999).

From the perspective outlined above, a number of questions arise when studying PSR changes and reforms of the research council system. Who and what form the organisational structure? When and why do radical shifts in organisational structures and routines take place? How will the research council and its policy constituency system be affected by changes in the political, economic and socio-cognitive environment of PSR? We begin with a short description of contemporary changes in the economic, political and cognitive landscape for PSR.

Research policy in the 1980s and 1990s world-wide has stressed that PSR should contribute more directly to economic growth, and that scientific research should be evaluated not only on the basis of scientific excellence but also societal utility

Changing conditions for public-sector research

The interaction between models of research funding and the evolution of the organisational structure of PSR systems is a good illustration of our argument. The research councils were established as organisations to integrate the interests of the academic and political systems in the modernisation of academic research. The key groups acting in favour of the institutionalisation of the new form for research funding during the 1970s were, generally, politicians, top bureaucrats and leading academic researchers.

There were a number of exogenous factors stabilising this model of research funding. The dominance of research councils in some PSR systems can be explained by the combination of a benevolent political climate towards academic self-regulation, relatively closed domestic economies regulated by demand-side management, and an innovation process with relatively clear boundaries between academic research and industrial development (Slaughter and Leslie, 1997).

During the last few decades, the exogenous factors influencing PSR systems have changed. Research policy in the 1980s and 1990s throughout the world has stressed that PSR should contribute more directly to economic growth, and that scientific research should be evaluated not only on the basis of scientific excellence but also societal utility (Etzkowitz *et al*, 1998; Ziman, 2000).

In more concrete terms, this policy is expressed in increased ambition to commercialise the result of PSR, a growth of industrial liaison offices, and proliferation of technology transfer functions, science parks, and so on adjacent to the universities. This has been coupled with a growing orientation among university presidents to strengthen their managerial capacity (Clark, 1998; Slaughter and Leslie, 1997). The general objective of these changes has been to reduce academic self-regulation and to establish closer linkages between academic research and socio-economic development.

The reorientation of policies for PSR is related to the increased globalisation of the economy. With the integration of world markets for products and services, many of the traditional instruments of national governments to foster economic growth are seen as inefficient. The demand-side orientation of the post-war era has been replaced with a supply-side orientation of public industrial policies.

This has led to the emergence of policies based on the assumption that governments can underpin the growth of high-technology sectors. By supporting R&D in fields where the boundaries between basic and applied research, and between public and private R&D efforts, are blurred and where innovations emerge out of highly institutionalised systems, these objectives can be achieved (Ostry and Nelson, 1995). This way of conceiving the interaction between the state and the market in the innovation process has often been referred to as the "systems of innovation" approach (Edquist, 1997).

One major element in the changing environment for PSR and its funding is the socio-cognitive forms of contemporary academic research. It has been widely claimed, for instance by Gibbons *et al* (1994), Ziman (2000), and Etzkowitz (1998), that the nature of knowledge production has changed. In cognitive and organisational terms, knowledge is produced in similar contexts to the application of that knowledge. The boundaries between public and private R&D are becoming less distinct with the expansion of science-based technologies and interdisciplinary research fields. Furthermore, new areas of scientific research often grow in-between established research trajectories.

An example of such interdisciplinary knowledge areas, with blurred boundaries between public- and private-sector research, and with clear commercial applications involved, is biotechnology. We will use this example in the following empirical analysis of how Scandinavian PSR systems respond to exogenous changes.

New landscape for research

On the basis of our theoretical discussion, we would expect the emergence of a 'negotiation' between the new demands on PSR and the existing organisational model for academic research. The key issue for the empirical part is to study the adjustment of one particular organisational form to changes in the political, economic and socio-cognitive landscape for research, and in particular how that adjustment process is related to different forms of research funding.

The changes in knowledge production, political demands and world economic changes can be expected to have a major impact on the organisational structures and routines, and reward models of academic research. Generally, we expect this change to influence three important dimensions in how academic research is funded: the organisational model; the decision-making structure; and the criteria for evaluation.

The first dimension covers the relationship between socio-cognitive developments and programme structures within the funding agencies. The second covers the relationship between individual researchers (and their projects) and funding agencies, where priorities are set and how grants are awarded. The third dimension is related to evaluation of investments in public R&D, and the patterns of behaviour among academic researchers that are encouraged.

On the basis of our discussion of changing conditions for PSR, we would expect the emergence of interdisciplinary and transinstitutional organisational structures, crossing disciplinary boundaries and involving a mixture of private and public participants and decision-makers. Furthermore, we would expect the expansion of large-scale programmes developed in collaboration between funding agency officials, representatives from industry and other PSR actors.

In addition, we would expect the proliferation of evaluation criteria blending quality assessment with emphasis on relevance and utility of PSR. Finally, our assumption is that the changes mentioned above to a large degree will be channelled through, and influenced by, the existing modes of research governance. Hence, we expect a path-dependent change in PSR governance, depending on the traditional forms of governance in the different countries.

In the following, we proceed along two tracks. First, we compare the evolution of PSR funding in Norway, Sweden and Denmark. Then we analyse how the systems of PSR support and organise biotechnology research.

Norway — an extended council system

In Norway, funding of academic research is dominated by a number of research councils, which have quite different organisational structures and modes of operation (NOU, 1991, no 29). Three research councils were established in the 1940s, two with an application orientation (industry and agriculture, respectively) and one with a more general orientation covering basic research for medicine, natural science, the humanities and social science. In the 1970s, two councils for applied social science and fishery were also established.

This organisation deviated considerably from the ideal-typical model of a research council. Particularly, the council for technical research was more of a traditional sectoral agency with the aim of supporting technical development in the business sector. Other councils maintained the tradition of academic self-regulation, with a 'bottom-up'-approach in relation to academic researchers.

There were attempts to refocus the funding model in these more traditional research councils as well. The most notable example was the large 'focus programmes' of the 1980s, in which academic researchers were invited to participate in interdisciplinary and mission-oriented structure programmes. They covered areas such as the oil industry, fisheries and renewal of the public sector (Mathiesen, 1996).

The research council system was reformed in the 1990s. All research councils and mission-oriented agencies were merged in 1993 into the single all-encompassing Norwegian Research Council (NFR).

The motive for the reform was to increase the interaction between basic and applied research and to make the Norwegian R&D system more efficient. Generic technologies, such as biotechnology, were said to make "it pertinent to abolish borderlines and only have one funding agency" (NOU, 1991, no 29; see also Skoie, 2000). It was also said that a single council would make it easier to establish and pursue international co-operation in research, for instance, within the EU (European Union).

Following the reform, the structure of the council is based on societal areas rather than traditional disciplinary boundaries. It includes the following divisions (or sub-councils):

Industry and energy (IE)
Bio-production and processing (BP)
Environment and development (ED)
Culture and society (CS)
Science and technology (NT)
Medicine and health (MH).

The board of the NFR is composed of a majority from academic institutions, but representatives from industry and interest groups are also included. The divisions do not have a common set of board representation: some, such as the division for science and technology have equal representation for academics and non-academics, while the division for industry and energy only has one academic board member and six representatives from industry.

The NFR as an organisation represents an interesting mixture of centralisation and decentralisation of the decision-making structure (Langfeldt, 1998). Common for all NFR divisions is a programme consisting of mission, priorities and implementation structure, but the council seldom influences the decision-making process of the divisions. Programmes — strategic and user-oriented — are an important part of the funding schemes in several of the divisions. Support to the very large institute sector is another big part of the council missions. One third of total Norwegian funding is allocated to the research institute sector.

The council divisions have quite distinct modes of operation for handling bottom-up-applications, which more or less resemble those existing prior to the creation of the NFR. MH and ED both have permanent committees making priorities among applicants. NT instead sets priorities on the basis of external referees, one Norwegian and one international — a procedure that leaves a large share of influence to the programme managers. Agency administrators, who make priorities on the basis of peer evaluations (reviewers are engaged on *ad hoc* basis) dominate the decision-making structure of the BP.

Despite these differences, as Langfeldt (1998) emphasises, the establishment of the NFR has contributed to a convergence of the decision-making structure in one respect. The share of funding that goes to large-scale programmes has generally increased, while the percentage of small-scale project support has decreased. The exception to this development is MH, which has retained a tradition of many smaller projects (currently about 40% of its total support).

As a result of the establishment of the Norwegian Research Council, the share of funding that goes to large-scale programmes has generally increased, while the percentage of small-scale project support has decreased

The sub-councils, similar to the research councils in Britain, have a mission statement, blending traditional basic research tasks with a more distinct application- and interaction-oriented role. Divisions are obliged to fulfil three tasks: funding research; counselling; and supporting and building knowledge networks. As we shall discuss later, the relative importance of these tasks varies between sub-councils.

The programme structure is different, since some councils mainly have a project-based structure, while others are based on large, programmatic efforts. According to Kyvik (1997), government-initiated R&D programmes in target areas were established in the 1980s as an innovation in the funding structure for enhancing the interaction between institutes and university research.

This difference is also reflected in the evaluation practices. Basic research programmes emphasise international peer review and the criteria of 'success' are mainly composed of traditional targets of publication and PhD degrees awarded, although other criteria, such as patenting and industry–university collaboration are also included sometimes.

More applied programmes have a more marked 'managerial structure', where the programme directors approach research groups and try to establish research collaboration between PSR actors and private-sector researchers. Evaluation criteria are also more mixed, including scientific quality and merit, as well as studies of relevance and utility.

Norwegian research governance represents a mixture of mission-oriented and discipline-based models existing in parallel, but without complete integration. One possible reason for this state of affairs could be that the NFR budget is based on appropriations from several ministries, not only the Ministry for Education and Research, but also the Ministries of Health, the Environment and Industry. Arguably, the fact that the council is funded from multiple sources has reproduced the policy communities connected to each of the separate agencies and research councils before they merged. This sector-wise governance model therefore seems to have survived the reform of the research councils in the 1990s, although all councils,

including those with an orientation towards basic research, have made some adaptations towards a new mode of funding. This new mode includes, as indicated above, a larger share of large-scale support to research programmes (at the expense of smaller projects).

Sweden — layers of research governance

Funding of Swedish PSR has emerged in three distinct phases (Stevrin, 1978; Sandström, 1997). The first phase, in the 1940s, consisted of the creation of research councils for different areas. Many of these councils were both basic and applied in orientation. The second phase, beginning in the 1960s and 1970s was a reform era in Swedish research policy. A whole array of mission-oriented agencies was established, some on the basis of the application-oriented research councils, others as major new agencies in areas with little or no earlier PSR funding.

This 'second layer' of PSR funding and research governance developed evaluation criteria of a completely different kind from those of the first. Here, socio-economic relevance and utility were the programmatic targets, and non-collegial orientation were the basis for selection and evaluation criteria. During the 1980s, and as a result of criticism from academic researchers, the orientation towards relevance and utility was modified, and the mission-oriented agencies introduced selection and evaluation criteria partly inspired by those of the research councils.

At the same time, Swedish research funding was subject to an increasing amount of political centralisation, for instance, when in 1981 a three-year research bill was introduced to co-ordinate the actions and strategies of research councils and mission-oriented agencies throughout the entire government administration. The effects of the centralisation have been relatively meagre, though, and, as we shall argue below, there are marked differences in how different funding agencies organise their research support.

The third phase began in the early 1990s when a new infrastructure for academy–industry collaboration, with an emphasis on graduate training and research, was established. The organisations instituted in this phase, mainly a large number of foundations, formally independent but founded on the basis of parliamentary decisions, represent the third layer of research governance in Sweden.

The current model of research governance in Sweden is therefore pluralistic, as in Norway (Benner and Sandström, 2000). The Swedish research councils are based on a bottom-up approach, and have few programmes of a more targeted nature, in contrast to the NFR and its divisions in Norway. Generally, their Swedish colleagues shun this kind of steering and instead rely on the spontaneous organisation of research through grant applications (Sandström *et al*, 1997). The networks of the research councils are based in the corresponding scientific communities.

Currently, there are four traditional research councils under the Ministry of Education — for medicine, engineering, natural sciences, the humanities and social sciences — and two under other ministries — social research, and forestry and agriculture. In financial terms and not counting the general government grants to the universities, the research councils represent about 25% of total PSR expenditure (see Table 2). The mission-oriented agencies have a much more focused and managerial structure, stressing certain types of research organisation — for instance, academy–industry collaboration — and change the focus of their support according to factors such as changes in the industrial structure and the knowledge interests of sectoral agents. The mission-oriented agencies, of which there are well over 100, account for about 30 % of total R&D expenditure (not counting 'floor funding') in the Swedish university system.

The new research foundations established in the mid-90s incorporate organisational elements from both the research councils and the mission-oriented agencies. They have relatively small secretariats and depend on externally recruited expertise. They have an elaborate steering structure, including central strategy committees and steering committees for the projects supported. The foundations have developed mixed networks, with industrialists, civil servants and academics on their boards and steering committees. Their financial support of university research accounts for about a 15–20% (in 1999) of universities' total expenditure, not counting the 'block grants'.

Swedish research governance thus is pluralistic and involves several models of governing research — disciplinary, targeted and strategic. In many respects Sweden represents an even more mixed version of the ideal-typical research council model than does Norway. The major difference between Sweden and the other Scandinavian countries is that pluralism is not organised within a single organisational structure (that is, the research council system), but rather as

Table 2. Funding of university research in the Nordic countries, financial year 1997

Country	General government grant	Research councils	Other government agencies	Private	Foundations	Foreign	Sum
Norway	69	14	6	5	3	3	100
Denmark (1995)	67	16	7	2	4	4	100
Sweden	52	12	14	4	14[a]	5	100

Note: [a] Including the new research foundations
Sources: SCB (1999); Kyvik (1997); Gulbrandsen *et al* (1999)

different layers of PSR support with fairly distinct roles and modes of operation (research councils, mission-oriented agencies and strategic foundations).

Denmark — weak but unitary research governance

Denmark has been a laggard in the institutionalisation of research funding. A more stable infrastructure for PSR funding was established as late as 1968, when councils organised along disciplinary lines were established (Grønbæk, 1999).

In relative terms, research councils governed by scientists play a more important role in Danish PSR funding than in the other two countries. Hence, research governance is more unitary in Denmark than in Norway, with its heterogeneous council system, and Sweden, where councils operate in parallel with several other important funding agencies, public and private.

The six Danish research councils cover the natural sciences, medical research, agriculture and veterinary research, social science, the humanities, and technical research. The councils themselves are designed in the traditional fashion, with a dominance of academic researchers and with evaluation criteria dominated by peer-review assessment. Nevertheless, some mechanisms for concentration and organisational renewal have been established. For example, there are a number of inter-council and inter-ministerial programmes, in areas such as biotechnology, food technology, and multimedia. These programmes are funded from the councils' budgets.

Furthermore, the councils' activities are co-ordinated by a Research Forum (called The Board of the Danish Research Councils). The Agency acts as an organisational umbrella for the six councils. Other steps have been taken to increase the co-ordination of research support in Denmark, such as the establishment of a Ministry for Research, and two government committees working on research planning and co-ordination. Hence, the Danish system is marked by, in Rip's (Rip and van der Meulen, 1996) terms, a "higher degree of aggregation".

Apart from this, the councils have been obliged to develop strategic plans since the 1980s, outlining strategic considerations and priorities for a five-year period. A number of cross-council strategic plans were also devised in the 1990s, focusing on areas of interdisciplinary collaboration with large societal interests, including biotechnology and food technology (OECD, 1995).

The Danish research governance model is therefore also the result of a mixture of different models, although to a much more limited extent than in Norway and Sweden. There are distinct elements of the 'block-grant' model, given the importance of floor funding to the universities. Nevertheless, improved capacity for adaptation to new political, economic and cognitive demands and opportunities evidently is the consequence of the strategic and proactive role that the councils have played, and the fact that research funding is organised in a coherent and non-pluralist fashion. Councils seem to have a crucial role in the PSR system.

To sum up, and on the basis of funding sources in the academic system, Sweden is the most pluralist system blending the interventionist and research councils models of governance, but also with about half the university research funds coming as 'block grants'. Denmark and Norway combine elements of the 'block-grant' and research council governance models, with research councils playing a somewhat more encompassing role in Norway than in Denmark.

Old structures and new opportunities

The organisation of research funding in Scandinavia was reformed in the 1980s and 1990s. Also, it should be underlined that the willingness to reform the system is still there. Tasks such as supporting academy–industry contacts, the commercialisation of academic research, and interdisciplinary collaboration have in many cases been added to the existing research council mission.

The reforms do not, however, represent a major restructuring of the research governance of the post-war period. The reason for this is that the research council concept has been fairly wide and liberal throughout the whole period. The research council in its 'pure' form has always been challenged in PSR funding. Accordingly, research councils have existed in parallel with organisations primarily oriented towards utility criteria and non-collegial decision-making patterns. Sometimes, these organisations have even been labelled research councils. This is especially true for Norway but also to some extent Sweden.

The most striking feature of PSR funding is therefore neither the strength of the research councils, nor the changes in the direction of utility criteria in the 1990s. It is rather the remarkable continuity of a combination of an intra-academic research council system and a relevance-oriented mission-oriented structure. Reforms of PSR funding have therefore been modelled on the basis of the existing organisational structures.

An illuminating example is the latest proposal from the Swedish government regarding a new organisation for research funding (Government Bill, 1999/2000, no 81). The existing four councils will be merged, only to reappear as sub-councils within the centralised council (much in the same vein as in Norway). In fact, there will be only one small adjustment as a result of the reform: the Engineering Science Research Council will be merged with the Natural Science Research Council.

The Norwegian example is particularly telling in this respect, since the new organisational structure was based on elements from the incorporated agencies rather than being completely new (Skoie, 2000). The Swedish case has a similar stability, whereby the growing significance of mission-oriented agencies

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has frozen the collegial procedures of the research councils. With a slight exaggeration, it can be argued that the Swedish research councils still base their activities on procedures established after the Second World War, namely relatively small projects and priorities made on the basis of incoming proposals. Indeed, it seems as if budget cuts in the 1990s have reinforced this funding practice (Sandström, forthcoming).

The Danish model remains formally unchanged but has incorporated the much stronger directive role for the funding agencies. Hence, our conclusion is that the reforms of PSR funding to a large extent can be understood in terms of the path-dependent evolution outlined in the theoretical discussion. Denmark may seem to be an exception here, but our argument is that Danish PSR governance was institutionalised successfully only in the 1980s and 1990s. Hence, Danish research governance has been a much more open issue during the post-war period than was the case in Norway and Sweden.

Organisational structures do not tell the whole story, however. To further our discussion on the path-dependent development of PSR, we now move to study how the established structures of PSR funding cope with an interdisciplinary area with close linkages between private and public actors, namely biotechnology. What we are searching for is the organisational responses to the emergence of new areas connected with political interests, economic potential and socio-cognitive dynamism. Our hypothesis is that these new fields represent a fundamental challenge to the existing models of PSR and PSR funding.

The reason for choosing biotechnology is also because there is an interesting reference point in the form of the British government's support of PSR in biotechnology. The British case shows how radical organisational reform was actualised to improve the linkages between the academic system and industry (Faulkner and Senker, 1995, pages 65ff).

A lacklustre response by the Medical Research Council to the growing potential of biotechnology fostered the establishment of the Biotechnology Directorate by the Science and Engineering Research Council in 1981. The Directorate seems to have been instrumental in fostering a coherent approach to academy–industry collaboration in biotechnology, and in concentrating resources to a selected number of sub-fields and research locations. It provided a national focus for academic and industrial interests in biotechnology, and stimulated and co-ordinated research and postgraduate training (Faulkner and Senker, 1995, page 66).

The Directorate's organisation and work seem also to have inspired the changes in the British research councils initiated in the 1990s (HMSO, 1993; Webster, 1994). The research councils have been given a broader role, integrating in the same organisation support of academic research and network activities with industry and other societal actors. Hence, the British example indicates the possibilities of path-shaping activities, especially that which refers to imitation of successful organisational innovations.

Biotechnology is, and has been, a key priority for research policy in the Scandinavian countries since the 1980s. At the same time, it is obvious that there are marked differences between the countries when it comes to the economic and technological significance of biotechnology for the industry sector. In Denmark and Sweden, the biotechnology sector is fairly strong, while the opposite is true for Norway.

Corresponding relations can be found in data from the *Science Citation Index*: Denmark and Sweden have high relative activity and high relative impact figures in areas such as biology/biochemistry and molecular biology/genetics while Norway shows low figures in both. According to figures from the EU inventory of public biotechnology (Enzing *et al*, 1999), the countries seem to spend similar amounts of money per inhabitant on biotechnology research.

Figures on funding of public biotechnology research are hard to obtain. The breadth of the field and the varying definitions allow for different interpretations. The EU inventory, covering 17 European countries, presents a fairly good picture, but is based on a wide definition of biotech-related scientific activities.

We would prefer a more narrow definition where biotechnology is "the integration of natural sciences and engineering sciences in order to achieve the application of organisms, cells, parts thereof and molecular analogues for products and services" (see EFB). Such a definition points to the fact that biotechnology is interesting because of its transdisciplinarity and its integration of science and technology. In these respects this area of research is a challenge to the traditional systems for research funding and organisation.

Norway

During the 1980s, the Norwegian Government launched priority areas in research and a National Plan for Biotechnology was initiated. Even though priority areas are no longer a national policy measure, programmes in biotechnology have continued in different forms. The Norwegian Research Council has adopted a 'strategy for biotechnology', emphasising health care and medicine, food production and marine biotechnology. The ambition is to strengthen disciplinary research and to contribute to the emergence of

private–public networks. Biotechnology is one of the key priorities of the NFR (1998, page 65).

The existing organisation of support for biotechnology in Norway reflects the country's traditional division of labour in research funding. The division for science and technology (NT) supports basic research in the academic system, that is, bio-science. The division for bio-production and processing (BP) supports applied research in the academic system, the institute sector and to a certain extent also industrial R&D. Technology development and commercialisation in the private sector is the primary target for the division for industry and energy.

There are four major programmes for biotechnology development, two with a distinct academic orientation, a third with an orientation towards applied research and pre-competitive R&D, and a fourth with a near-market orientation.

The NT division organises the programme 'Basic Biotechnology', whose targets are to expand basic knowledge in the field and to combine the strength in biological sciences with technological development. The intention is to link the Norwegian biological researchers into the world biotechnology community, in particular through collaboration within EU biotechnology networks.

The evaluation criteria in the Basic Biotechnology programme follow the model of a pure research council, emphasising publications in international journals, and international scientific collaboration. The division for Medicine and Health has another substantial programme in this area of research — 'Cell and Gene Technology' — which targets basic sciences, its aim being to establish and support large research groups. It is claimed that the programme will be implemented in co-operation with other programmes within the NFR.

The programme established by the BP division, called 'Biotechnology', is oriented towards agricultural exploitation and "strategic basic research" (as stated in its mission statement). Some projects supported by the programme are based on a modified bottom-up approach, whereby academic researchers apply for funding in areas that have been identified by the programme directors prior to the application round.

Other projects are driven by market demand, in the form of private and public cost-sharing of pre-competitive company R&D. Evaluations of bottom-up projects are to include both quality and utility. Criteria emphasising the utility of the projects dominate in the pre-competitive projects. 'KAPBIO' is a programme for the commercial exploitation of biotechnology, organised by the industry and energy division. It is not oriented towards the academic system but is focused on industry and industrial applications of bio- technology.

Since KAPBIO is not being oriented towards the academic system, there are only two programmes that dominate funding of academic biotechnology research in Norway. They are of roughly the same size, each with an annual budget of around NOK 5 million (£400,000). Their evaluation criteria, as well as the composition of programme participants, are different. The Basic Biotechnology programme is oriented towards the scientific community and is led by a committee comprising three industrialists, four academic and institute researchers and one civil servant. Somewhat surprisingly, the Biotechnology programme has fewer industrialists (two) and more academic researchers (six) on its board.

To conclude and summarise, the Norwegian organisation of biotechnology support follows the segmentation between different funding models that was reproduced when the new research council was established in 1992, with quite distinct criteria in the selection and evaluation of projects.

Sweden

The Swedish model of PSR funding is, as we argued above, based on pluralism and a variety of governance mechanisms. Unlike Norway, the different governance mechanisms have not been established within one organisational framework (the research council system), but instead in different organisations. This has given Swedish research governance a layered structure. On top of the research council layer, mainly focused on disciplinary research, an applied research layer was added in the 1970s, in the form of new mission-oriented agencies covering a diversity of sectoral research areas, such as environment, social problems, and transportation. A third layer of support for graduate schools and large research programmes has been added in the 1990s.

The consequence is that the organisations connected with the different layers have developed different operational routines. The main mechanism for reforming PSR funding has therefore been to establish new organisations. This is in contrast to the model developed in Norway and the UK, where new routines have been established in existing organisations (although the Norwegian example was somewhat half-hearted in this respect, as indicated above).

The layered funding structure in Sweden is shown also in the three-layer biotechnology support. There are a number of programmes financed in co-operation between the state and industry, and with a marked orientation towards industrial applications and utility in existing production. In these cases, the state is represented by the National Board for Industrial and Technological Development (NUTEK). After a reorganisation in the mid-1990s, when a third of its R&D resources were cut, NUTEK has increasingly emphasised near-market R&D support financed and organised in collaboration between universities and industry (SOU, 1996, no 29).

As a result, the programmes of NUTEK in biotechnology are heavily oriented towards utility and practical applications, with tasks related to problems and issues defined by industry and in particular the process industries such as paper and pulp, and food,

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but also biomedicine. Typical in this respect is the programmatic statement of the collaborative programme for biomedicine: "The program is guided by industry's need of new knowledge and R&D resources necessary for the company's development and growth" (NUTEK, 1999).

In contrast, the research councils — in this case natural sciences, medicine, engineering sciences and agriculture operate in a bottom-up manner, responding to initiatives taken by individual applicants. With one exception, the councils do not have specific programmes for biotechnology. The exception is the Engineering Science Research Council, which has a committee for biotechnology, which has more or less earmarked funding for biotechnology (ECU 3.2 million).

This council has also supported a number of multi-project grants making it possible for research groups to combine resources and strengthen research in this costly area (Sandström *et al*, 1997). Grant selection and strategic planning are generally concentrated to peers. Industrial interests play only a minor and indirect role in the process.

From interview data, it is apparent that academic researchers ten years ago found it hard to obtain funding from the traditional research councils. Researchers from old areas did not accept the competition from new scientific areas. Biotechnology researchers were directed to foreign funding sources or to rely on application-oriented funding from the NUTEK (which had observed the potential of this area quite early). In that situation the Engineering Science Research Council made it possible to build up new basic research, but the funds were much too small.

When in 1994 the Government took a decision to transform wage earners funds into research foundations, a new avenue of funding appeared for biotech researchers. The largest of the foundations, the Strategic Foundation (SSF), opened its doors to applications for a number of new areas of research judged to be of strategic importance for the economy of Sweden, among them biotechnology.

The Strategic Foundation is interesting in many ways in this context. It supports a number of graduate schools and training programmes in the bio-sciences, including biomedicine and biotechnology. For these programmes, academic researchers join industrial researchers in organising graduate training in bio-sciences and biotechnology. Management of programmes is organised by executive boards with representation from both academic researchers and industrialists. Their daily activities are, however, organised within the academic departments where the graduate schools are located.

An overall impression is that the programmes orient themselves towards traditional research council criteria, such as publications and connections with the international scientific community, but with added relevance and utility dimensions. After only a few years, the SSF has become a substantial provider of funds for biotechnology research and its decisions are nowadays co-ordinated with the research councils. According to recent estimates (Martin, 1999; Backlund *et al*, 2000) the SSF is the single largest spender on biotechnology-related research accounting for 20% of total PSR funding (ECU 12–15 million).

Denmark

As we argued above, the Danish research council system has enabled a quicker adaptation to changes in the political, economic and cognitive environment of PSR, since the path-dependency of the Norwegian and Swedish systems were not as evident. This was because the Danish research councils were newly established , and have been more dependent on state regulation and ministerial steering than in Norway or Sweden.

This governance model has aided the development of a more coherent and concentrated model of support for biotechnology research (*Forskningsforum*, 1998). For the period 1998–2002, the research councils have named nine interdisciplinary areas of high priority, of which bio-research is one. One large programme, the Biotek initiative, was started during the 1980s. The aim was to establish a network of Danish research facilities in biotechnology. The programme is still running and has a budget of around 70 MDKK (about £6 million) per year for the next three year period. It builds on the existing research council funds for biotechnology research.

The idea behind the programme, called 'Biotechnological instrument centre', is to co-ordinate public resources for biotechnology, and to enable concentrated research efforts by PSR actors, and private- and public-sector collaboration. A central programme committee that is appointed by the Research Forum (see above) will administer this type of funding. It builds on a private/public collaborative programme for biotechnology established in the late 1980s, for which the development of co-operative research networks was a dominant target (OECD, 1995). Hence, there existed a tradition of viewing public- and private-sector research in biotechnology as complementing and integrated activities.

The intention is that public biotechnology funding should be used to develop a "centre without walls".

The centre should function as an instrument for a concentration of PSR efforts in biotechnology, with increased collaboration between different research groups with different research foci, but also as a facilitator of public- and private-sector collaboration. Hence, its activities should be financed not only by the Ministry of Education, but also by industry and by sector ministries. Private industry has also been invited to perform some of its R&D within the centre.

The evaluation criteria are close to the research council ideal, but the strategy of joining different departments from different disciplines, as well as industry, in the organisation of the programme represents a clear deviation from that ideal. The same can be said for the programme's managerial structure, which is more complex and hierarchical than in a traditional research council model.

Summary and conclusion

To sum up, we distinguish three different organisational approaches to biotechnology funding: inertia in Norway, change in Denmark, and both inertia and change in Sweden. The Norwegian model of funding PSR in biotechnology builds on an established model and a certain division of labour in the funding organisation. Biotechnology is not treated as an anomaly in the existing structure but rather as something that can be channelled through the established funding mechanisms.

In the Danish case, where the funding structure had never been institutionalised to the same extent as in Norway and Sweden, and where there existed an historical example of an integrated approach to biotechnology research and development, the development of organisational innovations has been easier than in Norway.

Sweden, finally, supports biotechnology R&D through different channels. The research councils stick to their traditional role as passive recipients of incoming proposals, while NUTEK, a mission-oriented agency, primarily supports near-market applications. The innovation in funding biotechnology comes from the fairly new strategic foundation, which has developed a relatively integrated and concentrated approach.

Three major conclusions can be drawn from our study of research councils. The first is that the concept of a research council system is loose and vague. There are in fact many different models of research governance connected with different types of research councils, some close to the 'pure' research council ideal, others of a more interventionist kind (compare with Skoie, 1996).

Second, national governance models are seldom pure. Funding of PSR comes from many different sources with different governance mechanisms attached to them.

Third, there is a marked continuity and path-dependence in how funding for research is organised. Once a model of research governance is established, it is difficult to re-arrange. This applies even to new areas, which despite their newness are channelled through the already existing organisational structures. The most successful example of an integrated approach to change in the political, economic and cognitive landscape for PSR, Denmark, can actually be explained by the fact that Danish PSR funding was very weakly institutionalised until the 1980s. Governance of PSR in Norway and Sweden, where different models of research governance have existed side by side for decades, has proved to be much less possible to reform.

The Swedish case exemplifies, as we assumed initially, a tendency towards an intellectual and organisational marginalisation of unreformed research councils within expanding areas. The Danish case, and to some extent also the Norwegian, show that traditional research councils can adapt to changing conditions, if and when they develop a more proactive organisational model. The division of labour in Norway and Sweden has, we argue, handicapped the research councils in their adaptation to changing demands on PSR. The councils have been relegated to an already established function in PSR governance. This role might, however, be destined to be obsolete in the long run. Nevertheless, the policy constituency of the councils will surely try to prohibit the demise of the councils as long as it possibly can.

A caveat is appropriate here. Research councils in their traditional, responsive form might (for instance, through their large-scale programmes for the bio-sciences) play an increasingly important role in developing a basic research infrastructure for biotechnology development. Hence, it could be seen as an advantage that there are a number of different funding mechanisms operating within biotechnology.

From a theoretical point of view, our main conclusions are that there are a number of different possibilities for highly institutionalised organisations to adapt to changing conditions. Even though organisations develop specific policy constituencies that stand in the way of more radical reforms in mission and structure there are a number of ways to modify tendencies towards inertia. One is the role of new organisations within the same field, as exemplified by the Swedish PSR funding system, where fairly rigid research councils have been complemented by strategic and mission-oriented organisations.

In the Danish case, the late development of the research council system has made it easier for policy-makers to reorganise the councils in a more strategic fashion. The Norwegian case may seem like a good illustration of the difficulties in reforming established research councils, but given the short time-span it might be too early to rule out the possibilities of cross-organisational alliances and learning within the new integrated council. Hence, although PSR funding models may seem difficult to reform, they are not immune to change. Instead they develop in a dialectic process between inertia and change, typical of all organised activity.

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